

COMPUTER BASED LEARNING IN SCIENCE

Conference Proceedings 2012

Learning Science in the Society of Computers

**Editors:
Roser Pintó
Víctor López
Cristina Simarro**

COMPUTER BASED LEARNING IN SCIENCE

Proceedings

Learning Science in the Society of Computers

An International Conference
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Centre for Research in Science and Mathematics
Education (CRECIM)
Barcelona, Spain

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Víctor López
Cristina Simarro

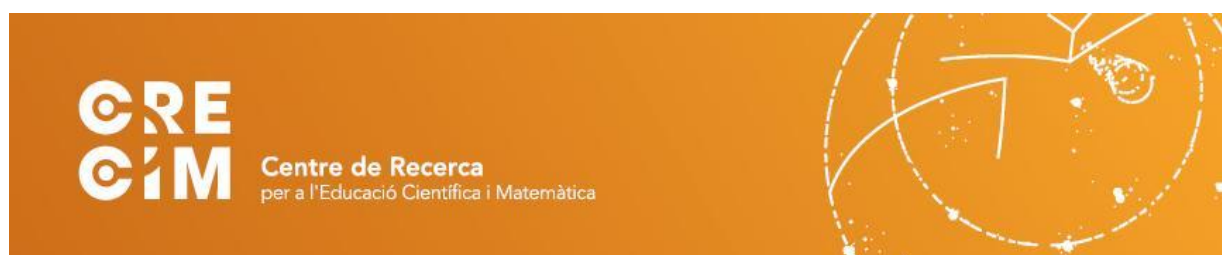
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PREFACE

Computer Based Learning in Science '12 (CBLIS '12) is the tenth in a series of international conferences that seek to provide a forum for researchers to present and discuss developments in computer technology aiming to assist learning in science and education. Papers have been accepted by authors working in science education at all levels together with papers by authors from other disciplines where the subject material offers transferability across disciplines.

The Proceedings contain the full text of the professionally refereed papers that were finally accepted for presentation at the conference and publication in the proceedings. The refereeing process operated in three stages:

62 abstracts were submitted for consideration – 1st refereeing process

55 authors were invited to present at the conference and submit draft manuscripts

33 papers were finally accepted for publication – 2nd refereeing process

The conference truly reflects international interest in computer based learning with 18 nations represented with a full coverage of all aspects of the topic.

A pleasing aspect and measurable success of the conference is the move towards jointly authored papers between contributors from different nations. These relationships have developed through collaboration between authors in previous conferences who see the benefits of sharing knowledge and expertise to the benefit of students worldwide.

The Conference Organizers would wish to see this develop further and are pleased to be the catalyst of good practice.

The Centre for Research in Science and Mathematics Education in Barcelona (Spain) is proud to host this conference.

To achieve the high level of presentation initially set at CBLIS '93 at the Technical University of Vienna, Austria and reinforced at the Silesian University of Opava, Czech Republic (CBLIS '95), De Montfort University, UK (CBLIS '97), University of Twente, Netherlands (CBLIS '99), Masaryk University, Brno, Czech Republic (CBLIS '01), University of Cyprus, Nicosia, Cyprus (CBLIS '03), University of Žilina (CBLIS '05), University of Crete (CBLIS '07) and the Computer Assisted Education and Information Technology Centre of Warsaw, Poland (CBLIS '10), it has been essential to maintain a strong paper review body. The Conference Chairperson and the Editors wish to express their gratitude for the support and encouragement provided by the International and the Local Scientific Committee:

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Roser Pintó Casulleras (CRECIM; UAB)

Most importantly, the Committee extends their thanks to all the authors who, in spite of busy workloads, have endeavored to meet the conference deadlines. The enthusiasm of the authors will guarantee the success of CBLIS '12 and will continue to stimulate both developments in the field and joint projects to explore ideas between participants.

Finally, we would like to express our sincere thanks to the organizing committee without whom the conference would not have been possible:

Organizing Committee:

Alba Masagué Crespi (CRECIM; UAB)
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Roser Pintó Casulleras (CRECIM; UAB)
Víctor López Simó (CRECIM; UAB)

Our final word of thanks goes to all the conference participants who continue to contribute to the evolution of this community of researchers.

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NOTE FROM THE EDITORS

Since the first conference held in Vienna in 1993, the CBLIS has become an international forum to share and exchange ideas about teaching and learning Science with computers, to deepen the construction and development of new educational models and to elaborate contributions to both theoretical and practical in the field of computer-based Science teaching and learning. Throughout all the previous years, hundreds of researchers from dozens of universities from all continents have allowed to build around the CBLIS a consolidated network of people who have the philosophy to promote, through collaboration and exchange of experiences, the efficient use of computers in Science education. We understand that the computer science classroom has to become a tool to improve the current educational methods, bringing science to students and preparing them with better skills and abilities as future citizens of the knowledge society. Thus the CBLIS, throughout all these years, has forged their identity traits, addressing simultaneously science teaching and computers-based teaching. While there are several powerful international conferences devoted to science teaching and other dedicated to computers-based teaching, the conference CBLIS combines the two aspects as inseparable.

Furthermore, if in previous years the conference had titles such as *Integrating New Technologies*, now that reality has changed. These technologies are not new, and paradigmatically, the term NICTs has changed for ICTs. The computer and internet are not something futuristic, but they are already part of our lives (many children *digital-natives*). Additionally, the international conference CBLIS arrives to Barcelona at a time of global crisis and public debate on the role of innovation and research in the world. In the field of education - and specifically, the science education - we are at a point in the debate over the incorporation of educational technologies in classroom teaching and their use is more intense than ever, where we need to deeply reflect on how to manage public investment to advance the digitization of the classrooms at all levels, and to find formulas for success that really involves improvements for teaching and learning science.

In the compilation of papers found in this document, many of these questions are arised, and through scientific rigor and educational innovation, right answers are sought, contributing to improve Science learning and teaching in the society of computers.

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TEACHERS AND ICT: PROFESSIONAL DEVELOPMENT AND TEACHERS' ROLE

THE ROLE OF TEACHER MEDIATION USING COMPUTER SIMULATIONS IN PHYSICAL SCIENCES TO IMPROVE STUDENTS' EPISTEMIC COMPETENCES – A THEORETICAL FRAMEWORK

J. Bernardino Lopes, J. Paulo Cravino, António Alberto Silva, Clara Viegas

ABSTRACT

We present and discuss the theoretical framework of an ongoing research project about the role of teacher mediation using computer simulations to improve students' epistemic competences in physical sciences. By teacher mediation we mean the languages and actions of teacher and students so that the teacher effort potentially leads to the intended learning outcomes. It is discussed the usage of computer simulations as semiotic registers or as manipulable mediator. Thus, the use of computer simulations may have a potentially significant impact on teachers' languages and actions, as well as on related patterns of classroom interaction. The core of this theoretical framework is synthesized on a model: the Teacher as Mediator Model. Teachers' mediation can influence the epistemic practices and the development of epistemic competences of students, namely by the way they choose and use the epistemic objects, the tasks, the semiotic registers and the manipulable and discursive mediators. The Teacher as Mediator Model can give important contributions to science education in general, and particularly in computer-based learning using computer simulations

KEYWORDS

Computer simulation, teacher mediation, students' epistemic competences, physical sciences

INTRODUCTION

This paper is related to a symposium about using Computer Simulations (CS) in physical sciences classroom (this and other 3 presented on CBLIS 2012). It presents a theoretical framework which is common to various empirical studies that are a part of an ongoing research, namely those that are presented on CBLIS: using computer simulations in pre and in-service primary school teacher training physical sciences (Pinto, Barbot, Viegas, Silva, Santos and Lopes, 2012); learning physics concepts in basic school with computer simulations (Sarabando, Cravino, Magalhães and Santos, 2012); the influence of the teacher's research experience in using computer simulations in secondary school students, in physical sciences (Cunha et al., 2012).

Computer simulations *per se* may not help students develop their knowledge and competences towards the learning goals. Roschelle, Pea, Hoadley, Gordin, and Means (2000) report that using CS may have a minimal effect on students' achievement tests. As stated by Schroeder, Scott, Tolson, Huang, and Lee (2007), in order to have a positive impact in learning the use of CSs needs special care regarding the teacher mediation (TM). However the role of teacher mediation in using CSs has not been considered in most research studies (Rutten, van Joolingen and van der Veen, 2012) in spite the recognition of their need (Adams, Paulson and Wieman, 2008). So, TM is crucial in computer based environments using CSs.

The importance of the mediation role of teachers is well established in science education research literature (Hennessy, Deane and Ruthven, 2005; Lopes, et al., 2008b; Reiser, 2004; van de Pol, Volman and Beishuizen, 2010; Vygotsky, 1962).

We present a theoretical framework about the role of Teacher Mediation (TM) in using Computer Simulations (CSs). In particular, it addresses how this mediation may improve students' meaningful learning and Epistemic Competences by promoting students' Epistemic Practices (EPs), e.g. questioning, argumentation, formulation of hypothesis, simulation, validation, modelling. Our perspective is: if teacher mediation foments students in developing epistemic practices while working with computer simulations, this could lead to the development of epistemic competences.

We define (Lopes et al., 2008a) TM as the languages and actions of teacher and students as systematic answers to the students' learning demands in their specific development pathways to the intended learning outcomes. Thus, in the study of TM we focus on the languages and the actions of teacher, on semiotic registers and on mediators, particularly manipulable mediators.

Our research in the field of computer based learning is about using CSs. As developed below, these may be used as semiotic registers or as manipulable mediator. Thus, the use of CSs may have a potentially significant impact on teachers' languages and actions, as well as on related patterns of classroom interaction. The core of our theoretical framework is synthesized on a model: the Teacher as Mediator Model.

THE “TEACHER AS MEDIATOR MODEL”

The core of our theoretical framework is synthesized on a model: the Teacher as Mediator Model, which is schematically presented in Figure 1. Its main features are:

I - Relating and distinguishing teaching and learning

Teaching and learning influence each other, but they are distinct process. They coexist temporally in a short period of time. The mediation occurs in three periods: (a) Preparation: preparing information, resources, environments, tasks, as well as their alignment and methods; (b) Contingent didactic interaction: coexistence in time of discursive practices and EPs; (c) After contingent interaction: oriented to internalize and expand students' learning.

II – Three timescales of TM

The TM of students' learning has three fundamental timescales (Tiberghien and Buty, 2007): (a) *Long* - (unit, course or cycle of studies - from student world to intended learning outcomes); (b) *Meso* - (what happens during the development of a task); (c) *Short* - (maximum contingency of discursive practices and EPs). The first occur in the articulation of the three periods referred in *I*. The others timescales occur mainly in the period of contingent didactic interaction.

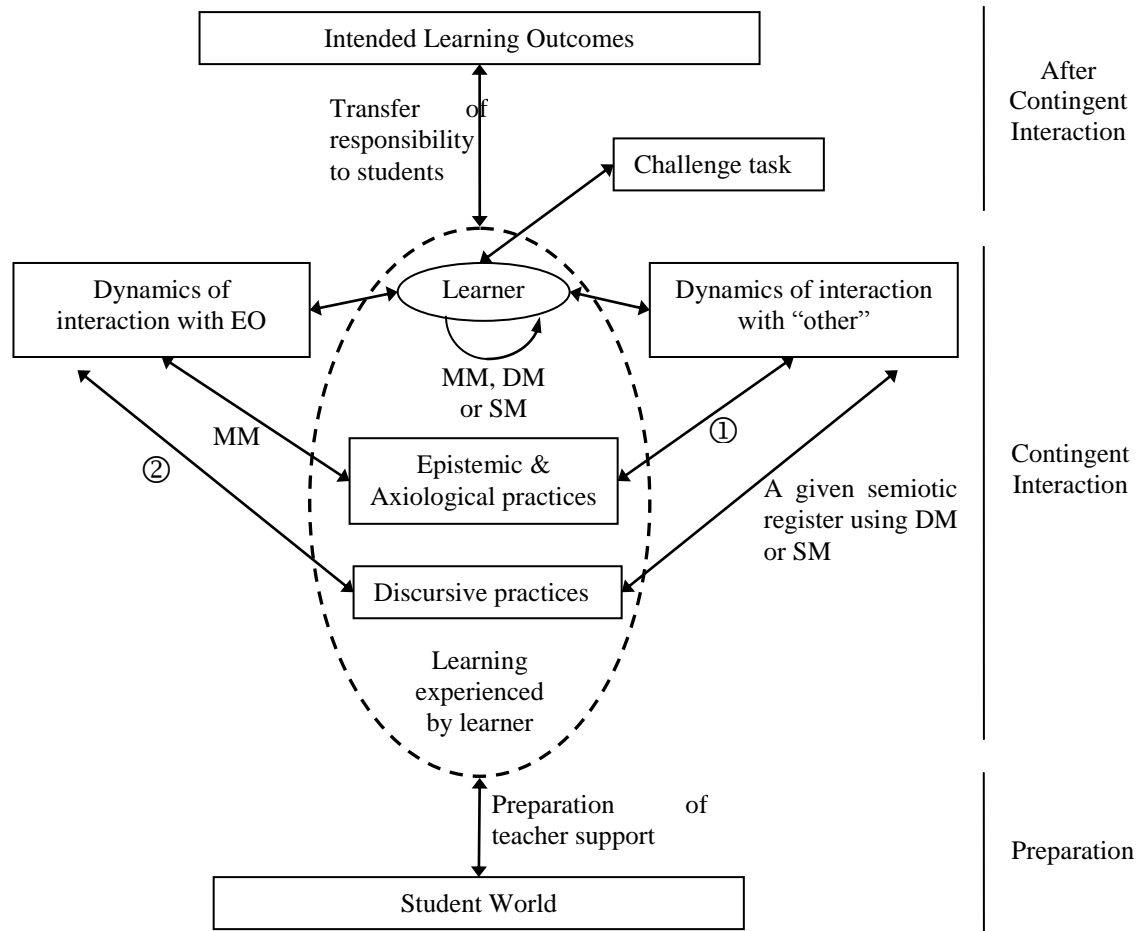
III – Two fundamental perspectives and related dynamics

This Teacher as Mediator Model is based on two *perspectives* and the related *dynamics*:

A - Epistemic-axiological perspective. The *dynamics of interaction with the epistemic object* (EO) through manipulable mediators with materiality (Magnani, 2004), in a given or constructed environment, allows a self-regulated learning (Richter and Schmid, 2010) and meta-cognitive processes (Richter and Schmid, 2010). The dynamics of interaction with the EO is the observable behaviour of the students in their interaction, via actions, with the EO. This dynamic is the structured way of the self-regulated learning.

B - Psycho-sociological perspective. The *dynamics of interaction with the other* (peers and teacher) in a certain community, with its rules, work organization, mediators and world vision, is based on psycho-socio-cultural perspectives (Reveles, Kelly and Durán, 2007; Vygotsky, 1962); cultural-historical

activity theory (Engeström, 1999); and argumentation (Toulmin, 1972). The dynamics of interaction with “the other” is the observable behaviour of students in their interaction, via languages, with the other members of the learning community.



Legend: EO – Epistemic object; MM – Manipulable mediator; DM – Discursive mediator; SM – symbolic mediator; ①- Scaffold EP or influence the dynamic of interaction with other; ② - Modify the dynamic of interaction with EO or support the discursive practices in a given semiotic register.

Figure 1. Teacher as Mediator Model

IV – Three types of mediators

Manipulable mediators are manipulable artefacts (e.g., common objects, CS, videos) with material existence (Magnani, 2004) with which a student can work an EO. The human body is important in the constructions of the mind (Damasio, 2010); and the manipulable mediators are important extensions of the human body. A manipulable mediator plays its role only when it is used to extend the student capacity of thinking about the EO. A manipulable mediator can have several functions: epistemic, emphatic, engagement, representing. Discursive mediators are linguistic resources (e.g. questions, analogies, metaphors) used in conversation for arguing, convincing, explaining, narrating, focusing, stating, etc. Symbolic mediators are special signs (e.g., mathematics symbols) that facilitate the thought about thought.

USING THE “TEACHER AS MEDIATOR MODEL”

We present now some crucial instances and recommendations about relating and using the four features presented above — *teaching and learning; timescales; perspectives and dynamics; types of mediators* — and some crucial concepts, namely those referred in the Introduction.

The epistemic and axiological practices deal with manipulable mediators; and they may follow a direction from observable world to theory or from theory to observable world. EPs develop epistemic competencies in long timescale.

In discursive practices there are negotiations to construct meaning, with discursive and symbolic mediators and semiotic strategies. Jakobson (1960) considers six discursive practices, according to their functions. Discursive practices develop discursive competences.

The dynamics of interaction with the EO may be improved by the use of appropriate manipulable mediators; and it is influenced by the choice of the appropriate EO, by the scaffolding of the EP, and by the choice of an appropriate challenging task. The dynamics of interaction with the EO fosters directly axiological and epistemic practices. The EPs take place only if there are interactions with the system under study. The dynamics of interaction with the EO may scaffold the discursive practices and be influenced by them.

The dynamics of interaction with “the other” can be promoted through the use of symbolic and discursive mediators. This dynamics can scaffold the EPs and be influenced by them. Discursive practices may influence the dynamics of interaction with the EO. This dynamic is the structured way of the mediated learning. It is influenced by changes in the “other” and by the choice of challenging tasks.

The quality of the TM in the contingent interaction may be evaluated by using EPs, discursive practices and their articulation to characterize students’ learning experience. The effectiveness of the TM in the long timescale may be evaluated by comparing the attained and the intended learning outcomes.

In the dynamics of interaction with “the other”, this may be present, implicit or at distance. If “the other” is implicit, then there is no feedback. The Teacher as Mediator Model helps in describing what is happening in e-learning and b-learning: the way the other interacts with the learner determines in a certain way the EPs and the discursive practices that may occur.

The TM is richer if there is an articulation between the dynamics of interaction with the EO and the dynamics of interaction with “the other”; and if teachers’ and students’ discursive practices and EPs foster each other.

Learning by internalization is possible through the use of mediators used in the dynamics of interaction with the EO and with the other; and through the appropriation of the challenging tasks.

The continuous assessment of students’ learning is a type of teachers’ and students’ discursive practices that aim to validate students’ EPs and discursive practices (meta-linguistic function of language).

An adequate sequence of tasks allows the articulation between long and meso timescales of TM. An adequate task allow de articulation meso and short timescales of TM

COMPUTER SIMULATIONS AND THE “TEACHER AS MEDIATOR MODEL”

A CS is an artefact with which the student can operate (see figure 2) in one or several semiotic registers that can be interchangeable. A CS may be: (a) a manipulable mediator, if students can interact with it; (b) a semiotic resource, if is used only to display signs (graphs, values, images).

A student interacts directly with a CS, e.g. by selecting variables from a menu (Chinn and Malhotra, 2002). A CS can replace an EO, because the CS can represent the EO and also the student can interact with CS without interacting with the EO. To interact with the EO, the student need to identify the pertinent variables and not only chose some of them from a menu (Chinn and Malhotra, 2002).

CSs are manipulable mediators with a different status from the one of an EO. When manipulating a CS, a student can obtain new experiences, perceptions and representations about the EO (Richards, Barowy and Levin, 1992). A student can also think in new ways and develop new inquiry skills (Richards et al., 1992). A CS only plays adequately its role of manipulable mediator if there is an EO as a reference: then, the CS helps to understand how the physical world and the models used in CSs are distinct and intertwined (Ingerman, Linder and Marshall, 2009).

When using CSs, students may not be guided by their explicit knowledge; but they are certainly guided by their implicit knowing (Cook and Brown, 1999). CSs may be its powerful in attaining effective learning (Wieman, Perkins and Adams, 2008). Nevertheless, they also may lead to wrong ideas if TM is not appropriate. According to Teacher as a Mediator Model, the use of CS as manipulable mediator is important to improve EPs, if there are discursive practices in the dynamics of interaction with “the other”.

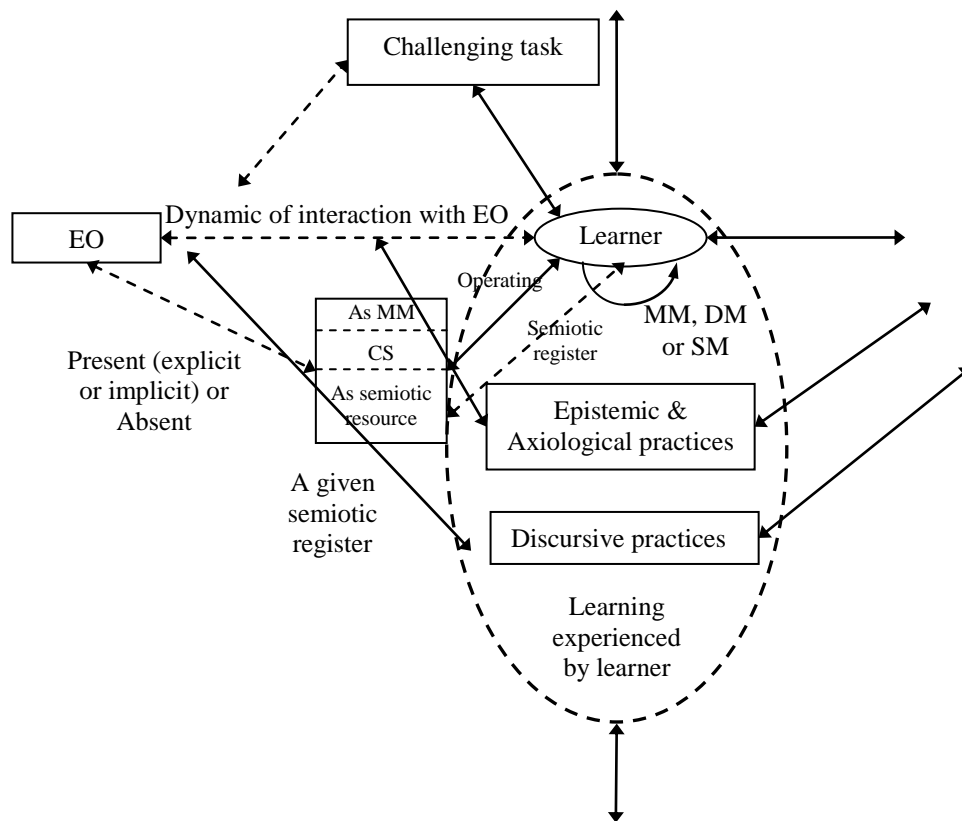


Figure 2. The role of CS in the context of the Teacher as Mediator Model

A CS is predominantly a semiotic resource (figure 2) when used to produce, rapidly, semiotic objects such as visualisations (Sadler et al., 1999), leading to work with different semiotic registers. It becomes a symbolic mediator “to enable more efficient communication of complex concepts and acted as cognitive props, alleviating the need for students to formulate their own mental representations” and to support dialogic communication (Hennessy et al., 2007:145). It is used to support the discursive

practices in teaching practices where the interaction with “the other” is predominant; and is used to produce new symbolic mediators and to quickly change from an abstract semiotic register to a more concrete one and vice-versa.

The TM is particularly important in certain occasions, to make the EPs and discursive practices public, by aiding the communication using the several semiotic registers that the CS allows.

CS working as manipulable mediator or symbolic mediator also allows new learning possibilities in the internalization process.

CONCLUSION

CSs are manipulable mediators with a different status from the one of an EO. A CS only plays adequately its role of manipulable mediator if there is an EO as a reference. CSs may be reduced to semiotic resource and work only as symbolic mediator.

CSs may be its powerful in attaining effective learning, but they also may lead to wrong ideas if TM is not appropriate.

According to Teacher as a Mediator Model:

- (i) The TM is richer if there is an articulation between the dynamics of interaction with the EO and the dynamics of interaction with “the other”; and if teachers’ and students’ discursive practices and EPs foster each other;
- (ii) The use of CS as manipulable mediator is important to improve EPs, if there are discursive practices in the dynamics of interaction with “the other”;
- (iii) The TM is particularly important in certain occasions, to make the EPs and discursive practices public, by aiding the communication using the several semiotic registers that the CS allows.

With the Teacher as Mediator Model it is possible to work in new lines of research and development in the field of using CSs: (a) developing new ways of TM (e.g. ways of scaffolding EPs, choices and uses of CSs as manipulable mediator; modifying the dynamics of interaction with EO); (b) news new ways of learning and of conceiving learning when using CSs, namely in relation to types of mediators, discursive practices and dynamics of interaction with the EO; (c) The roles of CSs as symbolic mediators and/or as manipulable mediators to enrich the dynamics of interaction with EO, to support discursive practices and to improve EPs.

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THE INFLUENCE OF THE TEACHER'S RESEARCH EXPERIENCE IN HIS MEDIATION OF SECONDARY SCHOOL STUDENTS LEARNING USING COMPUTER SIMULATIONS

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ABSTRACT

We report a multi-case study with three teachers from secondary school with different research experiences in science education. We use multimodal narratives (MN) (a description of what happens in the classroom, using several types of data collected inside and outside classroom) to analyse the teachers' effort to promote students' epistemic practices (EPs) during the proposed task. The results are obtained analysing the MNs of each teacher's lesson in micro and meso timescale. In the analysis we take in account two dimensions: (a) teacher's effort to promote students' EPs using the computer simulations (CS) and (b) the students' EPs during the use of CS.

The results pointed to the importance of research experience in the characteristics of the teacher's effort to promote students' EPs using CSs. In particular, there are subtle differences in teacher's mediation that can have a great influence in the students' EPs in a meso timescale.

KEYWORDS

Computer simulation, professional development, teacher's mediation, students' epistemic practices, Physical sciences

INTRODUCTION

This study aims to explore how teachers mediate students' learning of physical sciences in secondary school classrooms, in particular how teachers use computer simulations (CS) to promote the emergence of students' epistemic practices (EPs).

In the physical science classroom, the teacher's mediation (TM) must provide epistemic support (Sandoval and Reiser, 2004) for students' engagement on EPs, which are determinant for construct personal knowledge and develop epistemic competences about S&T. Through the occurrence of EPs, students have real opportunities for constructing meanings associated with the practice (Jiménez-Aleixandre and Reigosa, 2006) and developing competences (Lopes, Branco, and Jiménez-Aleixandre, 2011).

Through his actions and languages (Lopes, Cravino, Branco, Saraiva and Silva, 2008) teachers can scaffold and promote the students' EPs (McNeill and Krajcik, 2009), and helps them connecting theories, practices and explanations of phenomena (Sandoval and Reiser, 2004). The importance of the mediating role of the teacher is well established in the research literature (Hennessy, Deane, and Ruthven, 2005; Lopes et al., 2008).

The increasing availability of CSs and the growing emphasis on using these in teaching and learning have a potentially significant impact on established patterns of classroom interaction. Using CSs needs the TM to have positive impact in learning (Schroeder, Scott, Tolson, Huang, and Lee, 2007). However,

the role of TM using CSs has not been considered in most research studies (Rutten, van Joolingen and van der Veen, 2012).

Teacher professional experience, in particular his research experience, has influence on the characteristics of the dynamics of TM to promote students' EPs (Saraiva, Lopes, Cravino and Santos, 2012). The TM efforts for promote students' EPs can be faced through micro and meso timescales (Tiberghien and Buty, 2007).

METODOLOGY OF RESEARCH

Participants

This research work consists on a multi-case study (Cohen, Manion, and Morrison, 2010) involving three physical sciences teachers from secondary school (students age 15-18 years) with different characteristics in terms of professional experience (combining the time in teaching and the experience in research in physical science education field). The teachers taught in different public schools from Portugal. Their main characteristics' are presented in Table 1.

Table 1. Main characteristics of the three case studies

Teacher	A	B	C
Gender	Female	Female	Female
Academic degree	PhD student of Physical Sciences Education	PhD student of Physical Sciences Education	PhD student of Physical Sciences Education
Experience: Teaching/ Research	15 years / Yes	23 years / Yes	22 years / No
Grade and topic of the lessons analysed	Chemistry 12 th grade Electrochemical cells	Chemistry 10 th grade Photoelectric effect	Chemistry 10 th grade Photoelectric effect
CSs used	voltaicCellEMF (available on web)	PhET (available on web)	PhET (available on web)
Nr. of students in class/ Nr. of groups	17 / 3	13 / 3	8 / 4
Time of the lessons	90 min	135 min	135 min
Tasks	1 Tasks Through the CS: (a) identify the conditions to have a voltaic cell operating and find one that provides 1,5 V; (b) Establishing the relationship between the solution concentration and potential difference.	19 Tasks General pattern: Require to manipulate on CS (wavelength, potential difference, current intensity or material) followed by one or two questions about the observed in CS.	2 Tasks Through the CS: (a) find the main factor to have ejection of electrons and other factors that may affect the ejection of electrons; (b) Which is the lowest value of the voltage necessary to obtain an electric current, and other factors that influence this value.
Episodes analysed	3 episodes (one for each group)	20 episodes (8 for class; 7 for group III; 2 for group II; 3 for group I.	9 episodes (1 for class and 2 for each group)

The teachers were selected on the basis of their differences in terms of professional experience defined as the mix of time teaching and experience in research as participant as researcher in science education projects.

Data collection

Multimodal narratives (MNs) were used to collect and organize the data. A MN is the description of what happens (actions, languages, decisions, etc.) inside the classroom having as reference the tasks proposed and their development, audio recorded, several documents and multimodal elements (e.g. print screens of CS, student reactions, explicit teacher's intentions and decisions, students' notebook, teacher's documents, photos, indication of silences and gestures). The MNs have all the same structure, which allows its comparability.

Data analysis

Three MNs were analysed (one from each teacher), all made by themselves. The data analysis of MNs was done in several steps. The first order analysis was data driven and using the coding capabilities of NVivo 8[®], as follows:

- identify and code the parts of the MNs that contain evidences about the occurrence of students' EPs. The criteria used to recognize this occurrence was the identification of students' investigative actions, in order to solve a problem or answer to a question (Sandoval and Reiser, 2004);
- select and code the parts of the MNs related with the teachers' actions and languages adopted to promote, enlarge or inhibit the occurrence of students' EPs.

All parts of the MNs coded, were reviewed by other researcher, in order to determinate if all evidences about the teacher actions and students' EPs that take place are covered. If not, improvements were made. Each category was named and a briefly described (see tables 2 and 3). All MNs were reanalysed by other researchers, in order to get an effective verification, using the same criteria for evidences.

The second order analysis, guided by the aim of this research, allows the identification of TM actions that can have a great influence on the students' EPs. The analysis was conducted using two timescales: (a) meso timescale refers to all TM and students' EPs during one episode (teaching sequence that starts with a task proposal and ends with other task proposal); (b) micro timescale refers to each interaction (teacher action and subsequent students' EPs).

The results obtained in the first order analysis were used to construct two matrixes (one for each timescale – interactions and episodes), for all case study teachers. For all variables the respective presence (value "1, 2, ..." number of time that certain category occurs) or absence (value "0") of the category was considered. The two matrixes were submitted to cluster analysis (Krippendorf, 2004) using the software *Statistica* and the results were displayed using linkage tree-like diagrams (figure 1).

RESULTS

Categories of the TM and students' EPs found

From the first order analysis the categories identified for students' EP related with the use of CS in the classroom are described in Table 2.

The categories that emerge from the analysis about the TM actions that enlarge or decrease the opportunities for students' engagement in EPs are presented and briefly defined in Table 3.

Table 2. Categories of students' EPs

Students' EPs	Definition
Argumentation	Generate and justify knowledge claims, to understand the phenomenon(a).
Describe what happens	Describe systems and/or processes.
Present mobilising idea	Mobilise prior knowledge to guide a possible way to solve the problem.
Identify empirical conditions	Identify empirical conditions of a physical situation in which the phenomenon(a) occurs.
Relate	Establish relations between data variables and/or concepts in different situations.
Transform observational language to conceptual	Use scientific language when they describe their observations.
Handle factually CS	Handle equipment following instructions given by teacher, or tentatively without any guiding knowledge.
Handle conceptually CS	Handle equipment guided by knowledge.
Question factually	Ask questions to clarify terms or observations related to empirical conditions of a phenomenon.
Interpret	Interpret images, diagrams, objects, partial data, etc.
Question conceptually	Formulate questions based on knowledge to obtain new understanding.
Change representation format	Change the symbolic representation to another.
Conceptualise	Make a symbolic representation of a phenomenon.
Evaluate critically	Analyse, critically, hypothesis, resources, results, ideas, etc.
Formalise the model	Set up a model of a system
Modelling	Develop a conceptualization pathway in order to construct a model of a system.

Table 3. Categories for TM actions

Teacher's actions to enhance, or not, students' EPs	Definition
Short-circuit	Task with potential to develop students' EP. However, teacher doesn't allow students the opportunity to accomplish, by themselves, the task.
Absent or inadequate task for EP	Implicit task or an explicit request for some kind of activity that does not need EP.
Present task challenge	Propose task as a challenge.
Synthesise	Takes students' EP to reinforce their understanding.
Request additional aspects	Requests additional aspects to students to clarify the EP.
Give autonomy	Allows students to work freely, paying attention to what they are doing.

Patterns of TM using CS (episodes) and its influence on students' EPs

To identify patterns of TM using CS during the episodes and its influence on students' EPs it was used cluster analysis technique. Cluster analysis groups the episodes according the similarities in terms of the values of variables that characterize each episode. The output of the cluster analysis is a dendrogram (figure 1), where can be found the clusters of episodes with strong similarities among them. The patterns of TM and its influence in students' EPs, corresponding to each cluster, are obtained by cross-analysing each cluster of the dendrogram with the matrix made for all teacher's actions and students' EPs.

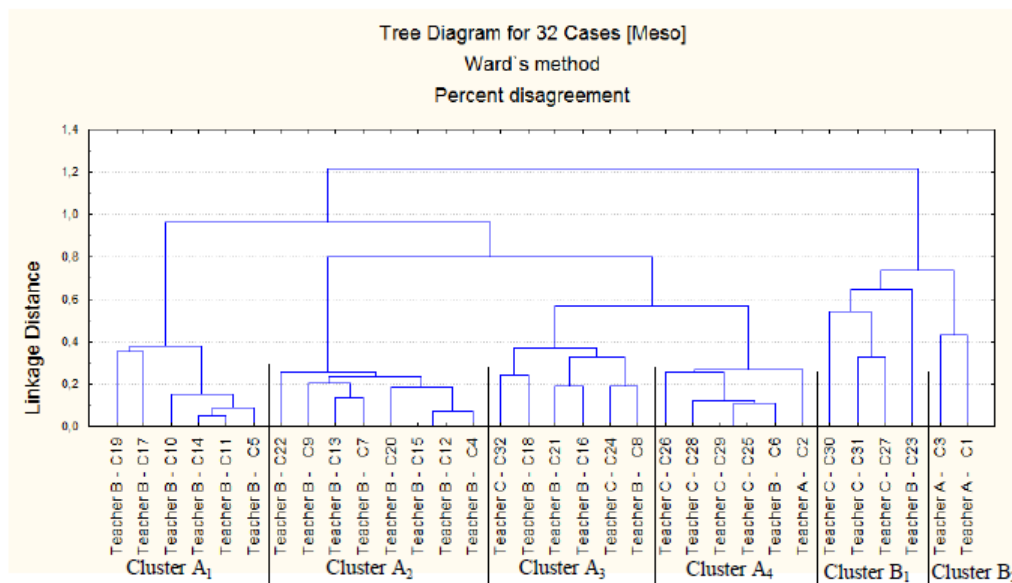


Figure 1. Dendrogram for all teachers' episodes (meso timescale)

There are patterns characteristics of a certain teacher/class:

- i) When teacher B propose a task as challenge related to CS (cluster A₁ – figure 1 and table 4) the students (working in small groups or with all class) evidence several types of EPs, dealing with the observable world. In cluster A₂ the tasks are not adequate to promote students' EPs (and they don't occur) although students remains working engaged with the CS.
- ii) When teacher A (cluster B₂ – figure 1, table 4) proposes a task as challenge related to CS followed by some teacher's efforts and giving students' autonomy, several types of students' EPs emerged, dealing with the observable world and available knowledge (for example, evaluate critically and formalize a model).

In the other hand there are patterns which are common to several teachers:

- i) Teacher proposes a task as challenge and requests additional aspects related to CS (cluster A₃ – teachers B and C), some students' EPs arise.
- ii) Teacher proposes a task as challenge and gives students autonomy they will be engaged with the CS (cluster A₄ – all teachers).
- iii) Teacher proposes a task as challenge, related to CS, followed by some teachers' efforts and students' autonomy (cluster B₁ – teachers B) or even when “short-circuit” (cluster B₁ – teachers C) the students' work several type of students' EPs emerged, related with the observable world.

Comparing the different patterns of TM and its influence on students' EPs, taking into account the tasks proposed by each teacher (see table 1), and teacher background, it was identified that:

- i) When the task is absent or inadequate, don't emerge students' EPs;
- ii) The teacher proposal of a task as a challenge related to CS it's associated with the more important students' EPs when they use CS;
- iii) When teacher gives more autonomy, the number of students' EPs increase. Were found two main ways of giving students' autonomy when working with CS: allow the freely use of CS; or scaffold students to develop EPs;
- iv) If teacher proposes a lot of tasks, the students only have more EPs if teacher have an intervention for the class as whole(compare clusters A1 and B1)
- v) The crucial characteristic of TM to improve the students' EPs, in quantity and quality, and for relating observable world and knowledge available are: (a) propose a manageable number of tasks as challenge for students; (b) give students autonomy; (c) scaffolding students work in decisive moments with some type of teacher's effort;

- vi) The teacher background (teaching and research experience) has influence on TM. The most important criterion is the research experience. In some circumstances the teaching experience is helpful to scaffolding the students' work.

Table 4. Patterns of TM actions identified in cluster analysis in terms of episodes and its influence on students' EPs

Pattern	TM actions	Students' EPs
Cluster A₁ (Teacher B, 6 episodes)	- task proposal as challenge, related to CS.	- EPs related with the CS, in groups and classroom: Argumentation; Describe what happens; Interpret; Relate; Transform observational language to conceptual.
Cluster A₂ (Teacher B, 8 episodes)	- Absent or inadequate task to EP, related to CS.	- Students use CS in groups and classroom.
Cluster A₃ (Teachers B and C, 6 episodes)	- task proposal as challenge and Request additional aspects, related to CS.	- Students use CS. - EPs related with the CS, in groups and classroom: Conceptualise; Identify empirical conditions.
Cluster A₄ (Teachers A, B and C, 6 episodes)	task proposal as challenge (related to CS) and give autonomy to students	- Students use CS.
Cluster B₁ (Teachers B and C, 4 episodes)	- task proposal as challenge, synthesise, request for additional aspects, give students autonomy or "short-circuits" the students' work (only teacher C); (all actions related to CS).	- Students use CS. - EPs in groups (teacher C) and classroom (teacher B): Argumentation; Describe what happens; Handle conceptually CS; Identify empirical conditions; Interpret; Modelling; Question conceptually; Relate; Transform observational language to conceptual.
Cluster B₂ (Teacher A, 2 episodes)	- task proposal as challenge, synthesise, request for additional aspects and give autonomy to students (all actions related to CS).	- Students use CS. - EPs in groups: Conceptualise; Evaluate critically; Formalise the model; Handle factually CS; Handle conceptually CS; Identify empirical conditions; Interpret; Modelling; Question factually.

Patterns of TM (interaction scale) and its influence on students' EPs

The cluster analysis of teacher interactions with students (a total of 117 interactions) allowed the identification of twelve different groups of patterns, concerning the TM actions and the student's EPs that emerge, using the CS in the classroom.

In some interactions the TM actions have immediate impact in the emergence of students' EPs (they occur after the teacher action). In particular, for two clusters of teacher B, the most experienced teacher, the TM action was the proposal of a task as challenge. For one cluster of teachers B and C, the TM action was the request for additional aspects. For another cluster of teacher A, the TM action was the autonomy given to students.

Most of TM actions during each interaction (eight clusters) don't have immediate impact on the emergence of students' EPs, although students continue using CS (two clusters of interactions from all teachers when they request for additional aspects; two clusters of interactions when teachers propose a task; two clusters of interactions when teachers propose an inadequate task to EP (teacher B) or "short-

circuits” the students’ work (teacher C); two clusters of interactions from all teachers when they demand other actions).

DISCUSSION AND CONCLUSIONS

The use of a great number of tasks does not facilitate the emergence of students’ EPs, especially when tasks are not adequate to develop students’ EPs (Lopes et al., 2008). Even when tasks are adequate, teachers often have to resort to additional requests (Saraiva et al, 2012), or engage the entire class to create the adequate workflow.

The most experienced teachers (especially in research terms) have a better TM with influence on epistemic work that is in accord to McNeill and Krajcik (2009). In particular, the differences arise in terms of tasks, students’ autonomy, and scaffolding in decisive moments. In this case, emerge sophisticated students’ EPs, such as evaluate critically, modelling and formalize the model alongside a CS handling that is intentional and informed by knowledge.

The students’ EPs occur during the use of CS, because its use creates dynamics of group working with a fairly high degree of autonomy in relation to the teacher. This is related with the fact that CS works as manipulable mediator, i.e., an artefact which students can manipulate to generate their own understandings about scientific knowledge and practice (Kelly and Duschl, 2002; Lopes, Cravino, Silva and Viegas, 2012).

The presentation of tasks as challenge to students (which is a determinant TM action for promote students’ EPs) happens more frequently in the case of teacher with less teaching experience. However, the experience of participating as researcher in science education projects, gives explicit professional knowledge (Nonaka and von Krogh, 2009) for being attentive to this important TM action. When comparing tasks with an equivalent degree of challenge and in appropriate number, the teachers with more years of teaching experience, take important TM actions that will scaffold the students’ work (e.g., requesting additional aspects or the use of synthesis). This is consistent with the fact that they have acquired a larger tacit professional knowledge (Nonaka and von Krogh, 2009) over the years of teaching.

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LEARNING PHYSICS CONCEPTS IN BASIC SCHOOL WITH COMPUTER SIMULATIONS

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ABSTRACT

We present results from the use of a computer simulation (CS) in basic school (grade 7; 12-13 years old students) to learn physics concepts (mass and weight). Our simulation was produced using Modellus. We try to understand differences in learning quality when using only CS, only experimental work, or both. We also address the influence of teacher mediation when using CS in the classroom, based on information from five teachers from four schools in Portugal. Our results show that the use of CS is not enough for effective learning of the concepts addressed in this study, in line with other studies (e.g. Yaman, Nerdel, & Bayrhuber, 2008). It is also noticeable that teacher mediation plays an important role in promoting student learning, both when using CS and hands-on experimental work. When using CS, teachers tend to expect the software to be sufficient and do not fully prepare its use in the classroom. Learning results are better when teachers assure that students understand the tasks they have to perform and the goals of such tasks. Total autonomy in the use of the CS may be counterproductive, in the sense that students may not understand the goal of the activity and engage in exploring the software in a more or less random fashion. The structure of the activity, the resources supplied to students (activity guides or other forms of guiding documents) and the balance between support and autonomy given to students during the activity are fundamental.

KEYWORDS

Computer simulation, learning physics concepts, teacher mediation

INTRODUCTION

It is in basic education¹ that many of the fundamental concepts of science are introduced. However, research results show that many students do not understand the scientific concepts of earth and space (Libarkin, Anderson, Dahl, Beilfuss, & Boone, 2005). These concepts are highly resistant to change through traditional interventions (Dahl, Anderson, & Libarkin, 2005). The concepts of weight and mass are fundamental, but are also among the least understood by students, from primary to university education (Gönen, 2008). The difficulties related to these concepts are revealed by several studies (Galili, 2001; Philips, 1991; Sequeira & Leite, 1991; Tural, Akdeniz, & Alev, 2010). After space (length, area and volume) and time, these concepts are among the fundamental physical notations, thus affecting the overall physical knowledge (Gönen, 2008). The evidence based on experimental studies suggests that we can improve learning by integrating computer simulations on topics that students find conceptually difficult (Webb, 2005). Previous studies have shown the efficiency of CS on student learning. Many of these studies focused on acquiring knowledge of specific content (Huppert, Lomask, & Lazarowitz, 2002; Trey & Khan, 2008). Some researchers also noted the success of CS to develop skills of questioning and reasoning (Chang, Chen, Lin & Sung, 2008). Other investigations reported less impressive results in the use of CS in science education. Some of them found no advantage in using simulations over traditional methods (Winn et al., 2006). Clearly, the efficacy of CS is closely linked to

¹ In Portugal, basic education consists of nine years of schooling after kindergarten (children aged 6 to 15).

the pedagogy through which they are implemented (Osborne & Dillon, 2010). Failure to take account of the pedagogy of technology use may explain some of the negative results obtained (Marshall & Young, 2006; Waight & Adb-El-Khalick, 2007).

The students' learning about the concepts of weight and mass has raised interest in research over several decades. Most of these studies have been descriptive, with the aim of cataloging alternative conceptions of students (Galili, 2001; Philips, 1991; Sequeira & Leite, 1991; Tural et al., 2010). As far as we know there are not many studies focusing on the effects of teaching strategies on students' understanding of the concepts of weight and mass. We focused the use of computer simulations as a possible contribution to the problems described, regarding the difficulties that students show in basic education when learning the concepts of weight and mass.

We intend to answer the following questions:

- Are CS combined with hands-on activities more effective, than simulations or hands-on activities alone, in promoting students' learning about the concepts of weight and mass?
- What characteristics of the teacher mediation when using CS can enhance students' learning about the concepts of weight and mass?

METHODOLOGY

Participants

Two interventions were planned, with the students, on the concepts of weight and mass. The study took place during the academic years 2009/2010 (1st intervention) and 2010/2011 (2nd intervention), in a lesson of Physical and Chemical Sciences (90 minutes). Since students were already divided into classes, it was not possible to make a random selection for the different treatments. The students were all from four schools in northern Portugal. The first intervention was developed by the teacher-researcher (pilot study), and involved the participation of 51 students from three different 7th grade classes (12-13 years old). The second intervention involved the participation of five teachers of Physical and Chemical Sciences and students from two of their classes (total of 216 students from 7th grade). Each teacher would teach two 7th grade classes (code named X and Y) at a school in the region. Before the implementation of the second intervention, all teachers invited to participate in this study were informed about its aims, and all aspects to be considered during the implementation with students in the classroom.

Study Design

Figure 1 shows the study. Before this lesson about weight and mass, students had no other lessons on the concepts of weight and mass. Based on an activity guide, consisting of three tasks designed to assess students' understanding of the concepts of weight and mass, students performed the experimental activities. In Task 1 students were asked about the relationship between weight and mass of a body. For Task 2 students were asked to explain how the weight of a body relates with the mass of the planet where it is. In Task 3, students were asked to identify the main differences between the two concepts (mass and weight). In the groups that performed hands-on activities and CS, the students tried to answer Task 1 using laboratory equipment and Task 2 using the CS.

Activities

Hands-on activities

The implementation of hands-on activities involved the use of measuring instruments (beam balances and dynamometers) and objects with different masses.

Computer simulation

The simulation used – “Weight and Mass” – was built by our team based on Modellus software (Modellus, 2000). The CS used in this study addresses the impractical space requirements typically associated with the experimental teaching of the concepts of weight and mass, which would involve

measurements on other planets. The simulation, by allowing students to explore and test predictions, can also facilitate the development of students’ scientific understandings about the concepts of weight and mass (see Figure 2).

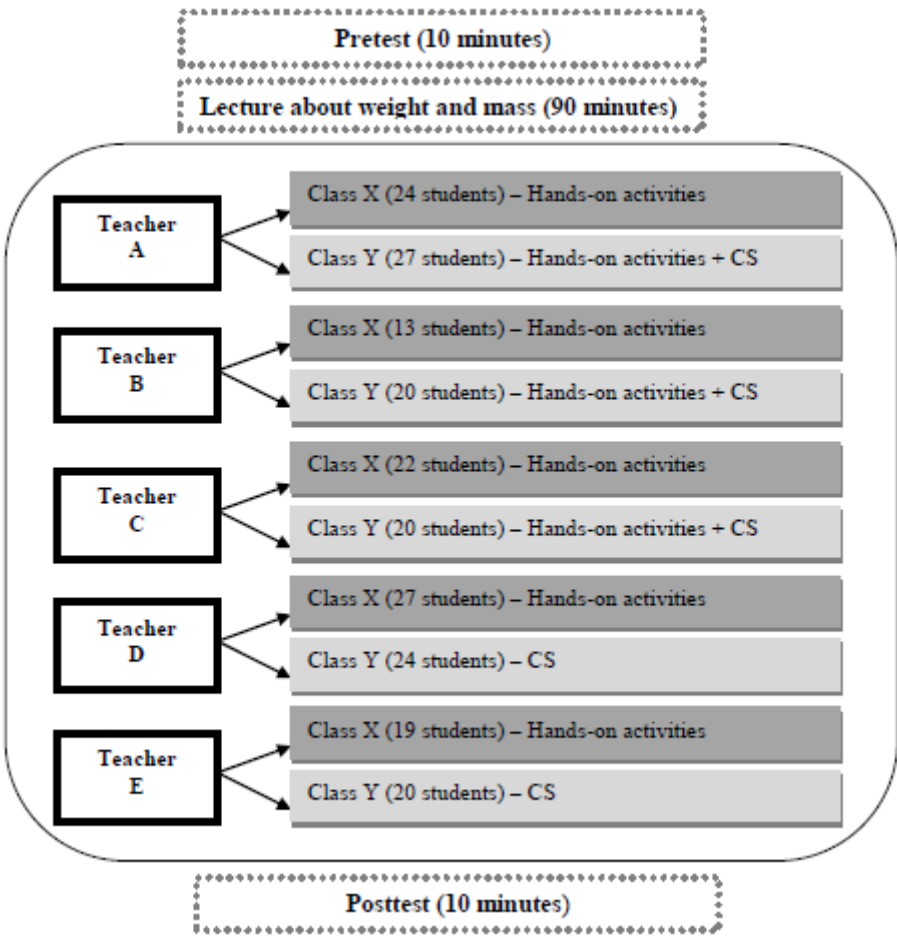


Figure 1. Study Design



Figure 2. Screenshot of CS “Weight and Mass”

Data Collection and Analysis

Data collection about teaching was conducted through semi-structured interviews, four weeks after instruction, with teachers participating in the study, to try to gather information about how they conducted their lessons. The interviews lasted an average of 30 minutes. Based on the interviews conducted, it was concluded that three of the participating teachers (A, D and E) implemented in the classroom a methodology similar to that used in the pilot study, while the remaining teachers (B and C) implemented quite a different methodology. Thus, the results based on data from students of teachers B and C are not taken into account in the analysis of the results. To assess students' learning on the concepts of weight and mass, conceptual tests were administered: a pretest (before the educational intervention) and a posttest (after the educational intervention). The time that elapsed between the completion of the pretest and posttest ranged between 13 and 70 days. The test was developed by our research team and refined after the pilot study (first intervention). The pretest and posttest are both composed of the same three questions (see Table 1).

Table 1. Questions about weight and mass used in the tests

Question 1 - In the empty space where there is only one body, this body has
(a) Mass and weight
(b) Only mass
(c) Only weight
Because,
Question 2 – Mass and weight have
(a) The same physical meaning
(b) Different physical meaning
Because,
Question 3 - When a body is transported from Earth to the Moon
(a) its weight and its mass not change
(b) its weight and its mass change
(c) The weight changes and its mass does not
(d) its weight stays the same and its mass changes
Because,

Answers of the students that answered both tests (pretest and posttest) were analyzed according to criteria that are found in Table 2 (based on Gönen, 2008). The classification was given essentially based in the justification that students gave in each question of the test.

Table 2. Criteria used to describe the conceptual understandings

Level	Criteria
3	- Answer that includes all the components of the validated response
2	- Answer that shows some understanding of the concepts
1	- Answer incorrect or irrelevant, illogical, or a answer that is not clear, or blank answer

RESULTS

Table 3 provides a summary of pretest and posttest results. Prior to participating in their respective treatments, a large majority of students in each group respond incorrectly to the three questions.

After application of the different treatments, most students continue to show scientifically incorrect views of the concepts weight and mass. These results show that students' previous conceptions are resilient and tend to persist, as mentioned by Gönen (2008).

Figures 3, 4 and 5 present the average normalized gains (Hake, 1998), obtained for each question (see also Table 4).

Table 3. Frequencies in percentage for the three types of conceptual understanding about weight and mass (pre and posttest)

Question		Teacher A				Teacher D				Teacher E			
		Pre		Pos		Pre		Pos		Pre		Pos	
		X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
Q1	3	0	0	0	0	4	4	7	21	0	0	5	15
	2	8	7	36	30	15	21	33	25	16	5	26	15
	1	92	93	64	70	81	75	59	54	84	95	68	70
Q2	3	0	4	20	15	0	0	8	54	0	0	0	5
	2	12	11	32	48	7	0	44	13	5	0	5	40
	1	88	85	48	37	93	100	48	33	95	100	63	55
Q3	3	4	4	20	15	0	0	0	13	0	0	11	5
	2	44	11	40	63	22	25	33	33	5	20	26	60
	1	52	85	40	22	78	75	67	54	95	80	63	35

Table 4. Average normalized gains, as a percentage, obtained by students in classes X and Y

Question	G (%)					
	Teacher A		Teacher D		Teacher E	
	X	Y	X	Y	X	Y
Q1	14,6	11,5	14,6	22,0	11,4	20,5
Q2	31,9	32,7	26,9	60,4	32,4	25,0
Q3	18,9	40,8	6,2	19,0	21,6	27,8

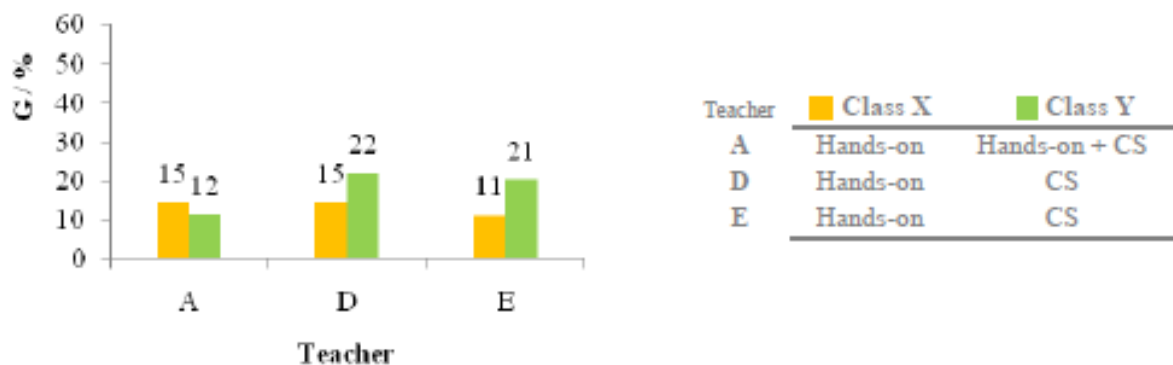


Figure 3. Graphical representation of average normalized gains obtained, in question 1, by the students of the different treatment groups: class X and class Y

From figure 3, it can be concluded that the gains from pretest to posttest, in question 1, were higher in the groups that used only the CS. This question involves some degree of abstraction, which may explain the relatively low gains. Moreover, the fact that this particular situation was not addressed directly in the CS should also be taken into account.

The gains from pretest to posttest in question 2 were approximately equal for all the students, with the exception of students of class Y of teacher D, where gains were substantially higher (see figure 4). The mediating role of the teacher cannot be forgotten here, and teacher D did performed oral and written summaries of Task 3 in the activity guide, which is partly addressed in this second question of the test.

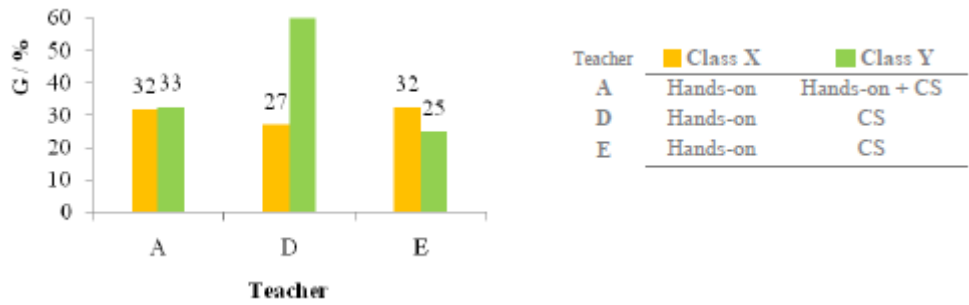


Figure 4. Graphical representation of average normalized gains obtained, in question 2, by the students of the different treatment groups: class X and class Y

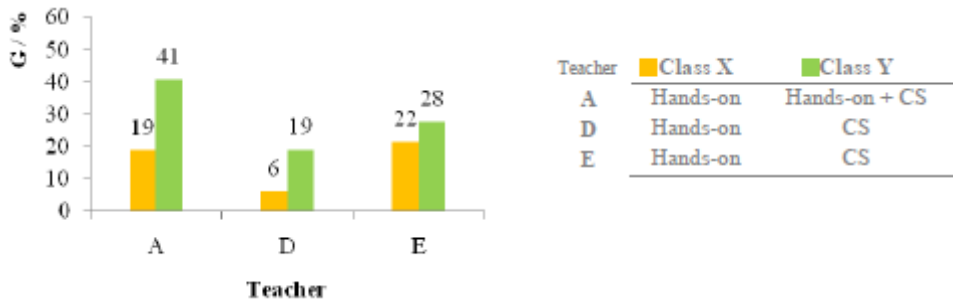


Figure 5. Graphical representation of average normalized gains obtained, in question 3, by the students of the different treatment groups: class X and class Y

With regard to question 3, the gains were higher for students who used the CS. The gains were even higher when students used the CS integrated with hands-on activities. Q1 and Q2 were more decontextualized whereas Q3 involved the exploitation of a physical situation. The physical situation selected was inferable directly from the CS. Students manipulating the CS visualize information in ways that students using laboratory equipment cannot see, like the weight vector of a body in each planet.

CONCLUSIONS

Prior to the different treatments, most students presented scientifically incorrect conceptions about the concepts of weight and mass, in agreement with the results obtained by several researchers (Galili, 2001; Gönen, 2008; Tural et al., 2010).

The different treatments were not highly effective in promoting the development of scientifically accepted conceptions about weight and mass.

In this study, teachers familiarized students with the use of the CS and provided a written guide to focus students' attention. However, only one of the three questions of the tests (Q3) was inferable directly

from the CS. That may explain the higher gains, in this question, when students used the CS. In this case, the CS coupled with hands-on activities seems to promote even higher gains. For the two other questions, the gains obtained by students seem very dependent on what the teachers did in the classroom.

These results emphasize the close connection between the efficacy of CS and the pedagogy through which they are implemented (Osborne & Dillon, 2010).

We can then say that, despite high expectations for the CS, we can not guarantee an overall conclusion about its effectiveness, as referred by Yaman and colleagues (2008). CS provide new affordances for learning, particularly when they are based on phenomena that cannot easily be observed and explored in the real world (Webb, 2005). However, teachers have a crucial role in planning the learning experiences of their students using simulations and in promoting their learning through appropriate mediation.

Teachers participating in this study used the same resources (laboratory equipment, CS), used the same activities guide. However, they certainly guided students in different ways, leading to very different learning gains. To fully address this question we will conduct further in-depth analysis of the interviews with the teachers.

It is important to note that the present research is based essentially on three cases with a small number of participants. Thus, it would be helpful for future research to explore the benefits of using this simulation with more teachers and students. Further information about how teachers taught their lessons and more in-depth information from the students (obtained from interviews) would be very helpful to better understand the observed differences in learning.

ACKNOWLEDGEMENT

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TEACHER EDUCATION USING COMPUTER SIMULATIONS PRE- AND IN-SERVICE PRIMARY SCHOOL TEACHER TRAINING TO TEACH SCIENCE

Alexandre Pinto, António Barbot, Clara Viegas, António A. Silva, Carla A. Santos, J. Bernardino Lopes

ABSTRACT

The objective of this work is to study how teachers' mediation promotes the development of students' epistemic practices (EPs), in a classroom environment, using computer simulations as a didactical resource, in topics related to hydrodynamics. In particular, we want to explore what EPs occur between theory (T) and the observable-world (OW), in both pathways (from T to OW and from OW to T). We report a multi-case study with two teachers from higher education, one from an undergraduate program and another from a master's program. We use multimodal narratives (a description of what happens in the classroom, using several types of data collected inside and outside the classroom) to analyse the students' EPs and the teachers' mediation. This analysis is made using the qualitative analysis software (NVivo 8®).

The results point to that the conclusion that the differences in the occurrences and pathways found in students' EPs can be related to the different characteristics of teachers' mediation. When teachers' mediation incorporates the use CSs, there is great potential in promoting various types of students' EPs.

KEYWORDS

Computer simulation, teachers' mediation, students' epistemic practices.

INTRODUCTION

The use of computer simulations (CSs) as a complementary tool in classroom (lectures or laboratory) is referred in science education literature as particularly adequate (Khan, 2011). There is a growing interest in interactive and collaborative CS because of their potentials in constructivist learning (Richards, Barowy and Levin, 1992; Webb, 2005). CSs are good tools to improve students' hypothesis construction, graphic interpretation and prediction skills (Sahin, 2006). However this usage in classroom requires some attention regarding the teacher mediation in order to potentiate students learning (Lazonder, Hagemans and Jong, 2010).

In physical science classroom, teacher should provide epistemic support (Sandoval and Reiser, 2004) in order for students' engage on epistemic practices (EPs), which is determinant for personal knowledge construction and epistemic competences development about S&T. Through the occurrence of EPs students have real opportunities for developing the positive attitudes about science (and ways of doing it), constructing meanings associated with the practice (Jiménez-Aleixandre and Reigosa, 2006) and developing competences (Lopes, Branco and Jiménez-Aleixandre, 2011).

Teachers' mediation, through actions and languages (Lopes, Cravino, Branco, Saraiva, and Silva, 2008) can scaffold and promote the students EPs (McNeill and Krajcik, 2009), helping them connecting theories, practices and explanations of phenomena (Sandoval and Reiser, 2004). The importance of the mediating role of the teacher is well established in the research literature (Hennessy, Deaney, and Ruthven, 2005). The teacher mediates the interaction between learner and environment by selecting,

changing, amplifying and interpreting objects and processes (Barton and Still, 2004; Tharp and Gallimore, 1988).

As some important science philosophers show (Bachelard, 1971; Bunge, 1973) the bridge between observable-world and theory demand both pathways: from theory to observable-world and from observable-world to theory. Data can promote a pathway towards a theoretical construction, which can be useful for many systems; with a theoretical model it is possible to better explore the phenomena, to specify its context of use, or create new artefacts.

The objective of this work is to study how teachers' mediation promotes the development of students' EPs, in a science classroom environment, using CSs. In particular, we want to explore which EPs occur in the epistemic pathway from theory (T) to the observable-world (OW), and vice-versa pathway.

We used the CS as a didactical resource to explore relationships between T and the OW in topics related to hydrodynamics. In particular, we are interested in understanding, in higher education, how these pathways are related to students' EPs (studying in pre and in-service primary school teacher training courses) and teacher didactical intentionality and orientation by presenting tasks.

METODOLOGY OF RESEARCH

Participants

This research work consists on a multi-case study (Cohen, Manion, and Morrison, 2010) involving two physical science classes from higher education: one from a masters' programme (case A) and another from an undergraduate program (case B). Each case had a different teacher that taught physics in the same higher school of education in Portugal. The main characteristics and background information about our two case studies for this qualitative research are presented in Table 1.

Table 1: Main characteristics of the two case studies

		Case	
		A	B
Teacher	Gender	Male	Male
	Academic Degree	PhD student of Physical Sciences	PhD student of Physical Sciences
	Teaching experience	20 years	4 years
	Research experience	14 years	6 years
Students	Age range	24 - 55	18 - 35
	Grade and Course	2 nd year of a Master Programme in Science Teaching	1 st year of an Undergraduate Programme in Basic Education
	Teaching experience	In-service primary school teacher	No experience
Classes	Discipline	Experimental work in Science Teaching	Physics
	Topic	Hydrodynamics – Experimental approaches	Hydrodynamics – Archimedes' Law
	Number of students	19	16
	Classroom	Physics Laboratory; space for 4 work groups, 1 computer per group	Physics Laboratory; space for 4 work groups, 1 computer per group
	Time duration	120 min	120 min

Data collection

We used multimodal narratives (MNs) as a central component of the hermeneutic unit that encompasses all types of data collected inside and outside the classroom. According to Lopes and colleagues (2010), a MN include multimodal elements such as schemas of spatial organisation of the classroom, schemes put on the blackboard by the teacher and/or by students, student reactions, explicit teachers' intentions and decisions, teachers' documents, photocopies of students' notebook, photographs of used equipment, indication of silences and gestures, print screens of CS, amongst others. The MN is a description of what happens in the classroom (Lopes, et al., 2010), based on audio recording of the lesson, using several documents and the multimodal elements obtained from the teacher, referred above. The MNs have all the same structure, which allows comparability.

Data analysis

In this study, we have analysed one MN of each teacher. Teacher mediation efforts to promote students' EPs were studied taking into account the way CS were introduced and used in class.

The process of MNs analysis was done in several steps implying different researchers, based on content analysis (Bardin, 1977; Krippendorff, 2004), and using the coding capabilities of NVivo 8[®]. In all steps the analysis was made by one researcher of our team, who identified and coded the parts of the multimodal narratives which contained evidences about: (a) students' EPs that took place in classroom and; (b) teachers' effort to promote students' EPs using CS as a didactical resource to explore relationships between theory and the observable-world. Then, the MNs were analysed by another two researchers, in order to validate the process. This procedure allows us to express the results with high level of reliability.

The steps of our first order data analysis, which was data driven, were the following:

- Select and code the parts of the MNs related to the pathways from OW to T and from T to OW;
- Identify and code the parts of the MNs that contain evidences about the occurrence of students' EPs. The criteria used to recognize this occurrence was the identification of students' investigative actions, in order to solve a problem or answer to a question (Sandoval, 2005). This identification was made in the previously coded pathways.

Then the coded MNs were reviewed by other researcher in order to verify if all evidences about the teachers' actions and students' EPs that took place were covered. Each category was given a name and a brief description (see table 2). In order to get an effective verification, all MN were reanalysed by other researchers (also using NVivo 8[®]), using the same criteria for evidences. In this verification, a 95% of agreement was obtained in categorizations made by different researchers. When any divergence in the analysis process occurred, involved researchers discuss and reflect together in order to achieve consensus about the emergent categories.

RESULTS

Teacher mediation

From MN analysis, there were differences in teachers' mediation in both cases. Namely, tasks, CSs and teachers' actions. Teachers introduced tasks and CS with different objectives.

The tasks and the CSs introduced by teacher in case A had the main objective of formalising a model that could explain the observable phenomenon of water flowing through a hole made in a bottle. In this case, teacher challenged students to find the best position to make the hole in a plastic bottle, so that the water would go as far as possible, once the bottle was placed on a table. The provided resources were two CSs available on internet: Projectile Motion – Phet; that allows predict how varying initial conditions affect a projectile path (various objects, angles, initial speed, mass, diameter, initial height, with and without air resistance) and Hydrostatic Pressure in Liquids – Fendt (the simulator allows to explore the relation between hydrostatic pressure and depth, enabling to select one of several liquids). Teacher gave autonomy to explore the CSs and followed students' work. His main task was interacting

with students to reinforce their motivation, challenge students to compare the obtained results (using the CS) among them and share their point of view. Through several attempts using the CS students tried to find a model that could explain the phenomenon. The main difficulty was to understand and match the two physical concepts (Projectile Motion and Hydrostatic Pressure) with their observations with the CS.

The tasks and the two CSs introduced by teacher in case B had different characteristics: students used an existing model that allowed them to simulate different situations of the observable phenomenon of fluctuation. One CS used was Buoyancy – PhET that allows exploring how buoyancy works with blocks. In this CS, students can change the properties of the blocks and the fluid and show up arrows that represents the applied forces. The other CS used was an Excel spreadsheet simulation (Silva, 1998). By inputting data in this simulation, students could determine the minimum of potential energy of a system composed by a body in a fluid. Students could change parameters for both body and fluid (area, height, density), and see what happened to the body, fluid and system (body + fluid) in terms of potential energy. Equilibrium occurs at the minimum potential energy of the system (left graphic of Figure 1). Teacher of case B distributed a guide of activities that defined, in a general way, the dynamics of the class. The teacher followed closely students' work, asking them to explain tasks development in detail in order to motivate and engage them in the activity. The teacher gave detailed information, in particular, about the excel simulation due to its characteristics.

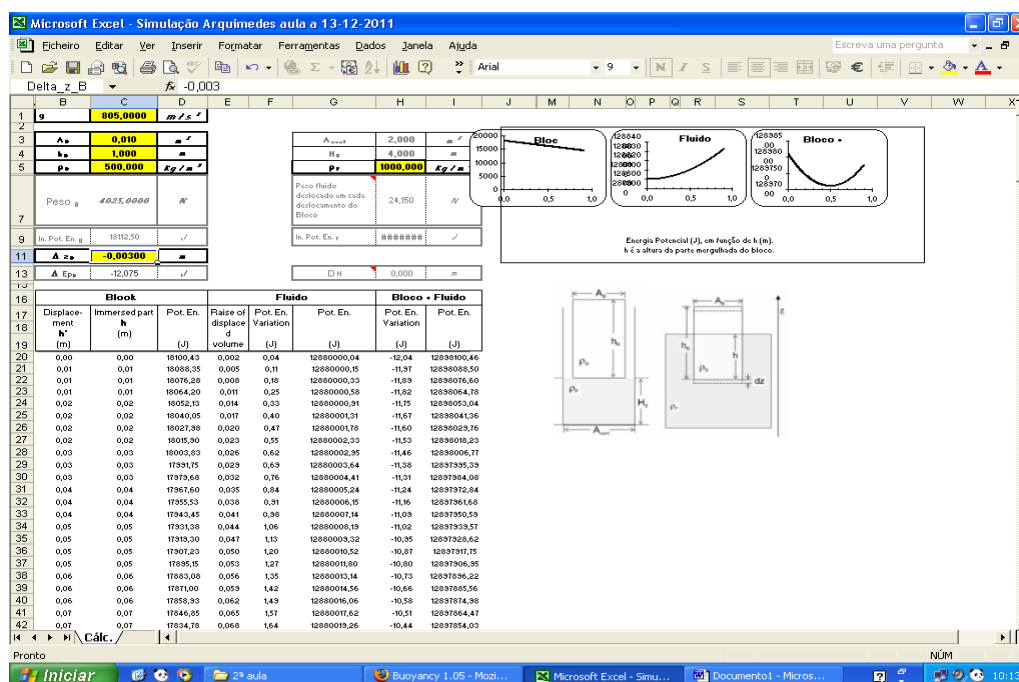


Figure 1 – Layout of the Excel simulation

Students' EP pathways

From the MNs analysis (categorization process) the identified categories for students' EPs, related with the use of CS in classroom is described in Table 2.

The total number of students' EPs occurrences in each pathway (OW-T and T-OW) and for each teacher can be seen in Table 3.

Table 2 – categories of students' EPs

Students EPs	Definition
Communicate (Comm)	Present ideas about their epistemic work
Conceptualise (C)	Make a symbolic representation of a phenomenon.
Evaluate critically (EC)	Analyse and argue, making critical evaluation of hypothesis, resources, results, used language, etc.
Formalise the model (FM)	Establish a model of a system.
Handle factually CS (HF)	Handle equipment following instructions given by teacher, or tentatively without any guiding knowledge.
Handle conceptually CS (HC)	Handle equipment guided by knowledge.
Identify empirical conditions (IEC)	Identify empirical conditions of a physical situation in which the phenomenon(a) occurs.
Interpret (I)	Interpret images, diagrams, objects, partial data, etc.
Modelling (M)	Develop a conceptualization pathway in order to construct a model of a system.
Prediction (P)	Make predictions of experimental or theoretical results based on the reasoning with knowledge.
Present information (PI)	Present information known that is relevant to the situation in use.
Present mobilising idea (PMI)	Mobilise prior knowledge to guide a possible way to solve the problem.
Questioning (Q)	Formulate questions and problems based on knowledge to obtain new understanding of phenomenon, concepts, models or to clarify terms or observations related to empirical conditions of a phenomenon.
Relate (R)	Establish relations between data variables and/or concepts in different situations.
Use symbolic mediator (USM)	Use a symbolic mediator to explain an idea that is relevant to the situation in use.
Introduce manipulable mediator (IMM)	Introduce a manipulable mediator to explain an idea that is relevant to the situation in use.

Table 3 – Total number of students' EPs occurrences

	Pathway	
	OW-T	T-OW
Case A	66	5
Case B	38	66

We can see that in case A most of students' EPs occur in the pathway OW-T. In case B most of the students' EPs occur in the pathway T-OW. This trend of students' epistemic pathway is according to teaching intentionality: obtain a model to explain observable phenomena – case A; use an existing model to understand how it works in different situations – case B.

Figure 2 shows the more frequent students' EPs in cases A and B in the pathway OW-T (*predicting, identify empirical conditions, questioning, communicate, relate, handle factually and modelling*) and in the other pathway T-OW (*formalise the model, handle conceptually and use symbolic mediator*). The students' EPs *interpret* occurs evenly in both pathways.

We can observe that in the OW-T pathway there is more diversity in the type of EPs than in the T-OW pathway. This can be explained by the fact that those types of EPs, like *questioning, predicting* and

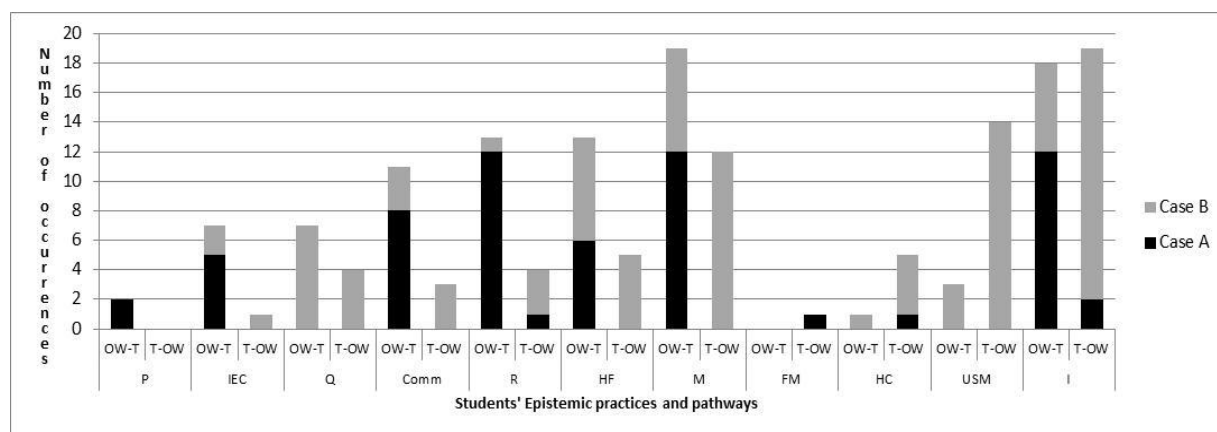
communicate, are relatively usual and common practices in everyday life (observable-world) phenomena.

On the other hand, *interpretation* requires support of both dimensions: theoretical and observable-world. Thus, the EP *interpret* occurs in both OW-T and T-OW pathways.

As seen in Figure 2, we can also see that there are differences in the students' EPs that occurred in both cases: some EPs occur only in one case, e.g.: *predicting* and *formalise the model*, that occur only in case A; *questioning* and *using symbolic mediator*, that occur only in case B.

This also can be related to the different type of mediation carried out by teachers. In case A, teacher wanted students to do some *predictions* on where to make a hole in a bottle in order to *formalise a model* that they could use in a similar situation. In case B, were it was used a model as a starting point, the first need of students was to understand how the model work. In this situation, *questioning* is an expectable attitude of students. The students' EP *use of symbolic mediator* had to do with the introduction by the teacher of graphics, tables and equations and its interpretation by students; these were the main symbolic mediators used, as the interpretation of equilibrium in terms of potential energy was made based on them.

Independently of epistemic pathway it can be verified that students' EPs *questioning*, *handle factually or conceptually*, *modelling*, *use symbolic mediator* and *interpret* are more frequent in students of case B than the case A. Given that in case B there was a general pathway T-OW this poses the question of the need of mobilization of theory to improve certain students' EPs. The more surprising is the *questioning*.



Legend: OW – observable world; T- Theory.

Figure 2 – Students' EPs that occur in OW-T and T-OW pathways

DISCUSSION AND CONCLUSIONS

Teachers' intentionality had large impact in students' epistemic pathway as the results shown and according to literature (Lopes, Cravino, Branco, Saraiva, and Silva, 2008; McNeill and Krajcik, 2009; Sandoval and Reiser, 2004). In spite of this general trend, the results point to the need to students have many EPs on OW-T pathway when the general epistemic pathway. Perhaps the students need having an OW reference, in order to better understand the theoretical model. When students have an OW reference (case A), most of their EPs occur in the OW-T pathway, as they are familiarized with most of the phenomena. On the other hand, when students have a T reference (case B), there is the need of getting some reference from the OW, in line with the literature (Bachelard, 1971; Bunge, 1973)

The results, limited, point to the claim that is not the type of students' EPs that made an epistemic pathway, because almost EPs are present in two cases. However: (a) there are EPs that are very important in any epistemic pathway (e.g. *questioning*, *modelling* and *interpret*); (b) there are EPs

(*questioning*) that need the explicit mobilization of theory to be improved and others that will be better improved if students deal with OW (*identify empirical conditions, communicate and relate*). In the T-OW epistemic pathway the *use of symbolic mediator* is determinant to help students to have meaning in their epistemic work.

The results point to the conclusion that, when teachers' mediation incorporates the use of CSs, there is great potential in promoting various types of student's EPs. Further research will be made in order to study if this occurs with other teachers, with different tasks or different CS.

Note: The CSs used can be viewed at <http://phet.colorado.edu/en/simulation/projectile-motion>; <http://www.walter-fendt.de/ph14e/hydrostpr.htm>; <http://phet.colorado.edu/en/simulation/buoyancy>

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PRE-SERVICE SCIENCE TEACHERS' EXPECTATIONS OF COMPUTER COURSES

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ABSTRACT

The aim of this study was to examine pre-service science teachers' expectations and opinions of the computer courses. The study was carried out with pre-service science teachers (female: 5, Male: 7) attending computer courses on preservice teacher education at the Education Faculty of Dicle University. Among the participants, 4 of them were from the department of physics education, 4 were from the department of chemistry education and 4 were from the department of biology education. Interviews that included 19 questions were used as the data collection tool. The participant students indicated that the theoretical part of the computer courses was not useful and practical for their educational life. Moreover they stated that they had already known and familiar to the applications (power-point, Word, excel) of the course. So they indicated that these applications were not at level that makes any contribution to their academic educational life.

KEYWORDS

Computer courses, pre-service science teacher, views

INTRODUCTION

Computers are one of the most important technological developments that make like easier for every day classroom activities which lead to an increasingly dependence on computer systems day by day. (Bektaş and Semerci, 2008). This is why teachers have to develop their skills for using computer effectively (Sarı, 2002). Computers can create a flexible learning environment for students and it can, therefore, be a powerful tool to develop the teaching-learning processes (Kleiman, 2000). A study by Smarkola (2008) that included 160 student teachers and 158 experienced teachers found that both groups of teachers strongly believed in the need for additional computer-integrated training while Willis and Montes (2002) reported that pre-service teachers viewed computer technology as a useful tool for personal and professional development. Sime and Pristley (2005) argued that although many initial teacher education programmes provide appropriate support for students to develop their skills, it is important that the development of educational technology pedagogies are underpinned by a reasonable level of generic skills. Being technologically competent allows teachers to use computers as a part of the curriculum and as tools for authentic student engagement and learning (Smarkola, 2008).

The computer courses in preservice teacher education can be used as a base for training teacher candidates for computer education so that they can use computers effectively in their classes.

In Turkey, secondary science curriculum has been redeveloped. New curriculum which largely depends on constructive learning put a special emphasize on instructional technologies that includes computer. The aim of this study was to examine pre-service science teachers' expectations and opinions about computer courses.

METHOD

The study was carried out with pre-service science teachers (female: 5, Male: 7) attending computer courses on preservice teacher education at the Education Faculty of Dicle University. Among the participants, 4 of them were from department of physics education, 4 from department of chemistry education and 4 from department of biology education. An interview form consisted of 19 questions was used as the data collection tool. This form was developed by the researchers. After transcription of the recorded data, it text was coded was categorised. The interviews took place during spring term of May 2012. Content analyse method which is a qualitative research design was used for the study.

RESULTS

The participant student teachers indicated that the theoretical part of the computer courses were not useful and practical for their educational life.

Student A, "We learned computer history but I think it was not necessary. We learned computer software history as well. I was very bored. And software languages were very difficult to learn at the same time we don't know what does it means".

Student B, "We learned computer equipments. It was not practical so I forget all knowledge that I learned".

Moreover they stated that they had already known or were familiar with the most of the content (power-point, Word, excel) of the course. They argued that these applications were not at level that makes any contribution to their academic educational life.

Student C. "I can use word, power point and excel effectively. So it was not meaningful to see these again. It will be perfect if the curriculum is developed as the technology progresses".

Teacher candidates suggest that they want to use computer and internet to find the up to date information's about their academic life.

Student D. "I want to keep up to date about my academic life. But I don't know how to use computer for my aim. Which sites are useful and reliable? It has to be taught. But we don't have this kind of subject".

Students had computer courses only one semester and 2 hour per week. They also indicated that computer courses hours were not sufficient.

Student F. "Computer courses should be given at least two semester. 2 hour isn't enough. Because there are lots of information to learn. So we couldn't have sufficient time to practice. I think practice with computer is more important than to learn history of computer".

Students argued that that they did not know how to integrate computer to their subject.

Student G. "I will become a biology teacher. I want to use instructional technologies in my class. But I really don't know how I am going to do this. In computer courses, lecturers should train students for using computer effectively in class. For example, computer simulations. I know what is it but I couldn't use it".

Students also want to the computer lessons follow the new developments of instruction technologies.

Student H. "There is no new curriculum for computer courses. The curriculum is very old but technology develops by day by. We have to capture new knowledge about instruction technologies. Because we will be a teacher, we have to know more than our students".

In addition, students want to learn how to use computer programs which are useful for science education and how to make graphics on computer.

Student A. "I heard some computer programs for using biology teaching. But I don't know how I can use them".

Student G. "I will become a chemistry teacher. We use graphics all our lessons but i don't know how can manage them on computer".

IMPLICATIONS

The following suggestions can be made by looking at the results of the study.

- Study hours of computer lessons could be increased.
- Studies can be done to increase teacher candidates' skills in computer usage.
- The curriculum can be reorganized and vocational computer skills can be added as a sub-subject.
- In computer courses, more time can be allocated for computer usage applications.
- New developments on instructional technology can be taught to lecturers during in-service training.
- High-level computer usage skills could be taught as well as lower-level computer usage skills, in computer courses.

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THE EFFECT OF AN ICT ON THE COHERENCE OF THE TEACHER DISCOURSE: CASE STUDY OF AN ELECTRICITY SEQUENCE AT GRADE 12

Suzane El Hage, Christian Buty

ABSTRACT

This paper presents an analysis of the teacher's discursive coherence in a "natural" physics sequence at grade 12 in France. In this sequence about electricity, the students and the teacher use an ICT-tool, belonging to the category of "data-logging systems and Microcomputer-Based Laboratory", following the typology by Pinto and colleagues (2010).

The theoretical framework is based on four elements: 1- an element borrowed from work about the discourse analysis in science classroom, particularly the notion of episode (Mortimer et al, 2007); 2- the categories of articulations proposed by Badreddine & Buty (2011); 3- the semiotic registers (Duval, 1995) and 4- the modelling processes (Tiberghien, 1994).

The collected data consist in the video recording of all the sessions of the sequences, as well the practical sessions as the lectures and debriefing in whole class.

The methodology consists in two parts: first, dividing the video tapes into microscopic episodes using Transana, software for video- and audio-annotation; second, inventorying in a table the links between episodes realised through each category of articulation. In general we use the method of zooming out (Lemke, 2001) for studying the coherence in the discourse at different moments in the sequence.

In this contribution, we will present two cases: the first one when the teacher establishes relationships between an earlier stage of the sequence, and the second one when the teacher makes connections with an episode later in the sequence. We shall particularly highlight how the ICT device intervenes in these connections.

KEYWORDS

ICT, electricity, coherence, discursive analysis

INTRODUCTION

It can be reasonably hypothesized that teaching coherence is an important factor of learning; a frequent classroom observation is that expert teachers spontaneously establish many cohesive links between the various parts of their discourse. The use of ICT tools, which is rather common nowadays in science instruction, raises a specific problem regarding the coherence of the classroom discourse. Very often, the intervention of ICT tools is limited to one or two sessions in a whole teaching sequence, and the kind of activity or result produced by this intervention is rather disconnected from the usual course of the instruction, from the other activities. This tendency is strengthened by the fact that ICT tools are seldom used in evaluations; this encourages both teachers and students to consider this kind of activity as secondary, compared for example to classical exercising sessions, which prepare classical tests.

This is the reason why this case study turns on how an expert teacher establishes links between the different moments of his teaching sequence about electricity at grade 12. The context gives several reasons for a potentially high degree of coherence in this sequence. The domain (electricity) and the

state of classroom technology (the availability of rather cheap and easy-to-use acquisition and modelling devices) make it possible to obtain a high students' engagement in handling computer-based measurement systems; the existence of an experimental test in the national final exam (the *baccalauréat*), where such ICT tools can be used, constitutes a stake for using these tools during the instruction, and for learning to use them autonomously. In the same time, electricity is also a domain where exercises are frequently given in the national exam; it makes it necessary for the teacher to ensure strong links between the computer-based experiments and the concepts and relations allowing the solution of the exercises.

CONTEXT

The observed teacher has around ten years of experience. The school is one of the best ones in an important French city; in the division where the data were collected, students have generally a good sociocultural level. As always in French scientific instruction at this stage, courses belong to two categories: *lectures* in whole class, and *practical sessions* with the half of the class. In this class, practical sessions happen on Monday (for both groups) and lectures happen on Tuesday and Friday, each week.

The teaching sequence in electricity is divided into three chapters, in accordance with the official curriculum: R-C dipole; R-L dipole; R-L-C dipole. Each chapter is divided into several *activities*, mainly elaborated by the teacher himself; in this sense it is a "natural" teaching sequence. Most of the time, during practical activities, students use computer-based acquisition and modelling devices; in fact it is always the case, except in the first practical session. During lectures, the teacher often uses the same ICT tools, projecting the screen of the computer on the white board with a video projector, and adding simultaneously drawings, schemas or equations on the board.

The two ICT tools that are used are on the one hand *Mesures Electriques* (ME; voltage or current acquisition) and on the other hand *Regressi* (data treatment and modelling). They can be classified as data-logging systems and Microcomputer-Based Laboratory following the typology of Pinto and colleagues (2010).

THEORETICAL FRAMEWORK

The analysis of the discourse and its coherence consists essentially in describing the different types of relational marks between the different segments in a text. The use of ICT can affect any links in the discourse, both for their frequency and their characteristics. We need theoretical categories for identifying those links, and for characterising their nature. Identifying the links means first isolating some moments in the flow of discourse that can be linked, and secondly naming the kind of relationship established between two moments.

For defining moments in an objective enough manner, we use the notion of episode as developed by Mortimer and colleagues (2007, page 61): "a discursive unit which constitutes a coherent set of actions and meanings produced by the participants in interaction, which has a clear beginning and end, and can be easily distinguished from the previous and subsequent episodes". The set of episodes constitute a complete mapping of a session or a sequence, objectifying the rhythm of discourse in the classroom.

For characterising the links between episodes identified at different moment of a sequence, we use the categories of articulation defined by Badreddine & Buty (2011, page 783), pointing from a given episode to previous or posterior ones: three directed to the past (resume, call, remind) and three turned to the future (postpone, announce, advance).

For characterising the nature of the links that is, the eventual transformation they imply in the knowledge content, we use a set of descriptors for science teaching-learning situations (Buty & al., submitted): the epistemological aspects of the situation, particularly the modelling processes (referring

to Tiberghien, 1994); the form of representations (referring to Duval, 1995); the management of verbal interactions (referring to Mortimer & Scott, 2003); the management of students' engagement (referring to Engle & Conant, 2002). In this communication, the two first descriptors only will be used (in particular due to the fact that we are analysing teacher's discourse, almost always during authoritative moments).

RESEARCH QUESTIONS

Our aim is to understand how the use of ICT tools for data acquisition and modelling in physics teaching can strengthen the coherence of the instruction, from various points of views, namely the knowledge content and modelling processes, and the link between semiotic registers, through the management of social interactions in the class. In the linked episodes we analyse, we shall especially focus on the existence, or absence, of corresponding knowledge elements.

COLLECTING AND ANALYSING DATA

As far as this communication is concerned, the collected data were essentially constituted by the video-recording of the classroom activity, through a camera at the back of the room, aiming at the teacher. Besides of that, the useful documents for the present analysis were the instruction sheets for the concerned activities.

The treatment of the data is far more sophisticated. In a first step, the whole sequence is divided into episodes, as said before. In a second phase, each episode can be attributed a set of keywords; among these keywords, the categories of articulation described in the theoretical framework are used. In a third step, a table is fulfilled, indicating for each episode affected by such a keyword, to which other episode(s) the articulation establishes a link. In a fourth and last step, after choosing a couple of episodes linked by articulation categories, we consider both episodes in their context (that is mainly their theme or sub- theme, see Tiberghien & Buty, 2007) to describe more accurately the meaning of this articulation.

ANALYSIS

We analyse here two opposite cases of links between two episodes of the sequence. In the first case, the teacher establishes a relation with a previous situation, what Badreddine (2009) names a *call*. In the second case, after another call, the teacher indicates that a subsequent situation will involve such and such piece of knowledge; for Badreddine (2009), this is an *announcement*. All these episodes occur at the beginning of the sequence, when the topic at stake is the R-C circuit.

From the present to the past

In the second session of the sequence, which is a practical session, the teacher performs alone an experiment consisting in the charge of a capacitor with a current generator, that is, the intensity being constant (the circuit is the same than on figure 2). In a first step (episodes 21-29), this experiment is realised with traditional equipment, that is, a chronometer, a voltmeter and an A-meter, all of them visible by students. Students, working by pairs, have to notice the voltage function of time, and draw the graphical representation of this function, which is a line. Students must calculate the value of the capacity from their measurements. We must notice that not all students succeed in this part of the practical activity.

After this first experiment, the teacher introduces (episode 30) the computer-based measurement system (Mesure Electrique software) and shows it gives the same result than the traditional experiment, but with much more points and faster (figure 1). He somewhat legitimates the use of a computer-based system.

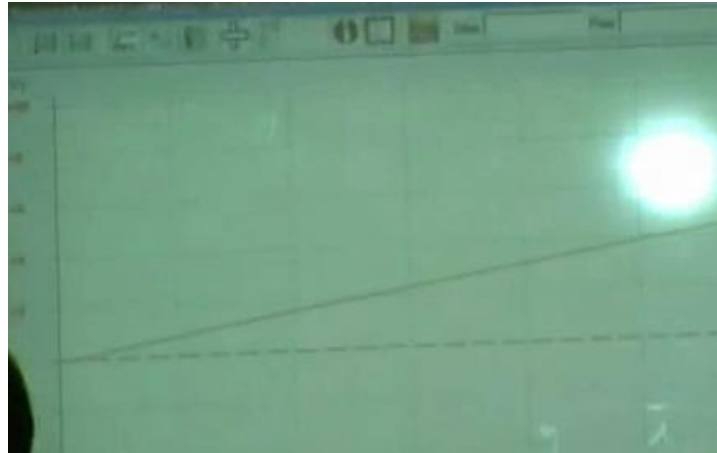


Figure 1. Voltage on the capacitor, versus time.

In the third session of the sequence, which is a whole-class lecture, the teacher makes a first call to the practical session (episode 8), and projects the computerised data acquisition of the line (voltage versus time), which students have seen in the practical session. The students calculate the value of the capacity from the measurements produced by the teacher; at this occasion the teacher makes a link between the world of objects and the world of models, because he reads the value of the capacity on the component, including the uncertainty, and everybody can ascertain that the nominal value and the value found through application of the theory are compatible.

In the same session, a few minutes later (episode 38), the teacher projects a circuit schema and a representation of the plates of a capacitor (figure 2); in this episode we find a second call to the practical session. On this projection we see a superposition and an articulation between two modelling scales, a microscopic model (the elementary charges which accumulate on the plates, symbolised by individual boxes for the electrons or 'plus' signs) and a macroscopic one (the quantity q , linked to other macroscopic quantities such as $i = dq/dt$ and U_{AB}). In this representation and its intervention in the classroom discourse, three semiotic registers (Duval, 1995) are used: a schematic one, a symbolic one (the equation $i = dq/dt$ and other notations), and natural language (for example, it is noticeable that the words 'macroscopic' and 'microscopic' are made explicit by the teacher). Some conversions are made by the teacher: for instance, he translates the equation $i = dq/dt$ by "i is the flow of charge".

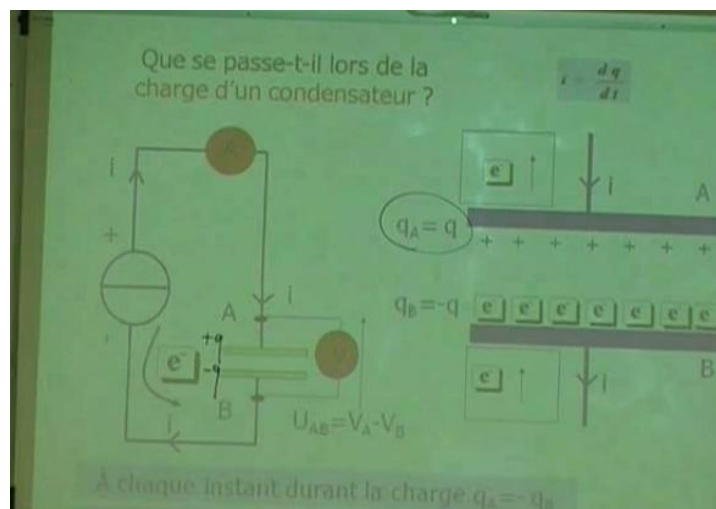


Figure 2. Projection of a slide during the lecture in session 3. One can remark that the teacher has manually added some indications (the circle around $q_A = q$, the charges $+q$ and $-q$ on the schema, left).

From the present to the future

During the second session of the sequence, which was a practical session like it has already been said, some students have made two different acquisitions for two different values of the capacity in a circuit R-C powered by a voltage-generator (episode 100), and observed that the shapes of the two curves were different, particularly that the time necessary to reach the limit was longer if C or R was bigger.

During the following lecture (already discussed in the previous paragraph), the teacher *calls* back this observation and *announces* that this point will be discussed again later (in the next practical session). He also makes an-extra sequence call, because he tells that it is basically the same phenomena than in radioactivity and in kinetics, and that the aim of the discussion will be the same: finding the temporal evolution of the charge of the capacitor.

Three days later (in the following lecture, session 4 of the sequence), the teacher performs again the experiment with two different values of C, in front of the whole class (episode 35, figure 3). Then, he projects three new curves, which he had previously recorded, coming from the same experiment, but with the same value of C and three different values of R (he *announces* there is a link with τ , Episode 46). These two experiments allow him performing a dimensional analysis, and showing that the product RC has the dimension of a time.

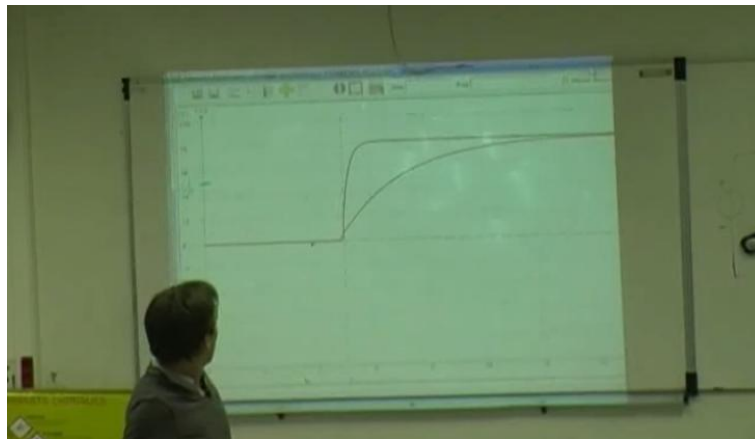


Figure 3. Projection of the results of an acquisition just realised in front of the whole class.

On the next session (5, which is the second practical one) the teacher performs an acquisition followed by a modelling through Regressi. Thus he validates that the time constant, τ , is RC both in the world of theories and models (by this modelling process through the software) and in the world of objects and events (by calculating the product R times C, quantities read on the components, episode 51).

DISCUSSION AND CONCLUSION

In both cases that were discussed, we find some important characteristics of computer-based tools in science instruction.

The fact that the teacher has the possibility to perform the same experiments during the lecture that have been performed during the practical activities strengthens the coherence between these two moments of the sequence, and allows the teacher being sure that all the students have drawn the same conclusions of the practical activities. This portability of modern acquisition systems also gives the possibility to teachers to facilitate the links between the experiments (the world of objects and events) and the theory, which is generally exposed and worked out in the whole-class lectures.

Of course, the fact that the tool exists does not mean that the teacher is able to use it. Like Pinto and colleagues claim (2010), the teacher's role is critical. In the analysis of this case, we must not forget that the observed teacher is an experienced one, who has a deep reflection about modelling processes and the use of combined semiotic registers, due to his proximity with a science education research team. Or, to say it another way, and again in line with Pinto and colleagues remarks (2010), the choice of such software and the decisions on how to use it show a conception of learning in science, for this teacher, based on the establishment of meaningful relationships between the world of objects and events and the world of models and theories, on the one hand, and between symbolic and iconic registers, on the other hand.

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LEARNING THE CONCEPT OF SCIENTIFIC MODEL BY MEANS OF ANALYSING DIDACTICAL SCIENTIFIC SIMULATIONS

Rufina Gutierrez, Denise Whitelock

ABSTRACT

It is well known from the data provided by the literature that the concept of a scientific model is far from having been accurately assimilated by students and by teachers. This paper presents a preliminary study, the aim of which is to test the possibility of using the analysis of didactical scientific simulations (ADSS) to introduce the concept of the scientific model (SM). We carried out the experiment with six science postgraduates. For the ADSS we took advantage of a validated instrument based on ontological approaches to the SM concept. We designed a four-hour seminar, divided in two parts: In the first, we administered a previously validated questionnaire, in order to see the conceptions of the sample about what an SM is; subsequently, we introduce the concept of scientific simulations from a theoretical perspective, and guide the practical analysis of several scientific didactical simulations (SDS), applying the SM concept. In the second part, we presented several simulations to the subjects, and we asked them to analyze each of them with the same criteria, but without any guide. At the end of the whole process, we asked the subjects to write down how they could explain the concept of SM to a colleague. The results of the comparison between the answers collected in the questionnaire and the explanations provided in the last task, gave us enough evidence to be optimistic about the efficacy of using this methodology in introducing the learning of the SM concept.

KEYWORDS

Analysis of didactical scientific simulations, scientific models, ontological approach to scientific models, learning, know what, know how

INTRODUCTION AND AIMS

On revising the literature on the concept of a scientific model held by teachers and pupils, we found that the conceptions of either group have little in common with what, in Science, we mean by “scientific model”. This fact is particularly worrying in the case of Science teachers (Cfr. Van Driel and Verloop, 1999; Justi and Gilbert, 2003), as it is commonly accepted nowadays that it is not possible to teach Science adequately without understanding this concept correctly (Drechsler and Schmidt 2005). Despite this, the concept of a scientific model is often considered as the central axis of the teaching/learning of science (Windschitl et al., 2008; Clement and Rea-Ramirez, 2008). For this reason, authors agree on the need to design courses to introduce teachers to this content, which is fundamental in current day teaching. However, the results obtained on these courses have not been as satisfactory as was hoped (Cullin and Crawford, 200; Justi and Van Driel, 2005). Only some studies provide positive results, with treatments of up to three years’ duration (Danusso et al., 2010).

We suspect that the epistemological perspective, adopted by the studies mentioned above, could make the task of understanding the concept more difficult. For this reason, in some of our previous studies (Gutierrez and Pinto, 2008) we point to the possibility that perhaps by adopting an ontological perspective, the task could be made easier. In this paper we present a pilot study of how a course for the

learning of the concept of “scientific model” could be planned using the ontological perspective as the central point of its design. Although it was carried out with a small sample, the results obtained encourage us to present our approach to this problem as our contribution to this conference. We believe that it could serve as a basis for the design of future training courses for teachers of this subject.

METHODOLOGY

Models and Simulations²

A simulation is no more than the running of a *model* (cf. definition by the *Institute for Simulation and Training*). A scientific simulation is, therefore, *the running of a scientific model*. From there it follows that a didactical scientific simulation is the *running of a scientific model with the aim of using it in the process of teaching/learning science*.

As can be seen, the central element of a simulation is a model; in the case of a scientific simulation (whether or not this is designed to be used in class), is a *scientific model*. To directly tackle the teaching of this concept did not appear to be the most appropriate course of action, given the not very encouraging results of the attempts cited above. Therefore, we decided to approach the problem differently: *via the study of didactical scientific simulations*.

We frequently find that teachers are familiar with the use of simulations in the classroom, where they are used for different purposes, for example: the introduction of concepts, the visualization of processes, etc. They rarely think to analyse the model which underlies the running of the simulation. *Our hypothesis was the following*: If we encourage teachers to become interested in studying and evaluating the models which make a simulation work and is useful to teach science, they will obviously have to study what a scientific model is. Thus the knowledge acquired will be not only declarative (*knowing what*), but also procedural (*knowing how*), with the advantage that the latter is more effective and longer lasting (Cohen and Squire, 1980). This is the basic idea which underlies our methodology.

Sample

Six science postgraduates, within the context of a Research Seminar on a Masters course in Research in Science Education. All the subjects had been introduced to the concept of a scientific model in previous courses/sessions. Also, all of them had some experience of teaching.

Resources

- A validated questionnaire (Gutierrez and Pinto, 2005), on the concept of the scientific model that the subjects of the sample held. The questionnaire consists of three open questions, asking for: in Q1, a *definition* of a scientific model; in Q2, its *main constituents*; in Q3, its *main functions* (Gutierrez and Pinto, 2005).
- An instrument for analysing scientific models and simulations, from an ontological perspective (Gutierrez and Pinto, 2004). See Figure 1
- A variety of selected simulations to be analysed with the instrument mentioned above (Figure 1)
- A straightforward questionnaire to see the application of the possible understanding of scientific models in a practical setting. See Appendix A

Procedure

Within the context of the research seminar, we designed two session-interventions of two hours each, with a break in between.

First Session

In the first session, we explained our intention of carrying out a small investigation about a method to teach the concept of scientific model. All participants agreed willingly to participate in this study. Then, we asked to the subjects to fill in the questionnaire anonymously, and assign a number to it. The aim

² The term “simulation” in this paper is always equivalent to “*computer simulation*”.

was to have information about the existing understanding of the concept by the group before starting the intervention.

After that, we presented the instrument for the analysis of scientific simulations (Figure 1), explaining all the details (*know what*): First of all, the distinction between animations and simulations, and among the different universes which can be found in computer simulations: e.g., fantastic (the imaginary world), formal (the world of mathematics or logic), factual (the physical world); then, the ontological constituents of scientific models and the criteria to refer the model to a specific universe. These distinctions were crucial, because we knew from the literature that sometimes, when teaching science, teachers do not pay attention to whether they are working with scientific models or with mathematical models (Sassi et al, 2005; Lemmer, 2006). Lastly, we paid attention to the limits of the validity of models.

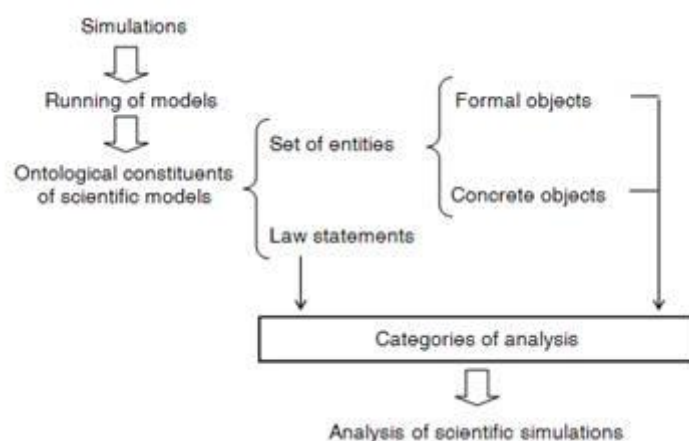


Figure 1. Schema for analysing scientific models and simulations, from an ontological perspective

As a third step, we presented several simulations to the subjects. We selected very simple ones. The aim was to introduce the concepts in an easy way, trying to avoid consuming too much time and also that the complexities of the contents of the simulations were the focus of attention. An example can be seen in Figure 2.

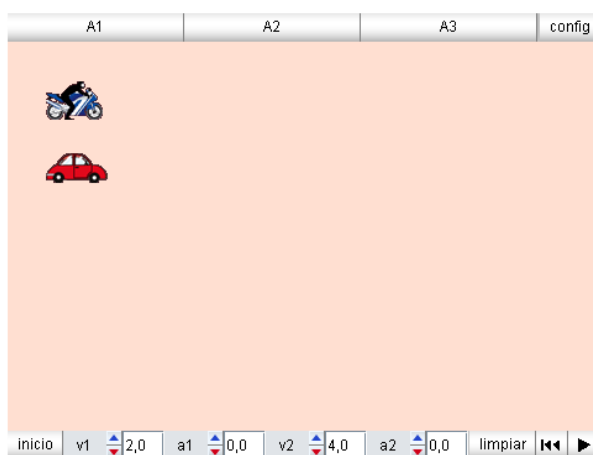


Figure 2. Motion with constant acceleration. Acceleration must be greater than zero³.

³ URL: http://recursostic.educacion.es/newton/web/materiales_didacticos/movimiento%28II%29/21mov2.htm?1&0

The simulations were examined collectively, the tutor acting as a guide in an intensive feedback session, pointing out the critical questions about the application of the criteria, clarifying doubts, etc, in order to recognize the model and assign it its universe (*know how*)

Second session

After the break, we started the second session. First, we presented new simulations (example in Figure 3), and the subjects examined them, and were asked to do the entire task (*know how*), following the criteria expressed in “Figure 1”. The subjects worked in pairs. The tutor acted as an observer, clarifying doubts when requested to do so.

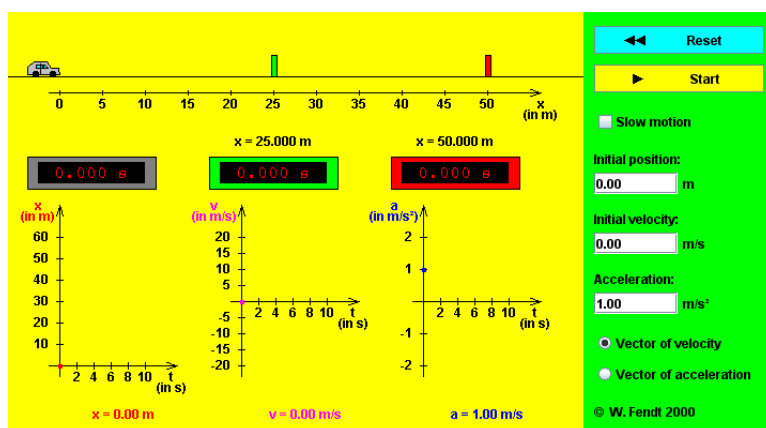


Figure 3. Motion with constant acceleration. Acceleration can have any value⁴

Then, we presented a *new simulation, quite different from those examined so far* (see Figure 4), and asked the subjects to analyse it by applying the criteria shown in “Figure 1”. This time, the subjects worked individually, and were asked to write down all the analysis (*know how*). At the end of the work, the tutor collected the work produced. All of the contributions were anonymous and with the same number as they used before.

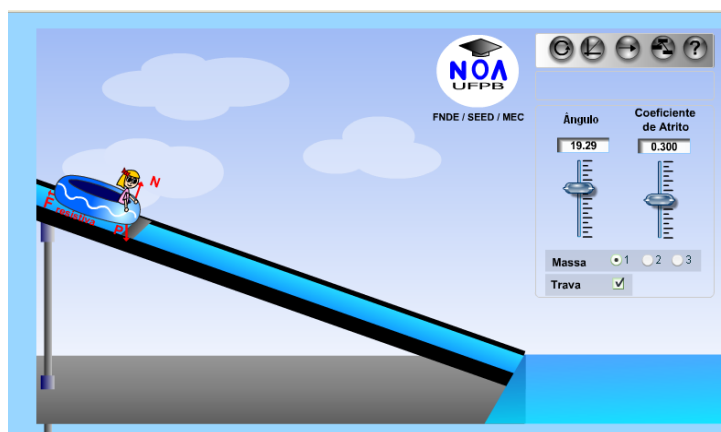


Figure 4. This simulation has more complexity than those examined so far. It even has a part in which the representation goes from “simulation” to “animation”⁵

If necessary, in order to run the simulation, download “*DescartesWeb2.0*”, a free program distributed by the Spanish Government. It can be downloaded at:

URL: <http://recursostic.educacion.es/descartes/web/DescartesWeb2.0/>

⁴ URL: <http://www.walter-fendt.de/ph14e/acceleration.htm>

⁵URL: <http://www.fisica.ufpb.br/~romero/objetosaprendizagem/Rived/03bForcasPlanoInclinado/animacao/anim.html>

Lastly, we asked the subjects to answer the simple questionnaire shown in Appendix A (*know how*). They answered anonymously, noting their numbers on the questionnaire.

RESULTS AND DISCUSSION

Analysis of questionnaire pre-intervention

The contents of the questionnaire were analysed using a qualitative methodology. The results obtained are shown in Table 1. “Q” stands for a correct answer, within the categories considered in the analysis. If the answer is partially correct, a “c” is added to the Q.

Table 1. Results of the analysis of the pre-intervention questionnaire. Subjects “5” and “6” were not able to fill in the pre-intervention questionnaire due to diverse circumstances.

Sample		Classification of answers to questions 1 (Q1), 2 (Q2), and 3 (Q3)				
Number	Scientific Theory	Scientific Model	Help to explain	Scientific Method	Others	Impossible to classify
1		Q1c,Q2c,Q3c				
2		Q1c,Q2c,Q3c				
3			Q1,Q3			Q2
4	Q2c	Q1c,Q3				
5						
6						

We have designed Table 1 maintaining the categories we found in others studies about science-teachers’ conceptions of scientific model (e.g. Gutierrez and Pinto, 2008; Justi and Gilbert, 2003). As can be seen, three of the answers are concentrated on the *scientific model* realm. Even if the sample is not significant (four subjects in this case), it is worthwhile to note that the differences from other studies are considerable. Although the answers within the categories are far from being accurate (many “c” added to “Q”)

Analysis of questionnaire post-intervention

Table 2 shows the result of the qualitative analysis of the responses to the questionnaire “*Appendix A*”.

As can be seen in Table 2, *all* the questions have been answered correctly. Only one subject has maintained the category “*Help to explain*” when pointing out the main functions (Q3) of scientific models. It can thus be assumed that the methodology used in the intervention has been effective for this sample.

Table 2. Results of the analysis of the post-intervention questionnaire.

Sample		Classification of answers in relation to questions 1 (Q1), 2 (Q2), and 3 (Q3)				
Number	Scientific Theory	Scientific Model	Help to explain	Scientific Method	Others	Impossible to classify
1		Q1,Q2,Q3				
2		Q1,Q2,Q3				
3		Q1,Q2	Q3			
4		Q1,Q2,Q3				
5		Q1,Q2,Q3				
6		Q1,Q2,Q3				

Comparison of Table1 and Table 2

If we compare the results obtained in Tables 1 and 2, as well as the evidence that learning took place after the treatment, we feel that it is important to point out that the category “Help to explain” has been considered very common in other research⁶. It is noteworthy that here it was maintained by only one subject in the sample. Given the results obtained in Table 2, we may assume that, in this case, it was not very important to know the situation of subjects “5” and “6” beforehand (cf. Table 1), as they achieved the proposed objective.

Methodology used

Let us repeat, once again, that the results obtained should be treated with caution, given the small size of the sample. Even so, we believe that this a experience has been positive for us with a view to the future design of training courses for teachers on the introduction of the concept of scientific model, because we believe that it presents some elements of originality which could help to explain, at least partially, the final result obtained:

Introduction of concepts

The students found the analysis of the “*universes*” on which the simulations were based very interesting. It was the first time that they had been invited to think about these distinctions. This prevented any of the confusion between “universes” detected in some of the articles revised (Sassi et al, 2005; Lemmer, 2006)

In relation to the “*ontologies*”, it was also the first time that this method of analysing the scientific models which underlie the simulations had been proposed to them. The distinction between “*objects*” (entities) and “*properties*” of the objects was a surprise for the students. For example: *an accelerated object* (which possesses the “property” of being accelerated) *can not cause the acceleration to itself*; it needs an external agent (another object) which provides it with this “property”. This was easy to see, for example, in simulations representing the movement of projectiles: without the gravitational attraction of the *object* “earth”, the projectile would not have the *property* “force” which would cause its vertical acceleration towards the ground. The problem of the confusion between objects and variables (properties of the objects), had already been detected in the literature (cf. Zhang et al. 2006, p 590-591). In our case, we think that this apparent difficulty was a stimulus which captured our subjects’ attention.

⁶ e. g., Justi and Gilbert (2003) find it in 82 % of the teachers in the samples which they study in this research, which spans Primary, Secondary and University teachers.

The limits of validity of the models

This aspect was also new to the subjects of our sample. Some of the simulations with which they were working could be assigned to the physical universe for a determined period, while later going on to represent the mathematical universe. That is, the underlying model *went from being a scientific model to a mathematical model*. Neither had they paid any attention to this possibility in the simulations which they had manipulated previous to this Seminar.

The work with simulations: Know what and Know how

The introduction to the concepts (*know what*) was immediately followed by the task of *analysis of the didactical scientific simulations*, where these were presented functioning in contexts (*know how*). In reality, as we mentioned before, the feedback was very intense, and the questions relative to “know how” and “know what” were continually intermingle, reinforcing each other. We believe, as do other authors (e.g., Quay, 2004; Harnad, 2007), that this was crucial for the learning of concepts, in our case, for the learning of the concept “scientific model”.

CONCLUSIONS AND FUTURE IMPLICATIONS

The first thing which we must point out is that the limited nature of our sample leads us to be very cautious with the conclusions this experience has led us to. Bearing this in mind, with the data obtained and the critical analysis of the elements which we have used in this study, we believe that it is possible to extract some interesting conclusions:

- The analysis of the didactical scientific simulations, adopting an ontological perspective, has been effective in the learning of the concept “scientific model”, by the teachers in the sample.
- We think that the method used, in which the “know how” and “know what” questions have been alternated, has been particularly important for the achievement of the proposed objective.
- The subjects of the sample, despite having been previously introduced to the concept of “scientific model”, have found some novel questions in our way of approaching the problems of analysing the simulations. This really caught the subjects’ attention, and added a motivational bonus for the work. We feel that these aspects of novelty and motivation may also have influenced in the results obtained.

All the previous considerations lead us to a further conclusion: it is possible to design teacher training courses with the conceptual approach and the methodology used in this work. It has been effective with a small sample, and with subjects who had already been introduced to the concept of “scientific model”. Now our challenge is the following: Will it work for more representative samples, and with subjects who have not been introduced to the concept? This is the challenge which we propose to take up in the near future.

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APPENDIX A

WHAT WOULD YOU SAY TO A TEACHER COLLEAGUE?

Imagine that a teacher, a work colleague of yours, asked you to tell him how he could define a scientific model, and what its main functions are. What would you tell him? Note down your answer below, using only the words you consider essential, so that your meaning is clear to your colleague.

At most, your explanation can be one page long.

Thank you very much.

EXPERIMENTA, A SCIENCE TEACHER TRAINING PROGRAM IN CBLIS

Ana Pino Álvarez, Juan de Dios Jiménez Valladares, Ruth Jiménez Liso, Carlos Sampedro Villasán

ABSTRACT

Experimenta is a teachers' training program developed during the last three years by the Parque de las Ciencias de Granada in order to improve the use of CBLIS in secondary schools.

After some experimental sessions to introduce teachers in the use of interface, sensors and CBLIS, the plan includes training activities online as well as experimental tasks developed at school with their students. Teachers are thus allowed to progress in their own training process and practice with their students the use in an actual context of CBLIS methodology.

KEYWORDS

CBLIS, training teachers, network training, methodological change

INTRODUCTION

Experimenta is a teacher's training program developed since 2009 in order to introduce CBLIS strategies in school. This would be a suitable way to improve success in student science understanding and to update teachers' knowledge of some features concerning science and science teaching, as well as to improve the scientific literacy of the students and their interest for science in the future.

The program has been planned in three stages, coinciding with the last three school years, with the main goal of exploring the possibility of creating a school network able to share CBLIS equipments, working together to train teachers and to plan joint research activities.

THEORETICAL FRAME

Research activities are necessary to promote students learning. However, as pointed out by some authors (Hofstein and Lunetta, 1982; Pérez, 2001), it is difficult for teachers to introduce in class experimental activities, what results in an almost total absence of these activities at school.

Weller (1996) considered that CBLIS increased the range of possible experiments, since it offers to the students the possibility of designing a wide range of experiments, capturing data in real time, with graphical data representation in the screen or changing variables rapidly. Many authors highlight the advantages of this new technology in school teaching in comparison with the classical laboratory equipments (Newton, 2000; Ebenezer et al, 2011). Nevertheless, although this technology is expected to be a suitable tool for changing the way the teachers deal with experimental work in school (Collins and Halverson, 2010), this is one of the features of using CBLIS less investigated up to the moment.

Nevertheless, the success in science learning linked to the use of CBLIS should not be taken for granted. Pintó (2009) reports the case of Cataluña, where the great economical effort made by the educational authorities to provide schools with experimental materials, has not resulted in a frequent teacher use, even though training was simultaneously offered.

Using CBLIS in a suitable way requires the investigation of its educational context in order to know the conditions that allow a better use, and its effects on learning science, as well as the elaboration, selection and evaluation of appropriate teaching materials made in collaboration with teachers (Osborne and Hennessy, 2003; Russell et al, 2003).

Public investment in materials for primary and secondary schools will or not end in an effective educational innovation depending on teacher beliefs, knowledge and skills (Couso, 2009). Additionally, this efficiency will also be determined by the way of promotion, since it will be a driving professional force only if its implementation arises from the teachers (upwards), but not from the educational authorities or the research groups (downwards), as indicated by Couso and Pintó (2009).

Due to this, we have studied the perception of the teachers who take part in our training courses.

GOALS AND METHODOLOGY

Goals

- To create a school network using CBLIS in classes of science.
- To study student and teacher perceptions about using CBLIS in the experimental work.

From the beginning of the Experimenta program we were aware that the required equipment for CBLIS activities was expensive and not available at schools. Therefore we combined the training of teachers with the loan of the required equipment, so that training could be developed directly at school. This aspect, initially perceived as a program weakness, has turned out to be a strength of the activity carried out.

From the Museum we wish that the program contributes to the development of the technology potentialities and serves to encourage the numerous schools that visit the Museum to incorporate it into their classes of science.

We also wanted to involve educational researchers in the process of generating knowledge in a scientific area which we consider strategic in Andalusian scientific education. For this reason we have counted with the collaboration of the Department of Didactics in Experimental Science from the University of Almería. The sequence of the Experimenta program is described in Table 1.

Table 1. Program planning

School year	Working sequence
2009-2010	Selection of a reduced group of teachers, collaborators of the museum. 1. Each participant selects a group of students. 2. The students start CBLIS activities in the museum in the presence of their teacher. 3. Activities in their corresponding school under the teacher supervision. 4. Teacher activities in the corresponding school under the museum advice.
Sample	Schools 4 Teachers 6 Students 96
Evaluation	Evaluation tests to be answered by teachers and students.
2010-2011	Open call for a training course of 20 hours. 1. Each participant teacher selects a group of students. 2. Activities with the corresponding group in the presence of the teacher in the museum. 3. Equipment loan for activities at school under the museum advice.
Sample	Schools 10 Teachers 18 Students 245
Evaluation	External evaluation questionnaires carried out/developed/designed by the educational authorities passed to teachers. Evaluation questionnaires designed by the museum to be answered by teachers and students. Recording and analysis of the final evaluation session of the course. Semistructured interviews to some teachers.
2011-2012	Training of a working group. Monthly meetings. 1. Teachers freely design and develop activities in their corresponding school with material temporarily loaned. 2. Joint research activities with students.
Sample	Schools 6 Teachers 10 Students >350
Evaluation	Evaluation questionnaires designed by the museum to be answered by teachers and students. Analysis carried out by the group of teachers. Analysis of the materials requested and of the kind of activity carried out with the students.

RESULTS

The activities were welcomed by teachers and students. Table 2 shows the opinion of the students after their first working session at the museum, indicating the great interest aroused by the experiments and CBLIS technology.

Table 2. Students' opinion after their first working session

ITEMS (SCORE OF 1 TO 5)	2009-2010	2010-11
I found very interesting to use the labquest	4.3	4.2
I found the working guide easy to use	4.0	4.0
Experiments have been interesting	4.3	4.3
I found the labquest a device easy to use	3.8	4.1
After this first contact, i could use the labquest without assistance	3.6	3.8

In all questionnaires, including those made during the academic year 2011-2012, students are keenly interested and want to continue to conduct similar activities in the future.

In this paper we pay more attention to the points of view of teachers because we believe they are the first barrier to overcome for implementing any new development in the classroom.

Table 3 shows some aspects of the survey of educational administration at the end of the training course in 2010-2011.

Table 3. Teachers' opinion about the whole course 2010-2011

ITEM	Qualitative assessment
COURSE LENGTH	Appropriate
THEORETICAL ASPECT	Interesting
CONTENTS NEWNESS	Innovative, original
CONTENTS UNDERSTANDING	Accesible
PLACE	Appropriate
TIME SPENT	Appropriate
Communicating skills of the speaker 1 to 4	3.9
Interest of the working session	3.7
Diversity of activities	3.7
Possibility of implementation	3.6
Organization of the working session	3.2
The best points	We can bring to the classroom the new activities. Interesting and original contents and teaching proposals.
The worse points	Length and the long time interval between two consecutive work sessions. Short time to use interface and sensors with the students at school.
Improvement proposals	To carry on with a new program including more experimental works to implement with students at school.
Global assessment 8.6 (scale from 0 to 10)	

The overall assessment is positive but shows weaknesses with regard to the availability of material to work with students in their schools. It also highlights the interest shown in further work and in deepening their knowledge of CBLIS. We can check both of them in the comments discussed in the recording of the final session of the course:

Teacher1. "It would be possible to have the interfaces and sensors at least for two weeks? This would be great, especially for using CBLIS in subjects with only an hour a week [...]"

Teacher 2. "During the school year you plan your activities, don't you? , and you say, I am going to use certain sensors in the first term because the contents fit better with some experiences, in the second trimester I need other kinds of sensors, and so on. It would be nice to have the opportunity to do that".

Teacher 3." CBLIS gives us a lot of opportunities. It would be better if the course was longer."

Teacher 4. "It was while I had the interfaces and sensors at school when I really felt I was improving my skills for using CBLIS".

The following table shows the results of the internal questionnaire.

Table 4. Internal assessment about teachers' opinion

ITEM	Average 1-4	(2009-2010)	(2010-2011)
1. Contents' interest of the course		4.0	3.5
2. Length (Number of hours)		3.5	3.0
3. Work sessions and activities distribution along the course		3.5	3.0
4. Training acquired during the course		3.5	3.0
5. Developing of practical sessions with sensors		3.5	3.0
6. Work sessions with students at Parque de las Ciencias		4.0	3.5
7. Material lend to schools for activities with students		4.0	3.5
8. Method used to lend material to schools		4.0	3.5
9. Activities made with your students at school		3.5	2.5
10. Using of interface and sensors during the course		3.5	3.0
11. Usefulness of CBLIS for didactic purposes		4.0	3.0
12. Strategies used for designing the own activities		3.0	2.0
13. Technical possibilities of CBLIS		3.5	3.0
14. Practical use of interface and sensors. STUDENTS		3.5	3.5
15. Competence in designing investigations		3.0	2.5
16. Competence in getting the meaning of graphics or draws		3.0	3.0
17. Competence in communicating results		3.0	3.0
18. Learning of scientific and technical concepts		3.0	3.0

These results confirm a positive assessment of the use of this technology and a high interest for using it in the future. Results also prove the difficulties found by teachers to design their own activities, as shown in items 9, 12 and 15. Teachers also had some difficulties to fit the experimental course into the normal development of the scholar curriculum, mainly as a consequence of the short timetable to develop the subject and the strict educational model used in most of the schools involved in the program.

Teacher 5: "I've felt much more free with my students of diversification than with those of 4º ESO, because in this case I had to finish the whole of contents of Physics and Chemistry included in the curriculum for this level and I often thought that these students need to learn these contents to use them next year, in the higher secondary level course."

It is important to say that only 4 schools out of 10 involved in the project during 2010-2011, proposed their own activities, and that most of them were adaptations of classical ones. The other 6 schools decided developing experimental works based on ideas and models provided by the coordinating committee. In some cases, experimental activities concerning everyday problems at school were planned and developed.

Teacher c1: "The better moment of our activity from the point of view of students' learning was while using the interface and sensors to prepare the experimental work because you realise the great number of questions raised around a single experience."

Teachers confirm that CBLIS reduces the disadvantage of an excessive number of students in the laboratories, or of the presence of students initially considered as "troublesome".

Teacher cf6: "I teach in a special school for students with learning difficulties of different level. Some of my colleagues may think that I am crazy for taking these students to the laboratory but...I proposed them to analyze water coming from different places near our school. I gave them small flasks to get as many samples as possible. The results were surprising."

Teacher cf7: "There's no laboratory in my school and so I offered experimental works as a voluntary activity in order to develop short projects linked to the problematic we had at school."

RESULTS FROM THE WORKING GROUP DURING 2011-2012

Here are some results achieved this year with the network of six schools. The group was comprised of ten teachers, two of them are co-authors of this paper and have a long experience in using this technology, three had participated in previous courses and the rest had no previous experience. Monthly meetings have been held combining technical information, activity planning and general discussions on science education.

At the beginning of the course a basic material was provided (console, motion, temperature and pressure sensors) to enable teachers to deepen their knowledge of the equipment and carry out experimental work with their students.

Along the course they have freely borrowed the material they needed to work at school. We always were able to meet their requests and no material loss or damage has been recorded. We emphasize these data because they confirm our hypothesis that CBLIS equipments can be shared.

The activities undertaken emerged almost entirely from the meetings and suggestions that we made. However, since they arose during the monthly meetings, they were considered of their own and were perfectly integrated into their curriculum. Additionally changes and improvements in experimental design as well as in planning work with students were also introduced.

Table 5 summarizes the type of activity performed from analysis of the number of borrowed equipment in each case. A certain preference was observed for master classes in comparison with group activities. An activity is considered for groups when a sufficient number of sensors and consoles is borrowed.

The number of activities varies widely among teachers but, in any case, they exceed those held during the two preceding years.

Teachers with more experience used the material more widely and intensely. The study of movement, including precise measurements of gravity, was performed by all the teachers; on the contrary, the use of the conductivity sensor was more restricted, although it is relevant in some subjects as the study of chemical bonds.

Table 5. Activity analysis according to the borrowed material.

School	Group activities	Master classes	Total
1	4	4	8
2	1	5	6
3	2	4	6
4	2	2	4
5	6	8	14
6	2	3	5

We finally stress that all teachers were willing to participate in a joint work to get relevant data concerning the simultaneous measurement of water boiling temperature and of the atmospheric pressure at the different school locations to check the effect of altitude.

A study of noise pollution at schools was also undertaken with the sound level meter a measurement device far from the conventional curriculum but which aroused much interest due to a generalized sensitivity to noise at schools.

Assessment and conclusions

Teachers admitted that a change occurred in their previous perception about the possibilities of applying CBLIS technology in their classrooms. This could be taken as a sign that CBLIS allows a procedural approach of the students to science even in the case of experimental activities prepared and developed by teachers to show the students some interesting physical phenomena. It's one of the reasons why teachers positively assess the course made.

The aims exposed by teachers of secondary when using CBLIS for experimental activities are similar to those expressed for the practical works in general. In this sense, CBLIS is considered as a new resource or educational material they can use to complete the scientific knowledge of the students, avoiding a very theoretical vision of science, giving them some experimental skills in order to make easier the understanding of scientific contents and introduce them to make some investigations.

Experimental work contributes to encourage students to study sciences and this effect could be stronger when using new technologies, because most students are very familiarized with the use of TIC.

The use of this technology requires to spend less time for the experimental process as well as to get data and to analyze them almost immediately, allowing teachers to spend more time for discussing results, making hypothesis, explaining and elaborating models, and thus giving students more opportunities of "making science and talking about science" if allowed by the methodology and classroom climate.

There is no doubt about the fact that CBLIS technology is attractive for teachers and students, produces positive effects on learning science and would be a suitable resource for changing the way in which most of science classes are planned and developed.

Nevertheless there are many difficulties and risks to implement the use of this technology, most of them linked to economical and logistic reasons, but also others concerning teachers training, school organization with strict timetable and so on.

Concerning the difficulties named firstly we are convinced that the program Experimenta has proved that it is possible to have devices to be shared by a group of schools not too far from each other and that the maintenance and management of the equipment are not too complex. Concerning other difficulties,

we think it is necessary to develop didactical research and to encourage teachers to work in teams in order to allow a better use of CBLIS and to get greater learning improvement.

We have observed that even teachers with a large professional experience seem to be interested in deepening about the use of CBLIS and they all agree to maintain a permanent contact through Experimenta program.

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VIRTUAL LEARNING ENVIRONMENTS AND E-ASSESSMENT

APPLYING DIFFUSION OF INNOVATION THEORY TO THE EVOLUTION OF ONLINE TEACHING

Thomas Lee Hench

ABSTRACT

Online learning over the past two decades has grown from offerings of single courses to complete degrees. As such, online teaching represents an educational innovation that has impacted and continues to impact many individuals and institutions. Hence, knowledge of the evolution of this innovation plays an important role in maintaining its efficacy. The Diffusion of Innovation Theory provides a basis from which the evolution of such an innovation may be traced. In brief, this theory posits that the population of potential innovation adopters is represented by a normal distribution which may be divided into innovators and early, early majority, late majority, and late adopters. When viewed over time, the cumulative number of innovation adoptions is thus described by an “s-curve” showing three stages of growth. In this paper, the Diffusion of Innovation Theory is applied to online teaching occurring over a period of thirteen years at the author’s institution. Specifically, the growth of online teaching was found to follow the predicted “s-curve”. Analysis of additional data acquired from instructor surveys further indicated that faculty experimentation with online teaching and recognition of its compatibility with and advantages over classroom instruction fueled its growth and acceptance. Furthermore, the observed rapid rate of adoption of the online teaching in the middle growth stage resulted, in part, from a change from television-based distance learning to a computer-based format. The paper concludes by proposing the concept of the “trans-classroom” as the next necessary innovative step to maintain the growth and efficacy of online teaching.

KEYWORDS

Diffusion of innovation, online teaching

THEORETICAL FRAMEWORK

The diffusion of innovation theory

An innovation may be defined as the introduction of a new idea, method, or device. The investigation of how innovations fail or succeed constitutes an important part of businesses and other institutions. Research into how innovations diffuse through a social environment dates back to the work of Gabriel Tarde in 1903. Later, research by Everett Rogers (2003) resulted in the Diffusion of Innovation Theory which has successfully been applied to innovations ranging from the adoption of agricultural techniques to cell-phone usage. For Rogers, diffusion represents “the process by which an innovation is communicated through certain channels over time among the members of a social system.” The essence of the diffusion of innovation theory is that the adoption of an innovation proceeds over time, starting with an initial group of adopters and then proceeding through subsequent groups. More specifically, Rogers identified five groups of adopters, each group possessing the general characteristics. Table 1 shows these groups and their characteristics relating to the adoption of new technology.

Table 1. Adopter groups and characteristics

Adopter Groups	Characteristics
Innovators	Source of new ideas Willingness to try unproven technology Accepting of unsuccessful attempts at implementation
Early Adopters	Opinion leaders Use innovator results to adopt new technology Viewed as careful users of new technology Source of information for future adopters
Early Majority	Rely on recommendations from previous adopters Avoid risks involved with the technology Relatively longer adoption times
Late Majority	Skeptical and cautious regarding technology Recognize the technical value but adopt out of necessity or peer pressure
Late Adopters	Avoid change Suspicious of innovation and other adopters Adopt when traditional approaches are no longer available

In addition, Rogers also concluded that, over time, the number of adoptions of an innovation by these groups was described by a normal distribution (Figure 1).

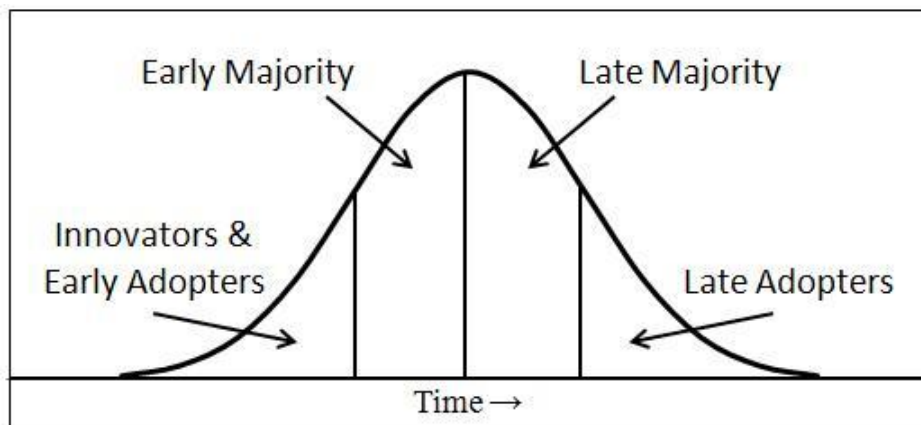


Figure 1. Adopter distribution.

As the adoption process proceeds over time through each group, the cumulative total of adopters follows what is known as an s-curve, as shown in Figure 2. More specifically, as indicated in Figure 3, the s-curve consists of three stages (Table 2) which describe the innovation-adoption process as a function of time.

Also shown in Figure 3 is the critical mass point which represents that point in the innovation adoption process when the innovation becomes self-sustaining. Typically, the critical mass is reached when the cumulative total of adopters is between 5 and 20 percent (Rodgers, 2003).

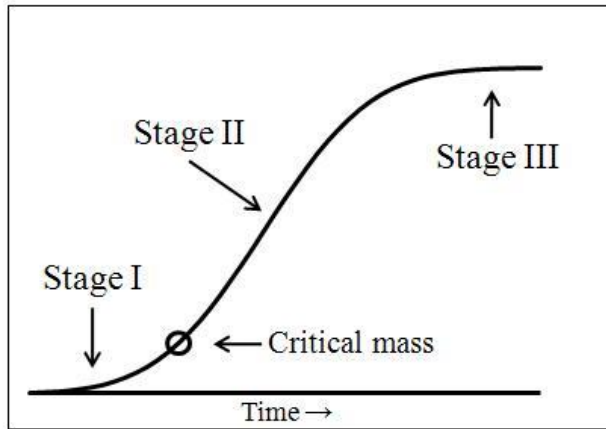


Figure 2. Cumulative total.

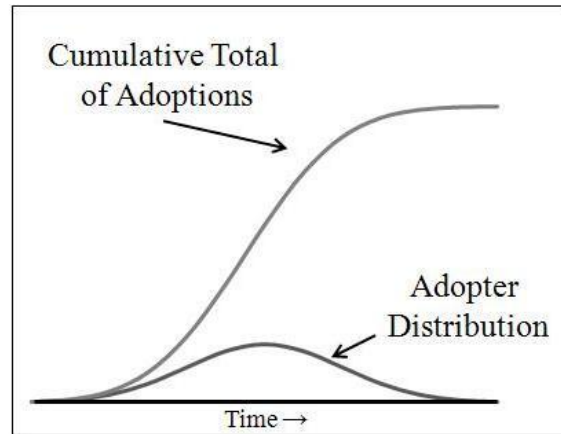


Figure 3. s-curve stages

Table 2. Stages of innovation adoption

Stage I	Initial growth of innovation from Innovators and Early Adopters Experience and knowledge base developed
Stage II	Innovation “takes off” with entry of Early and Late Majority adopters Innovators and Early Adopters provide support and direction Positive results leads to greater acceptance and increased adoptions
Stage III	Growth rate slows down as Late Adopters enter Resource and potential adopter limits reached

Applying the diffusion of innovation theory

Online instruction represents an innovation in education that has shown a rapid increase in use over the past decade. Indeed, the author’s institution is representative of this innovation adoption. Starting in 1999, the school has experienced a growth in the number of instructors teaching at least one course online per semester as shown in Figure 4. In this study, online teaching refers to courses taught solely over the internet and does not include television courses or hybrid courses.

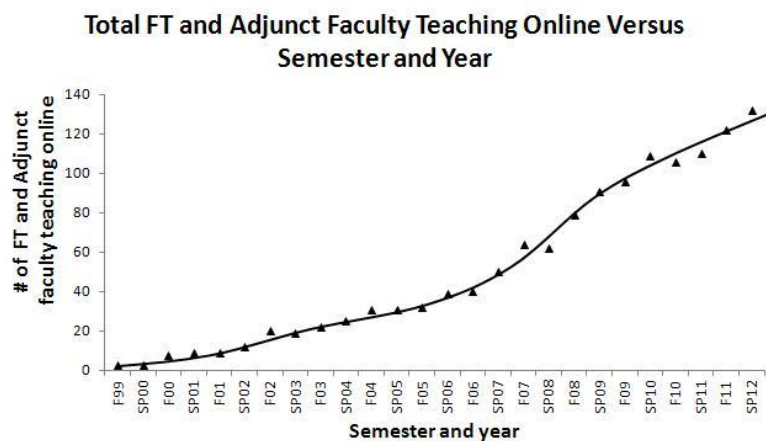


Figure 4. Number of instructors per semester teaching online at the author’s institution

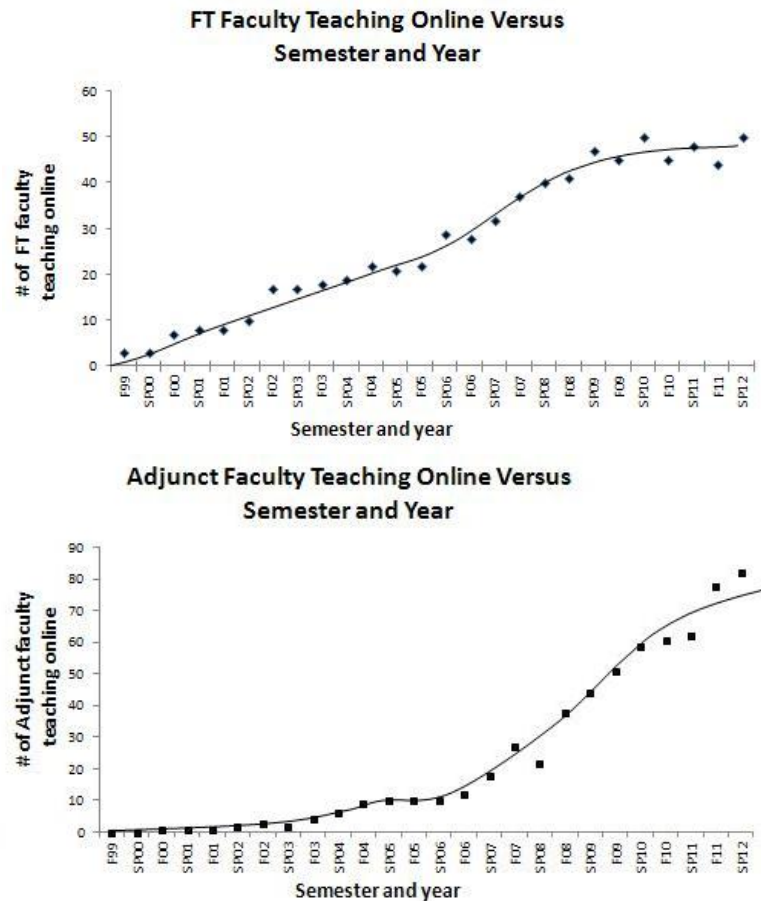


Figure 5. Separate full-time and adjunct online instructor distributions

A first analysis of this data suggests that the adoption of online instruction followed an s-curve and thus allows for an interpretation using the innovation diffusion theory. Specifically, the number of online instructors initially increased at a steady but low rate from 1999 to 2006. This period of time represents Stage I of the innovation adoption process. During this time, experience in online instruction was acquired and a knowledge base established. From 2007 to 2009, the number of instructors teaching online rapidly increased (Stage II) and then appears to head toward Stage III (2010 to present). The underlying structure of the s-curve in Figure 4 may be further understood by separately examining the number of full-time and adjunct faculty teaching online over the thirteen year span of the study (Figure 5).

As illustrated in Figure 5, full-time faculty adoption of online instruction proceeded at a steady rate from 1999 to 2007. During the same time, the number of adjunct faculty teaching online remained relatively low. Then, in 2007, both rates of adoption increased, with the adjunct rate increasing at a greater rate than the full-time rate. This observed Stage II growth is attributable to the decision of the author's institution to eliminate television-based distance learning courses. To maintain this distance learning option for students, many sections of the eliminated courses were re-established as online courses. This decision provided the critical mass required to initiate the growth observed in this stage, which continued until 2010. At this point Stage III growth for full-time faculty adoptions of online teaching leveled out and the adjunct rate increased at a slower pace. It should be noted that both the full-time and adjunct graphs follow the s-curve behavior. In addition, the full-time faculty acted as Innovators and Early Adopters with the adjunct faculty assuming the role of the Early Majority. Of particular interest to this study is the identification of the factors that permitted the Stage II to growth to occur and the determination of recommendations for the continued evolution of online learning.

To explain the Stage II growth mentioned above, Rogers (2003) identified five specific factors which influence the rate of innovation adoption (Table 3). By examining the presence or lack of these factors in the adoption process at the author's institution, the observed adoption rate during Stage II may be described in greater detail.

Table 3. Factors influencing innovation adoptions

Relative Advantage	The degree to which an innovation is perceived as being better than the idea it supersedes
Complexity	The degree to which an innovation is perceived as difficult to use
Compatibility	The degree to which an innovation is perceived to be consistent with the existing values, past experiences, and needs of potential adopters
Trialability	The opportunity to experiment with the innovation on a limited basis
Observability	The degree to which the innovation results are visible/available to others

It should be noted that the presence or absence of these factors are evaluated in this study from the prospective of instruction. While online courses certainly provide distinct and documented advantages to students, the focus of this study is on the appearance of the factors in Table 3 relative to adoption of online instruction by faculty.

Relative Advantage

To assess this factor the results of a survey conducted at the author's institution are shown in Table 4. In particular, the survey asked online instructors to rate the change brought in their classroom courses as a result of teaching online. Of the 36 responses, 29 (81%) taught both online and classroom courses and thus qualified to complete the survey. The choices were presented as a Likert scale, where 1 = No changes, 2, 3 = Some changes, 4, and 5 = Major changes.

Table 4. Percentage of changes to classroom instruction as a result on teaching online

Area of change	Percentage responding "some to major changes"
Assignments/assessment	62%
Course design/redesign	85%
Communication	65%
Multimedia use	58%
Course organization	65%

More specifically, in the area of assignments/assessment, survey responders noted more specific and focused assignments, the submission of assignments electronically, the posting of rubrics and project grades, and a more precise way of evaluating classroom participation through participation of weekly online discussion as change items resulting from teaching online. Examples of the changes made to classroom instruction in the area of course design/redesign included the creation of teams and group projects, the elimination required texts, more flexibility in teaching style, more supplemental material, and more independent activities and ways to monitor student involvement. While no major changes were reported in the area of communication, the use of forums for discussions, making materials available for the classroom course, more communication with students, and direct access to the instructor were examples of how online instruction has influenced classroom instruction. Similarly, responders indicated greater use of videos in classroom courses and a more flexible course organization

as benefits deriving from the transfer of online materials to the classroom. It is important to note that for the change areas shown in Table 4, some instructors (possibly the Innovators and Early Adopters previously described) were employing certain techniques and materials in their classroom course in advance of teaching online. Thus, when asked about the change in their classroom instruction brought about by teaching online, these individuals may respond with “No change”.

These results may be compared to other studies examining the “reverse” benefits to classroom instruction of online teaching. Kassop (2003) has identified 10 areas in which online teaching may benefit or improve classroom teaching, including but not limited to more frequent writing assignments, enriched courses materials, immediate feedback, and faculty development and rejuvenation. Research by Lowes (2008) indicates that teaching online has a substantial impact on the teaching of classroom, resulting in improvement in both environments. Table 5 shows the areas in which Lowes found at least 60% of responders making changes to their classroom courses as a result of teaching online. In addition, Lowes further found that change was present to varying degrees across disciplines (Table 5).

Table 5. Top areas of change in classroom instructor resulting from teaching online

Area of Change	Percentage responding change
Assignments/assessment Course design/redesign Communication	≥ 60%

When looking at the percentage of responses of 3 (Some change) or higher in Table 4, the results are consistent with those reported by Lowes in Table 5. This suggests that online teaching has made a recognizable impact on classroom instruction at the author’s institution and contributed to the observed Stage II growth, thus demonstrating an advantage relative to classroom instruction by providing options for improving face-to-face instruction. The data suggests that Innovating and Early Adopting full-time faculty demonstrated this advantage which then provided a faster adoption rate by Early Majority of adjunct faculty.

Complexity and Trialability

To address the other factors listed in Table 3, information from surveys conducted by the author of both full-time and adjunct online instructors prior to the beginning of Stage II (2006) and at the beginning of Stage III (2011) is presented (Table 6). Survey questions addressed both the frequency and usefulness of pedagogical practices of Student/Student Interactivity, Student/Instructor Interactivity, Student Content Interactivity, and Student Assessment.

As seen from the data, there were modest gains in the overall frequency and usefulness in Student/Student and Student Content Interactivity areas. More specifically, activities which were initially frequently used with high usefulness ratings (regular communication, course calendars, and summative assessments) showed little change. This suggests that these practices have reached a critical mass in their adoptions and acceptance. In addition, some activities declined or remained stable in their frequency yet increased in usefulness (collaborative group projects, resource and information sharing, ice breaker activity, automated testing and feedback, and formative assessment) while others showed increases in both frequency and usefulness (threaded discussions, PowerPoint or similar presentations, audio/visual materials, and games/puzzles). Finally, other practices (group problem solving, learning style matched activities, animations, and self and peer review) have increased in frequency but remain at the same usefulness level. These instances suggest presence of experimentation by instructors to

determine the most effective pedagogical practices for their courses and that “trialability” was a factor in determining the Stage II adoption rate of online teaching. Furthermore, these results also imply that the “complexity” factor was addressed and overcome for certain practices. At the same time, some useful practices (portfolios and animations) remain underutilized. Finally, the required certification of online instructors in the use of the online course management system provided further means to address issues of complexity. Since the initial survey occurred prior to Stage II, the data therein applies primarily to full-time faculty. The continued experimentation of this group provided the basis to overcome complexity and trialability issues, thereby contributing to the acceptance by the adjunct Early Majority and the documented Stage II growth.

Table 6. Pre- and post Stage II survey results of online instructors

	frequency		Usefulness	
	2006	2011	2006	2011
Student/ Student Interactivity				
Threaded discussions	0.83	0.93	3.6	4.0
Collaborative group projects	0.52	0.40	2.3	2.8
Group problem solving	0.39	0.49	2.8	2.8
Resource and information sharing	0.87	0.84	3.2	3.8
Peer review of projects or reports	0.26	0.44	3.2	2.7
Learning style matched activities	0.17	0.40	3.0	2.9
Average	0.51	0.58	3.0	3.2
Student/ Instructor Interactivity				
Regular communication	0.96	1.0	4.7	4.6
Ice breaker activity	0.91	0.91	3.7	4.2
Course calendars	1.00	0.95	4.4	4.6
Automated testing and feedback	0.91	0.82	4.0	4.3
Chats (synch/asynch)	0.74	0.61	3.4	3.3
Average	0.90	0.86	4.2	4.2
Student/ Content Interactivity				
PowerPoint (or similar) presentations	0.83	0.95	3.8	4.1
Audio/visual materials	0.65	0.88	3.8	4.4
Interactive simulations	0.31	0.46	3.4	3.6
Animations	0.22	0.33	3.4	3.5
Games/puzzles	0.26	0.37	3.0	3.4
Average	0.45	0.60	3.5	3.8
Student/ Assessment				
Portfolio	0.27	0.28	4.2	3.3
Summative assessments	0.96	1.0	4.3	4.6
Formative assessments	0.96	0.95	3.4	4.4
Self and peer review	0.32	0.56	3.0	3.1
Average	0.63	0.70	3.7	3.9

Regarding the underutilization of technology, online teaching as well as teaching in the classroom with technology grows out of immediate need. In particular, technology for teaching is underutilized until “something” becomes a real problem. At the authors’ institution, the problem was the need to provide more online courses to offset the elimination of courses taught via other distance methods. As indicated in this study, that need was met primarily by the adjunct early majority. Furthermore, while there are Innovators and Early Adopters, many still do not “get involved” until it is an absolute necessity. At this stage they either embrace the technology and wonder why they did not get involved sooner (Late Majority) or they complain that technology will only frustrate/interfere with what they need to

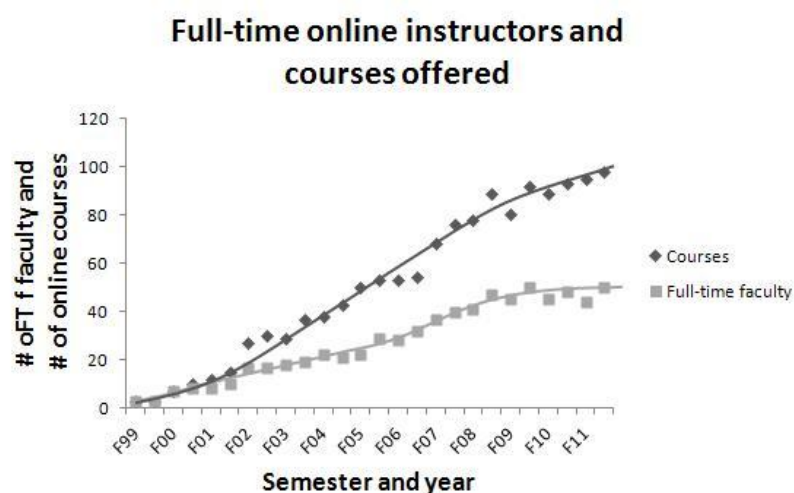
accomplish (Late Adopters). Showing faculty how to do something and then backing it up with support can expedite the usability/adoption process. The excellent ongoing faculty workshops held at the authors' school played a critical role in providing this support for the Innovators, Early Adopters, and Early Majority and continue to assist the Late Majority and Late Adopters.

Compatibility

The adoption of online instruction has met the needs of the faculty and institution by providing the population in its region with a greater access to education. In addition, as shown in the discussion of the relative advantage of online teaching, the pedagogical opportunities have increased and met the needs of some adopters. A critical point in gauging the compatibility of online instruction with classroom teaching is the issue of security. In particular, two concerns must be addressed; 1) the need to verify that the person taking summative assessments is indeed the person who signed up for the class and 2) whether any prohibited material (text, notes, etc.) been used by the student in completing the work. While meeting the former concern is difficult and represents an ongoing both at the authors' school and others, the latter concern has been addressed by previous work by one of the authors (Hench, 2010). By controlling the content, duration, and question type, scores for online assessments were found to be consistent with similar assessments given in a proctored classroom environment. Furthermore, options such as group projects, formative assessment, essay questions, and portfolios offer ways to make online assessment more secure (See Table 6 for the frequency and usefulness of options currently employed at the authors' school). However, online security remains a research area.

Observability

Faculty get involved in technology or alter their classroom pedagogy with technology when they perceive it to be purposeful to students, a worthwhile investment of their time, relatively easy to implement and is something that will be sustainable. Once the Innovators and Early Adopters have opened the way, online teaching becomes more available for others to adopt. Figure 6 illustrates the growth of online teaching, which shows the number of course sections taught online for both full-time and adjunct faculty compared to the number of online instructors.



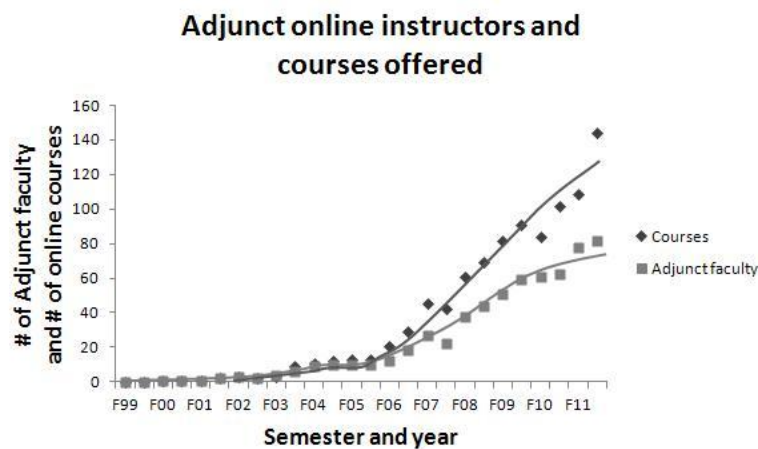


Figure 6. Full-time and Adjunct online instructors and courses offered

Initially, the ratio of sections of online courses offered was approximately one to one for both groups. After the Stage II growth, the ratio is approximately two to one for full-time faculty and approaching that ratio for adjunct faculty. However, as noted in the figures, the number adjunct faculty and the number of courses taught by them eclipsed the full-time faculty in approximately 2007, which corresponds to the start of Stage II. Hence, any additional increase in the number of online instructors will come from either the Late Majority or Late Adopter full-time faculty or the continued use of more adjunct online instructors. In a real sense, the Early Majority of adjunct instructors has acted as a self-replenishing population of online teachers.

CONCLUSIONS

By utilizing the Diffusion of Innovation Theory, the evolution of online teaching was investigated at the author's institution. This investigation yielded the following conclusions

- 1) The adoption of online teaching is describable by an s-curve and occurred in three stages with a rapid growth of online course offerings observed in the middle stage. Thus, Diffusion of Innovation Theory was applicable employed to describe the evolution of online teaching.
- 2) Full-time faculty provided the initial Stage I growth of online teaching by accumulating experience and developing a knowledge base. Presently, the growth of full-time faculty teaching at least one course per semester is in Stage III.
- 3) The factor supplied the critical mass necessary to initiate Stage II growth was identified as the institution's decision to eliminate television-based distance learning in favor of an online environment.
- 4) The sustained middle Stage II growth was the result of the innovators and early adopters' ability to demonstrate the relative advantage, compatibility, complexity, trialability, and observability of the online instruction as a viable innovation.
- 5) The increase in Stage II and III instructors teaching online is driven primarily by adjunct faculty. The data also suggests that adjunct faculty may be nearing Stage III.

- 6) The continuance of workshops in using technology in instruction played a critical role in supporting faculty to innovate by the adoption of online teaching. Furthermore, the teaching of online courses has resulted in a positive impact on classroom instruction for those teaching in both environments with one-on-one mentoring of new innovators strongly recommended.

As stated in conclusions 2) and 5), online teaching has entered or may be entering Stage III of the diffusion process. Thus, an appropriate question is “What’s next?” A proposed answer to this question is shown in Figure 7.

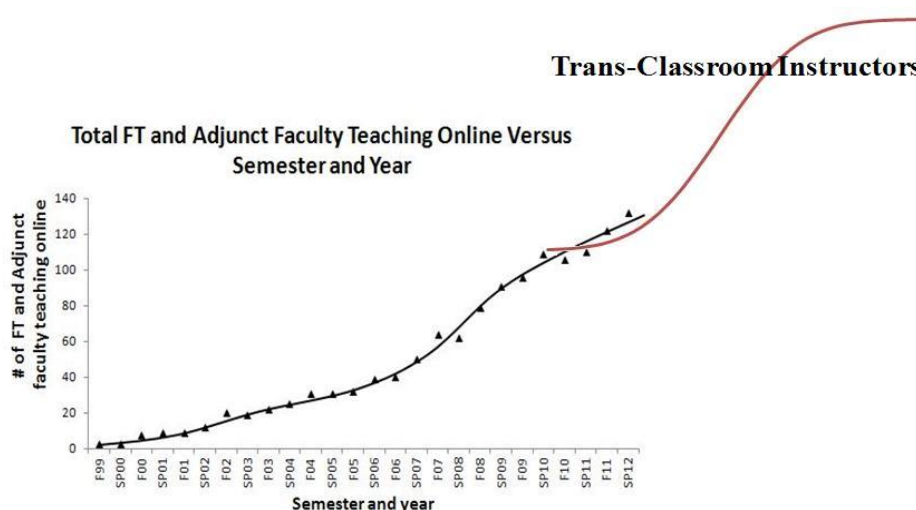


Figure 7. The Next Innovation - Trans-Classroom Instructor

Borrowing from recent social science research on trans-national migration, Lowes (2008) has coined the term “trans-classroom” teacher to describe an individual “who moves between the two environments, transferring ideas, strategies, and practices from one to the other ...”. The trans-classroom teacher makes no distinction between online and classroom instruction and uses the best of both environments to improve and advance instruction. Thus, the development of the trans-classroom teacher is offered as the next possible innovation for adoption at the authors’ institution and an answer to the question “What’s next?”.

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ASSESSING METACOGNITION VIA AN ONLINE SURVEY TOOL

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ABSTRACT

Metacognition is the ability to monitor and control cognitive processes while performing a task, the level of which is expressed through confidence judgments of how well the task was performed. To investigate the potential use of performance and confidence as metacognition assessment quantities, an online survey tool recorded, sorted, and downloaded answers to questions and confidence judgments (low, medium or high) assigned to the answers. Specifically, the survey tool recorded responses to multiple choice questions reflecting two critical thinking levels derived from Bloom's taxonomy - Level I questions testing knowledge and comprehension and Level II questions testing application and analysis. Preliminary results showed an underestimation of confidence in correct responses and an overestimation for incorrect responses at both levels, a situation known as metacognitive miscalibration. Quantifying this miscalibration required the creation for each question of a 3-dimensional vector whose components corresponded to the distribution of low, medium, and high confidence responses for that question. This vector, when compared to a vector representing an acceptable confidence distribution, resulted in a confidence miscalibration angle. Subsequent analysis revealed a variation in both the performance and confidence miscalibration angle among individual questions, a result used to determine a quantity called the metacognitive gap. This gap then enabled the assessment of metacognitive levels and the monitoring of changes in those levels. In conclusion, the research supported the use of an online survey tool to acquire data relevant to metacognition assessment and introduced an analytical framework to achieve that assessment.

KEYWORDS

Online survey, metacognitive miscalibration, critical thinking

INTRODUCTION

Metacognition has been described as thinking about thinking, knowing "what we know" and "what we don't know." In addition, three basic metacognitive strategies have been identified (Dirkes, 1985), namely; 1) connecting new information to former knowledge, 2) selecting thinking strategies deliberately, and 3) planning, monitoring, and evaluating thinking processes. Thus, measuring the metacognitive level or change in metacognitive level of a student is important when assessing learning. Furthermore, research indicates a significant positive correlation between levels of confidence and the use of effective learning strategies and self-regulated learning skills such as monitoring problem learning strategies (Okamoto, Leighton, and Cor, 2008). Therefore, a high level of confidence and performance suggests high level of both cognitive and metacognitive skills, whereas low confidence and performance infers lower levels. Importantly, it is noted that a higher level of cognitive skills may also be present in the low confidence/low performance situation, indicating that a student "knew what he or she didn't know". In addition, high levels of confidence may be expressed for in low performances and low confidence levels in high performances. These under- and overconfidence ratings of performance levels, as shown in Table 1, represent a matrix indicative of a disconnection or "metacognitive gap" between "knowing what you know and knowing what you don't know", a situation known as metacognitive miscalibration (Kruger, 1999).

Table 1. Confidence/Performance Matrix

	Confidence Level	
	High	Low
Performance Level	High	Higher level of cognitive skills and lower level of metacognitive skills (Under confidence)
	Low	Lower level of cognitive/metacognitive skills or higher level of cognitive skills (Over confidence)

As an example, the class averages for two specific questions in an exam are 25% and 75%, respectively. Which case demonstrates a higher level of cognitive/metacognitive skill use? From just these scores, there is little way of knowing the level of cognitive and metacognitive processes present. However, factoring in confidence permits a deeper assessment of the learning associated with these scores and establishes the pedagogical goal of lowering any metacognitive gap to the lowest possible level. This paper describes the use of an online survey tool to collect and analyze data to determine metacognitive gaps and supply a possible answer to the above question.

DATA ACQUISITION

To investigate the use of the metacognitive gap as an assessment quantity, an online survey tool recorded, sorted, and downloaded answers to questions and confidence judgments (low, medium or high) assigned to the answers by online students in an Introduction to Astronomy course taught by the author. As illustrated in Table 2, online surveys provide six important features when used as assessment tools. Of the survey tools available, the author selected SurveyMonkey for this study due to its incorporation of all the items shown in the table.

Table 2. Important Online Survey Tool Features

<p><i>Important Survey Tool Features</i></p> <ol style="list-style-type: none"> 1) Flexible start and cut-off dates 2) Question logic 3) Integratable into webpage or email 4) Multi-type questions (T/F, multiple choice, open ended text, etc.) 5) Real-time viewing of results 6) Downloadable responses to worksheet

Specifically, the survey tool recorded responses to multiple choice questions reflecting two critical thinking levels derived from revised Bloom's taxonomy (Krathwohl, 2002) illustrated in Figure 1. Whereas the original taxonomy listed categories in the cognitive domain, Krathwohl reinterpreted those categories as processes. Specifically, questions use in the study incorporating those testing knowledge and understanding designated as Level I ($N_I = 33$) and those reflecting testing application and analysis designated as Level II ($N_{II} = 23$). (See Appendix A for sample question and survey output.)

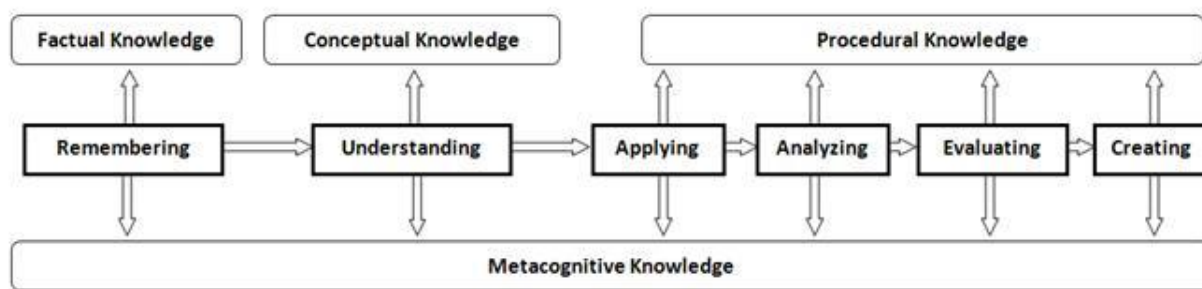


Figure 1. Categories of Bloom's revised taxonomy

Figure 2 summarizes the normalized data collected for 56 students answering these questions. Out of a possible total of 3136 responses, the survey tool recorded 2850 total responses (1904 responses to Level I questions and 946 responses to Level II questions). The 9.1% difference in these totals reflects students either forgetting to enter confidence values or skipping questions.

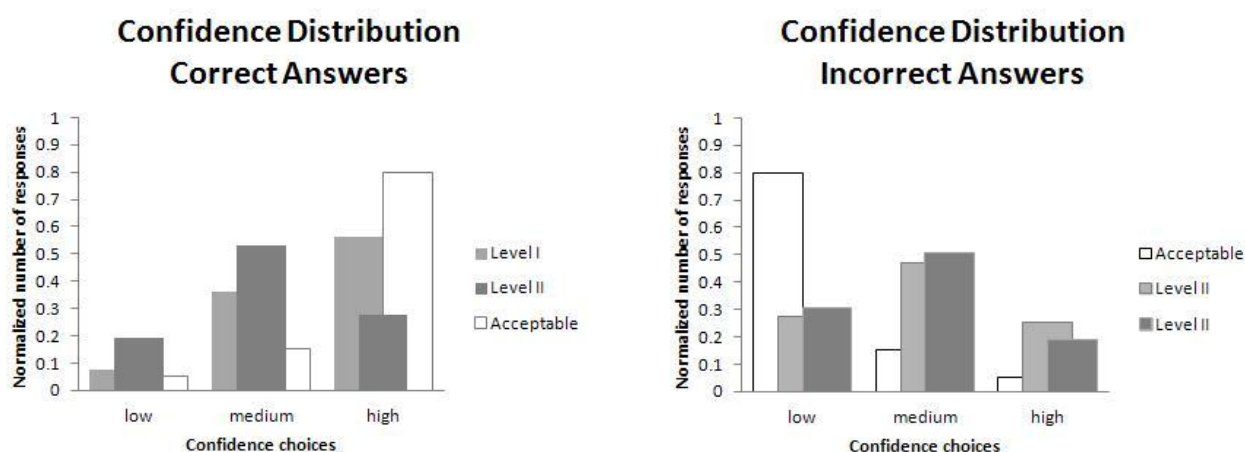


Figure 2. Correct and Incorrect Response Confidence Distributions

Also shown in the figure are confidence distributions labeled “Acceptable”, which represent an “acceptable” level of miscalibration. More specifically, the more the distribution of actual responses trend toward these acceptable levels, the more the students “know what they know or know what they don’t know”. In this study, the acceptable distributions for correct answers corresponded to 5% (low), 15% (medium), and 80% (high) and 80% (low), 15% (medium), and 5% (low) for incorrect answers.

ANALYSIS

As seen in Figure 2, an underestimation of confidence in correct Level II responses and an overestimation for incorrect responses occurred at both level I and II, thereby indicating the present of metacognitive miscalibration. Only the correct Level I responses showed a distribution trending toward acceptable. Since the level of miscalibration refers to multiple judgments of confidence, the response of a single student to one particular question is not meaningful. However, investigating all student responses for a particular question provides a more productive measure of calibration. To explore this aspect, a 3-dimensional vector (C) was created with components corresponding to the total low, medium, and high student confidence responses given by all students to each question (Figure 3). This vector, when compared to a vector representing the acceptable levels (denoted as C_{acc}), resulted in a quantity labeled the confidence miscalibration angle and designated by the symbol χ

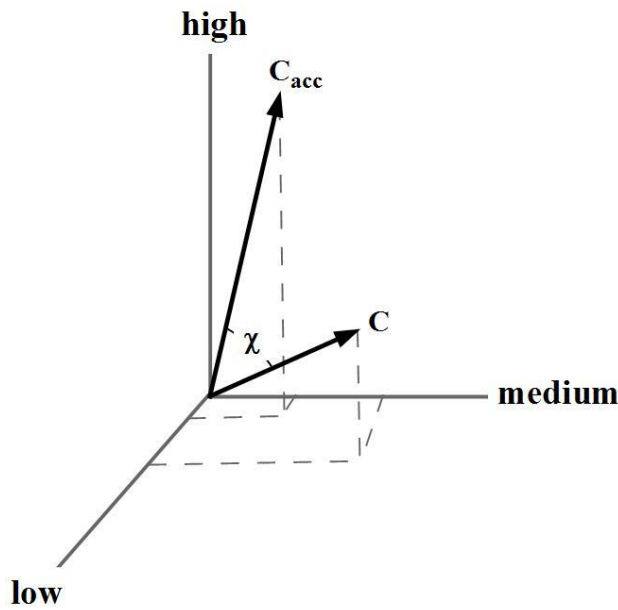


Figure 3. Construction of a 3-dimensional confidence vector.

Thus for a given question, smaller values of χ represent a closer alignment of student responses to the acceptable distribution. Conversely, larger values show a greater misalignment with the acceptable level distribution. It is noted that in subsequent analysis, the magnitude of the number associated with the confidence miscalibration angle is of importance and not the units in which it is measured. Hence, this angle is treated as a dimensionless quantity.

Just as the miscalibration angle measures the class confidence for a specific question, the overall class performance measures the probability of that question being answered correctly. Thus, if 25% of the students answered a particular question correctly, then for this question, a 25% probability is associated with it. Hence, there are two quantities of importance related to each question, the miscalibration angle χ and the performance probability P .

In terms of the metacognitive gap, the higher the performance probability P and the lower the miscalibration angle χ , the more evidence of higher metacognition levels and therefore a smaller the metacognitive gap. Lower values of P and higher values of χ suggest lower levels and thus a larger metacognitive gap. Therefore, the difference between performance and miscalibration angle, $(P - \chi)$, is inversely related to the metacognitive gap. Ideally, a performance value of 100 (again recognizing that percentages are dimensionless quantities) along with $\chi = 0$ yields a value of 100 for $(P - \chi)$, which indicates a perfectly calibrated situation and a metacognitive gap of zero. Hence, the metacognitive gap may be expressed quantitatively as the difference between $(P - \chi)$ and this ideal case, or the metacognitive gap = $100 - (P - \chi)$.

To calculate the metacognitive gap, the overall class performance probability P (expressed as a percentage) for correct responses to Level I and II questions was determined. Then, the corresponding values of χ were calculated using the existing confidence distribution data (Appendices B and C). To factor in the effect on χ of both the correct and incorrect confidence distributions, a weighted confidence angle χ_w for was determined each question. From these results, the metacognitive gaps for both Levels I and II questions were used to construct question/gap profile (QGP) (see Figure 4).

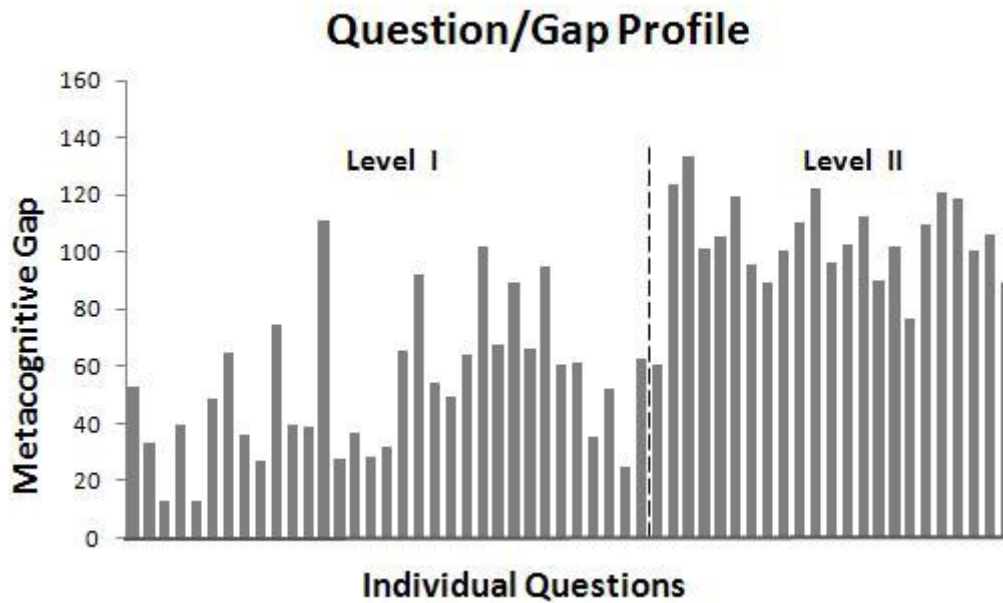


Figure 4. Question/Gap Profile (QGP)

DISCUSSION

As shown in the figure, the Level I question gaps are with a few exceptions smaller than for Level II questions. This is not unexpected as the Level II questions require higher order thinking skills than do Level I questions, skills that may not be present. Furthermore, it is noted that some gaps are greater than 100. This represents cases where the miscalibration angle exceeded the performance, again suggesting a lack of higher level metacognitive skills. In addition, some Level I questions have large gaps, perhaps indicating a misplacement of the question or a flaw in the question itself. This appears to be the case for the Level I question with the highest gap. When reviewing this question, the question statement was found to be potentially confusing, thus leading to lower performance scores and correspondingly higher confidence responses. This ability of the question gap profile to identify poorly worded questions and/or misplaced questions was an unexpected, yet important result.

In the Introduction section of this paper a question was posed regarding the class averages for two specific questions in an exam, these values found to be 25% and 75%. The question, restated here, asked “Which case demonstrates a higher level of cognitive/metacognitive skill use?” To answer this question, the confidence miscalibration angles must be known and the metacognitive gap determined. Table 3 shows possible answers to the question using different values of the miscalibration angle.

Table 3. Determination of the Presence of Higher Level Cognitive/Metacognitive Skills

Performance (%)	Miscalibration Angle	Metacognitive Gap	Cognitive/Metacognitive Skill Level
25	20	95	moderate to high
25	80	155	low
75	20	45	high
75	80	105	moderate to high

As shown, the use of the metacognitive gap indicates that even for low performances, moderate or even high metacognitive skills may be present (Know what we don’t know). Conversely, a small gap associated with high performances suggests that “we know what we know”. Furthermore, if learning

represents a change toward higher cognitive and metacognitive skill levels (Hench and Whitelock, 2010), then the measurement of the metacognitive gaps also provide for a means of assessing changes in metacognitive skills and thus changes in learning. Figure 5 shows the changes in the metacognitive gap for a selection of Level II questions that included time for reflection on the confidence initially given to answers and an opportunity to change the confidence as a result of the reflection.

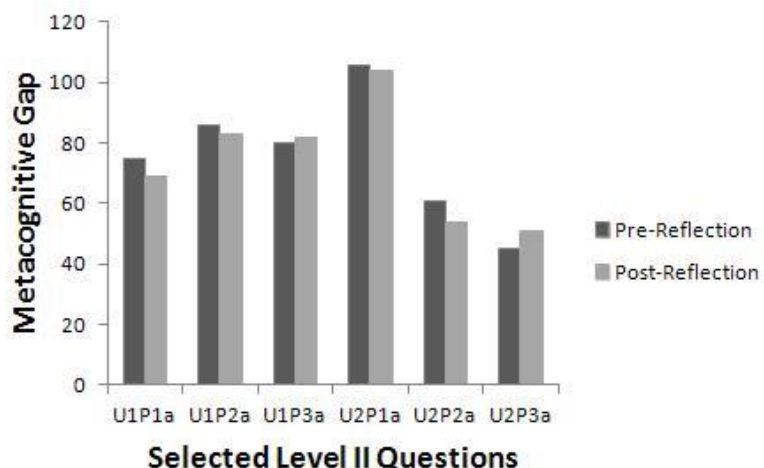


Figure 5. Effect of Reflection on Question Metacognitive Gaps

While the changes are small, they suggest the usefulness of metacognitive gap measurements to monitor potential changes in the development of thinking skills.

CONCLUSIONS

The results of the research described in this paper are summarized as follows:

- 1) An online survey tool investigated as a means to collect, sort, and download data to assess thinking skill levels demonstrated its effectiveness in accomplishing this task.
- 2) Initial analysis of collected data revealed metacognitive gaps due to miscalibration between performance and confidence. A method introduced to quantify these gaps resulted in the calculation of the metacognitive gaps for individual questions.
- 3) Further analysis found a difference in the measured metacognitive gaps between question levels and among questions in each level illustrated by a Question/Gap Profile (QGP).
- 4) The application of the QGP to monitor changes in metacognitive gaps demonstrated a potential use as a means to assess higher level thinking skills. In addition, the profile provides a means to evaluate the content and cognitive level of specific questions.

Future work by the author includes using the concept of a QGP to monitor changes in thinking skill levels resulting from experimental treatments prior knowledge and confidence weighing.

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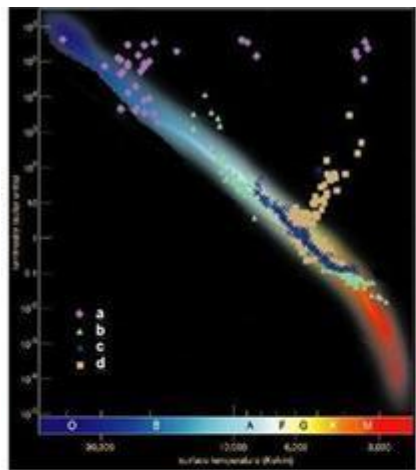
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APPENDIX A



*2. Unit 3 Problem 3:

The stars from four different clusters (a, b, c, and d) represented by the different colored symbols are plotted on an HR diagram as shown above. It is assumed that within each cluster all the stars formed at approximately the same time and with equal numbers in each spectral class. From this information, which one of the following statements regarding the four clusters is correct?

After answering the question, select the level of confidence that you have in the correctness of your answer to the question.

- ☐ Cluster a is the oldest cluster and cluster d is the youngest cluster
- ☐ Cluster b is the oldest cluster and cluster c is the youngest cluster
- ☐ Cluster c is the oldest cluster and cluster b is the youngest cluster
- ☐ Cluster d is the oldest cluster and cluster a is the youngest cluster
- ☐ All the clusters are the same age
- ☐ low confidence level - I have little confidence in my answer. It may be either correct or incorrect.
- ☐ medium confidence level - My answer is probably correct but I'm not completely confident.
- ☐ high confidence level - I am completely confident that my answer is correct.

Example of a Level II Question.

2. Unit 3 Problem 3: The stars from four different clusters (a, b, c, and d) represented by the different colored symbols are plotted on an HR diagram as shown above. It is assumed that within each cluster all the stars formed at approximately the same time and with equal numbers in each spectral class. From this information, which one of the following statements regarding the four clusters is correct? After answering the question, select the level of confidence that you have in the correctness of your answer to the question.		Create Chart	Download
		Response Percent	Response Count
Cluster a is the oldest cluster and cluster d is the youngest cluster	<div></div>	21.6%	11
Cluster b is the oldest cluster and cluster c is the youngest cluster	<div></div>	3.9%	2
Cluster c is the oldest cluster and cluster b is the youngest cluster	<div></div>	5.9%	3
Cluster d is the oldest cluster and cluster a is the youngest cluster	<div></div>	52.9%	27
All the clusters are the same age	<div></div>	15.7%	8
low confidence level - I have little confidence in my answer. It may be either correct or incorrect.	<div></div>	25.5%	13
medium confidence level - My answer is probably correct but I'm not completely confident.	<div></div>	52.9%	27
high confidence level - I am completely confident that my answer is correct.	<div></div>	21.6%	11
answered question			51

Real-time survey results

APPENDIX B

Level		P_{avg}	Correct				Incorrect				Metacognitive	
			l	m	h	χ	l	m	h	χ	χ_w	Gap
I	U1P1b	82	0	17	24	25	0	4	5	81	35	53
	U1P1c	83	0	12	32	11	3	4	2	45	16	33
	U1P1d	94	1	7	42	2	0	3	0	79	7	13
	U1P1e	79	1	9	31	6	2	8	1	65	18	39
	U1P2b	96	0	10	37	6	0	2	0	79	9	13
	U1P2c	79	2	14	25	19	2	5	4	62	28	49
	U1P3c	73	4	18	15	40	6	5	3	33	38	65
	U1P3d	88	2	14	28	16	0	1	5	84	24	36
	U2P1b	89	2	12	35	8	0	4	1	79	16	27
	U2P1c	65	2	13	19	24	2	10	6	69	40	75
	U2P1d	86	6	15	27	20	2	6	0	61	26	40
	U2P2b	83	3	14	23	21	6	4	2	26	22	39
	U2P2c	40	2	9	8	38	6	14	9	59	51	111
	U2P2d	92	2	14	30	14	0	2	1	79	20	28
	U2P3b	90	1	18	26	24	2	2	3	52	27	37
	U2P3c	94	4	16	27	20	1	2	0	53	22	28
	U2P3d	90	3	12	21	19	2	2	2	45	22	32
	U2P3e	82	4	24	14	49	4	5	2	42	48	66
	U3P1b	60	5	14	11	42	3	9	9	67	52	92
	U3P1c	81	9	15	18	33	4	4	4	45	36	55
	U3P2b	81	5	18	20	32	7	5	1	25	31	50
	U3P2c	68	2	16	18	31	7	6	4	35	32	64
	U3P2d	49	11	8	7	54	8	11	7	48	51	102
	U3P3b	78	3	21	18	39	1	7	2	71	46	68
	U3P3c	57	4	14	13	37	5	13	3	58	46	89
	U4P1b	71	5	13	17	28	3	4	6	59	37	66
	U4P1c	57	6	16	6	59	8	10	3	41	52	95
	U4P1d	82	7	17	16	38	2	7	0	63	42	60
	U4P2b	71	2	14	20	24	4	3	6	52	32	61
	U4P2c	86	2	16	26	21	3	2	1	26	22	36
	U4P3b	72	2	12	25	15	4	6	3	48	24	52
	U4P3c	91	7	11	31	12	1	2	0	53	16	25
	U4P3e	72	0	13	25	17	0	4	2	79	34	62

APPENDIX C

			Correct				Incorrect				Metacognitive	
		P _{avg}	l	m	h	χ	l	m	h	χ	χ_w	Gap
Level II	U1P1a	75	1	14	23	21	1	14	23	79	35	60
	U1P2a	43	2	16	4	65	4	20	4	68	67	124
	U1P2d	31	8	7	0	80	8	18	10	58	65	134
	U1P2e	46	5	14	5	60	13	14	1	36	47	101
	U1P3a	51	1	19	6	62	5	9	0	50	56	105
	U1P3b	38	5	10	5	55	7	17	8	58	57	119
	U1P3e	54	5	14	7	54	7	10	0	45	49	95
	U2P1a	58	2	18	13	43	7	14	3	53	47	89
	U2P2a	55	3	15	10	46	3	13	7	68	56	101
	U2P3a	47	7	10	7	50	5	19	3	64	57	110
	U3P1a	35	2	13	3	66	9	17	7	53	57	122
	U3P1d	62	10	17	4	68	7	9	3	42	58	96
	U3P1e	25	0	8	5	47	23	14	1	21	27	102
	U3P1f	20	5	5	0	80	22	12	6	20	32	112
	U3P2a	52	3	15	9	48	11	11	3	35	42	90
	U3P3a	43	4	11	8	44	10	14	6	46	45	102
	U3P3d	76	6	24	11	55	4	6	1	46	53	77
	U4P1a	49	4	13	7	52	4	16	4	65	59	110
	U4P1e	37	4	11	3	64	7	13	8	55	58	121
	U4P2a	45	8	15	0	79	6	11	1	51	63	118
	U4P2d	41	5	10	6	51	12	11	6	35	42	101
	U4P3a	54	10	15	4	67	7	14	3	53	60	106
	U4P3d	63	9	18	7	60	7	8	3	40	52	89

EVALUATING EACH PHASE IN THE LIFE CYCLE OF ELEARNING PROJECT

Jana Kapounová

ABSTRACT

We consider eLearning as an educational project. The eLearning project represents creation of a set of eLearning subjects or eLearning components or construction of LMS functions, e.g. adaptive instruction option. The eLearning project consists of certain phases. We apply the scheme of instructional system design ADDIE – it is also known as an educational parallel to the software development process. When considering eLearning project evaluation we established phases of an eLearning project which enabled us to specify phases of its evaluation, within which we have specified activities necessary to be carried out, people responsible for their fulfilment and inputs and outputs of activities. Results of the evaluation should show, if the people preparing the project have considered all of necessary issues, how thoroughly and in what depth. Evaluation activity outputs can be in the following form: questionnaire, review, checklist, evaluation report, survey record, evaluation statement, or data analysis conclusions. Some tools applied in practice: evaluation of the overall project plan, review of project draft management, review of proposed subject(s), evaluation of educational support by lay reader, expert opinion, pedagogical opinion, etc. Some tools used in our project we present in the paper.

KEYWORDS

eLearning project, project life cycle, project phases, evaluation of eLearning, LMS (Learning Management System), ADDIE model

INTRODUCTION

The paper continues studies about eLearning presented at previous CBLIS conferences. The stated articles summarized certain approaches to the evaluation of eLearning and further on, one of the proposed tools for evaluation of study supports was demonstrated:

- Approaches to the evaluation of eLearning (Kapounová, 2007);
- The evaluation of eLearning study supports (Šarmanová and Kapounová, 2010).

The summary of approaches to eLearning evaluation which we were inspired by during the development of our model is listed below:

- Kirkpatrick's Four Levels of Evaluation (Winfrey, 1999)
- Levels: Reactions – Learning – Transfer – Results
- A Framework for the Evaluation of eLearning (Huges and Attwell, 2003)
- Five major clusters of variables have emerged: individual learner variables – environmental variables – contextual variables – technology variables – pedagogical variables.
- Each of these can be disaggregated into more precise groups.
- Model of assessing quality in eLearning elaborated by the Swedish National Agency of Higher Education (Åström, 2009)

Their model comprises ten quality aspects: material/content – structure/virtual environment – communication, cooperation and interactivity – student assessment – flexibility and adaptability –

support (student and staff) – staff qualification and experience – vision and institutional leadership – resource allocation – the holistic and process aspect.

- Managing eLearning Strategies (Khan, 2005)

The author presents critical eLearning factors in the eight-dimensional eLearning framework with the following issues: institutional – management – technological – pedagogical – ethical – interface design – resource support – evaluation. Each dimension includes several sub-dimensions and each sub-dimension consists of items or issues focused on a specific aspect of an eLearning environment. Khan divides eLearning process into two phases: content development + delivery and maintenance. Another more important idea for our plans, which was developed by Khan in his work, is a model identified as PPP (P3): Persons, Processes, Products. There are persons in eLearning projects who are involved in processes in which eLearning materials (products) are developed.

The second article (Šarmanová and Kapounová, 2010) deals with the evaluation of eLearning study supports which have been developed for fifty six study subjects at three technical faculties. The evaluation was made both by experts in the particular subjects and by pedagogy-psychological professionals. The evaluation form is a structured questionnaire consisting of twenty six questions split into four areas:

1. Basic characteristics of text
2. Encouragement of students
3. Planning and organizing of study activities
4. Feedback and evaluation

Each question was answered by opponents verbally and evaluated by a point of 0 to 10; the record of those data resulted in establishment of the matrix counting fifty six lines (study supports, i.e. subjects) and twenty seven columns. For the purpose of analysis, several statistical and data mining methods were used, e.g. descriptive statistics, principal component analysis, analysis of associations or cluster analysis.

In conclusion, the results were used as feedback for improving both the study texts and the evaluation questionnaire. We can also enhance training organized for authors of study materials.

RESEARCH OBJECTIVES

Within the project “Evaluation of eLearning – the system approach” we intend to establish a procedure and determine factors that can affect quality, effectiveness and economy of an eLearning project. Most of theoretical studies and examples of good practice deal with evaluation of study supports and ways of communication between learners and teachers. The effectiveness of eLearning is with no doubts affected by other factors as well and we try to specify them in our work. We presume that the best way of how to prepare the methodology for eLearning evaluation should be the system approach.

METHODOLOGY

eLearning evaluation is understood as an eLearning project evaluation, i.e. the proposal of methods and tools for evaluation of individual phases and the whole project.

Let us consider eLearning as an educational project. An educational project, just like other projects, is comprised of design phases, proceeding one after another and interrelating.

Now let us define the term eLearning project:

eLearning project is such a project within of which an eLearning subject, or subjects forming one complex (e.g. a study programme), or just a part of a subject is planned, developed, implemented and introduced in instruction.

Note: By the term “subject” we mean a school subject; we prefer the term “subject” to the word “course”.

eLearning project represents

- creation of a set of eLearning subjects or eLearning components (most often);
- extension or construction of LMS functions, e.g. adaptive instruction option.

eLearning subject includes

- relevant content (study support, multimedia components, sources and links, tests, etc.);
- study system (student registration, task completion, test results, etc.);
- LMS (study flow monitoring).

PHASES OF eLEARNING PROJECT

The solution of the whole eLearning project can be divided in three parts:

the phase of setting and a part of analysis. If analysis is made and described well, the project is accepted for solution and its funding is promised. If the project is rejected it ends, or analysis must be made better and the application must be re-submitted;

solution – all phases starting with analysis and ending with the project results implementation in educational practice;

project sustainability, i.e. a long-term use of eLearning supports in instruction; it is not directly linked with project funding.

There are more methods on how to decompose work development in phases; they usually only differ by various level of detail or transfer of certain activities from one phase to the other. Each phase needs feedback, verification of the level of need, meeting its individual objectives, meeting quality level and effectiveness.

For example, the whole cycle can be displayed by waterfall model, whereby the result of each phase is an input for next phase; the result of a certain phase evaluation leads to modifications of any preceding phase.

For our research intention – evaluation of eLearning project – we accepted the ADDIE model (Analysis > Design > Development > Implementation > Evaluation) in instructional system design (Clark, 2002).

MODEL OF eLEARNING PROJECT EVALUATION

When considering the eLearning project evaluation we established

- phases of an eLearning project which enabled us to determine
- phases of evaluation, within of which we have specified:
- activities necessary to be carried out when evaluating and
- people responsible for their fulfilment, and further
- activities inputs and
- activities outputs

Starting point is usually to implement or update an idea or to expand eLearning project.

All of the above mentioned we have organized in a following table.

Table 1. Scheme the evaluation model development

<i>inputs</i>	<i>activities</i>	<i>outputs</i>
impulse from environment e.g. project application	activity name e.g. analysis of project readiness	outputs of activity (products) e.g. study support
+	allocation to ADDIE phase	
given limits human resources (HR) finances time (deadlines)	evaluation of activities e.g. check of readiness in the form of checklist	evaluation of output products e.g. opponent review

Table 2 Example of the eLearning project evaluation activities (part of analysis)

<i>eLearning project phase</i>	<i>evaluation phase</i>	<i>activity</i>	<i>who performs it (is responsible)</i>	<i>activity inputs</i>	<i>activity outputs</i>
<i>analysis</i>	in the educational institution				
readiness of the institution:	to consider the adequacy of	to compare or review			
curricular	accordance with the educational orientation of institution	the content of courses with the educational orientation	manager	comparative study of the educational content	evaluation statement, e.g. completed checklist
technical	functionality of hardware, software, internet	ICT requirements with available technologies	technician, manager	inventory of ICT equipment	
human resources	tutors, lectors, administrators, etc.	requirements for HR with professional and time potentials	manager, personnel officer	reference analysis	
financial	financial sufficiency	project budget with the institution financial plan	accountant, manager	balance sheet	
organizational	ability of the institution to accept the project	organisational scheme of the institution	manager, management of the institution	e.g. in a form of a questionnaire or interview	
client approach	e.g. awareness of the people concerned	information materials available	Public Relation (PR) specialist, manager	list of suitable information materials	

Evaluation of the project

When evaluating an eLearning project it is necessary to distinguish the evaluation of the entire project from the evaluation of the individual subjects (courses). It is also essential to distinguish evaluation from the submitters' point of view and those done by participants of the project: learners, teachers, personnel concerned, etc.

For the evaluation of the entire project we analyze data acquired from evaluation materials, e.g. study support evaluation reviews, but also the quality of "secondary products", e.g. the structure of the study support evaluation questionnaire. In the final evaluation the view at the whole eLearning project is also considerable. Then we can simulate different situations, e.g. what would happen, if we take out one of the subjects?

ACTIVITY OUTPUTS

We have chosen the following evaluation activity outputs: questionnaire, review, checklist, evaluation report, survey record, evaluation statement, data analysis conclusions. To make the process of evaluation less demanding and consuming, we need to optimize the set of evaluation materials. It is possible to cumulate some of the outputs, e.g. in the above mentioned table we can merge all of the evaluation statements of the readiness of the institution to a single checklist.

Which output documents were proposed and filled in with data (Šarmanová in Kapounová, 2012)

1. Basic identification of project – project heading.
2. Project *analysis*
 - Check of completeness of eLearning project analysis: a level of need and project contribution, its objectives, target group, plan of key activities, time schedule, quantification of outputs, sustainability
 - Key project activities: activity title, its description, implementation, output, and activity expenditures.
 - Quantification of project outputs in individual subjects: subject supervisor, subject title, number of text pages and costs per page, number of multimedia objects and costs of their acquisition, opponents.
 - Project time schedule (e.g. Gantt diagram): training of authors and tutors, purchase of technology, author's work, creation of multimedia...pilot courses, evaluation.
Note: Costs of funding of all-project needs result from activities and time schedule.
 - Project budget; we list here for example units, quantity, unit price, etc. in the structure: personnel costs, other costs.
3. Formalities – check of analysis completeness: technical readiness, human resources, organization readiness, client approach, readiness to project risks.
4. Project suitability – general project plan: its need and benefit, adequacy of target groups, contribution of didactics, experience of solver, project sustainability, adequacy of budget (related to objectives), project publicity and many others (Milková and Slabý, 2006).

Evaluation of analysis means assessment of the project need and readiness.

If the project is approved for solving, next phase is *design*. The analysis results are used to control the entire project and to manage each subject as well.

5. Project management – check of general and organizational activities such as training of authors and tutors, contracts with solvers, etc.

6. Control of each subject can be realized in the form of the checklist of completeness; again at the level of subject activities (e.g. content of text), followed by organizational activities of the whole project.

Next step is **development** of subject supports. That is the longest phase of solution and it is evaluated in terms of its result.

7. Development of learning supports and their verbal and score evaluation
 - lay reader review
 - expert opinion
 - pedagogical opinion; detailed analysis (Šarmanová and Kapounová, 2010) modified the original proposal (Mechlová, 2008).

After termination of the development phase, the course is ready for **implementation and testing** in pilot run either in LMS environment or on the Internet or all study materials can be delivered on CD-ROMs.

8. Assessment of students

The content of tests is defined by subject supervisor. Tests may involve pre-tests, intermediated tests, post-tests, etc. The advantage is automatic evaluation of results. All information can be stored and successively used for various analyses – about the subject, the overall project, individual student, etc.
9. Evaluation of support by student statement, e.g. using evaluation questionnaire (electronic or hard copy).

SUMMARY

Following completion of all project activities we have comprehensive data accumulated about each subject and we have overall and partial financial project costs.

What we discover from the final project evaluation, e.g.

- comparison of pilot course results with previous years results;
- benefits for students;
- benefits for pedagogues.

Then we can deduce about the effectiveness of each subject or of the entire project.

For individual subjects actual data it can be evaluated – mainly on costs (of subject, person involved, pilot student...), results of students' assessment, acquired knowledge and skills, student feedback, use of acquired knowledge and skills in practice (if feasible) and others.

For the whole project it can be assessed – overall costs, but also costs related to individual items (subject, person, etc.), analysis of reviews, questionnaires, and tests and finally the long term benefit.

The described model for the eLearning project evaluation was applied in several steps.

Firstly, expert and pedagogical evaluation was made of 56 study supports developed at three technical faculties (Šarmanová, 2009). The process and results of data analysis from questionnaires was presented at CBLIS conference 2010 (Šarmanová and Kapounová, 2010).

Next step involved evaluation of eLearning project for 27 subjects taught at two universities in Ostrava. Data was recorded in 14 tables for each subject and then, data on the whole project followed. The structure of evaluation forms was described in this paper. Individual items in questionnaires can be answered (according to the question type) verbally, by points (score), with semantic differential, or just to complete it as checklist.

Conclusions from this analysis were made and its feedback can help in project update. Proposed forms for evaluation were revised and made more precise, so that both project solvers and reviewers understand them clearly.

As a part of activities of the project life cycle is running in electronic environment, many data can be recorded automatically and stored data can be subsequently processed with suitable software (e.g. with statistic programs).

Existing eLearning environment enables more than to deliver study material to all learners in a uniform way. It is possible to prepare such course trajectory which could be tailor-made to study characteristics of learners. It is essential to prepare such study supports which satisfy requirements of individual student. The level of success in the development of the adaptive eLearning material can be assessed by the tool for evaluation of eLearning study material in light of the adaptive learning methodology. The adaptive study materials were prepared for several subjects. The attributes which can be considered for the adaptive method of education are evaluated in the specially designed questionnaire (Kapounová and Kostolányová, 2011).

The acquired data can be used for many kinds of analysis including statistic investigation while using e.g. methods for data mining (Šarmanová, 2007). The obtained results can be used as feedback in the whole process of evaluation. Hence, next run of endless cycle of learning support improvement and thus teaching enhancement is initiated.

In any project, it is essential to have a verified systematic process for development and evaluation. Our project utilizes system analysis to define relevant stages of the project. If we understand the eLearning project as development of a group of eLearning study subjects, it will include two levels: the first level is the specific content and the second level is for the entire project. In addition, we define suitable evaluation methods for each eLearning subject. Overall, it brings a detailed plan for eLearning evaluation.

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ADAPTIVE E-LEARNING MANAGEMENT

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ABSTRACT

The conventional form of e-learning is gradually being substituted by different modern instruction forms, one of them being the adaptive instruction form. Development of the e-learning environment is a complex process, which is carried out in several phases. After having assessed a student's learning style, it is essential to know the optimal teaching strategy which best suits the student's learning style. It is also crucial to provide a variety of tailored study materials. This paper suggests a structure for such study materials and describes rules to compile appropriate study materials for students in line with their preferred way of learning. These rules are fundamental for the development of an expert system based on adaptive algorithms.

KEYWORDS

Learning style, teaching style, adaptive rules, adaptive e-learning

INTRODUCTION

Learning may be defined as a change of behaviour which occurs on several levels – the sensorimotor, emotional, social and cognitive levels. A learning curve is dependent upon many factors – on the student's motivation, results from previous studies (the so called aspiration level, i.e. the expectation of a performance), and on the somatic and psychological state of the student.

At the present time, we frequently encounter “long distance” education more often; which is assisted by information and communication technologies, training courses and related e-learning. For this reason, much attention is paid to the possibilities which may make the e-learning more effective. One approach to improving this form of learning is to adapt the lessons to the students' individual needs.

ADAPTIVE LEARNING ENVIRONMENT AND TEACHING STYLES

A learning environment is considered adaptive when it is possible to monitor and interpret user activities, establish user requirements and preferences based on interpreted activities, and then dynamically modify the learning process (Brusilovsky, 2003). Learning adaptation may appear in many forms which are divided into the following categories: user interface adaptation, learning content adaptation, adaptation of search and the creation of learning content and adaptive cooperation support.

This proposal is aimed at the topic of learning content adaptation as it is the main source of learning information for students and, therefore, it is thought to significantly affect their learning. There are several systems for adapting learning content. Most of them concentrate on those characteristics of student which influence their learning process with so called teaching styles

“Learning styles are delicate manifestations of human individuality in different learning situations”. They are the procedures of learning which a person prefers to in a given period. They are procedures which are original by their orientation, motivation, structure, succession, depth, elaboration and flexibility. People use them in most pedagogical situations, so they are less dependent on the content of learning.” (Mareš, 1998)

Learning styles have a character of meta-strategy, which is grouping activities of lower order: individual learning strategies, learning tactics in them and parts of learning tactics – learning operations. Monitoring, evaluating and orienting them in a specific direction. Regulating them according to: the conditions, course, results and social context of learning.

LMS systems, which are now commonly used and include subject learning support, record student activities and results. However, they do not reflect learning styles. The curriculum is provided to students universally regardless of individual learning styles and knowledge levels. If students are not in direct contact with their teacher, they use textbooks for learning. Authors of these textbooks typically endeavour to approach topics in a system that fits the broadest possible group of students; however, in this case the learning styles of individual students do not have to be included. The electronic structure of the adaptive environment consists of three modules: student, author and adaptive.

The most important of these is the student for whom the whole system is built. Substantially more information is required about students, so the system can respond to their individual existing knowledge, their personal characteristics and their learning style. With the help of the Student subsystem, each student gets tested by the system or his/her characteristics are ascertained via a suitable questionnaire, and then recorded in the student database.

The second supportive subsystem is the Author module. This is used to store and modify the learning support in the author database. Learning texts, images, multimedia, etc., are stored in the database together with so called metadata, which is used to describe these objects. All the elements of teaching support are recorded here, whether it be a definition, a student motivation, an individual task, etc.

A customised management program, the Virtual teacher, then loads all the required student information, together with all the essential information on the structure of the teaching material, and from the knowledge of all this, determines the optimal way of teaching. In order to do this, the Virtual teacher needs pedagogical and psychological knowledge, based on which, it builds up a detailed plan of the teaching process. The Virtual teacher consists of an expert system which contains basic pedagogical rules, and from these elementary rules, it prepares an optimal teaching style for individual students, and also ensures optimal browsing through specific teaching material.

STUDENT MODULE – STUDENT CHARACTERISTICS TESTING

The following has been selected from the existing teaching styles analysis for the use of adaptive teaching (Kostolányová, 2009):

A group of characteristics named sensitive perception describes which form of information suits the student the most. Visual type students like diagrams, images, tables and graphs and the auditive types prefer spoken word and contact with other people. Kinaesthetic types like demonstrations, simulations and practical information and verbal types prefer text. For the evaluation of these characteristics the VARK questionnaire has been used.

Group social aspects are concerned with the type of company that students prefer when learning; if they like to learn with schoolmates, a teacher, or alone. For this evaluation the LSI questionnaire has been used.

Group affective aspects deal with the feelings and attitudes of students that affect their learning, of which the most important characteristic is motivation. For the evaluation the LSI questionnaire has been used.

The largest group is learning tactics, which describes the manner and course of student learning. This systematic approach describes the sequence of learning which can be either in the logical sequence of steps (pole discipline), or almost at random, without connections, in great steps (pole freedom). For the evaluation of this characteristic the ILS questionnaire has been used.

In accordance with the way of learning we can divide tactics into two categories - deriving and experimenting. Students with theoretical deriving tactics prefer thinking thoroughly about newly gained

knowledge. Students with experimental tactics like to actively put what they have learned into practice. For this evaluation the ILS questionnaire has been used.

In accordance with the sequence of learning we can divide tactics into detail tactics, which focuses on small pieces of information and then composes them into the global picture, and holistic tactics, which focuses on larger pieces of abstract information from which they work through to find more detailed information. For this evaluation the TSI questionnaire has been used.

The approach of learning can be divided into three tactics: depth, where a student's main goal is to fully understand the curriculum; strategic, where results and effectiveness are prioritized; and surface approach where students try to meet only the basic requirements. For this evaluation the ASSIST questionnaire has been used.

The level of the student's ability to independently control their learning is shown by their regulation of learning. From the information about this level of ability, students' need for outer control of the course of their learning is derived, where one type needs exact instructions and the other prefers their own independent way of learning. For this evaluation LSI questionnaire has been used. (Kostolányová, 2010a)

We find out the values of these characteristics through a specially constructed questionnaire. It has 31 questions that cover all selected characteristics. By means of this questionnaire, initial values of static student features are determined before the courses start.

METHODOLOGY OF ADAPTIVE LEARNING MATERIALS COMPILATION

Teaching material sources are of course necessary for learning. It has been already mentioned that in order to implement intelligent teaching, it is not possible to only use textbooks or even any other sources – encyclopaedias, monographs, the Internet, etc. Even classical, good quality distance learning textbooks are not enough.

In order to adapt to different student personalities, the managing program (Virtual teacher) must process teaching materials in multiple different ways – as if an experienced teacher reacting to different depths of knowledge, talent and approach towards the learning, reaction, habits and other characteristics of students. (Kostolányová, 2011)

The structure of the study material should be designed to be adaptable. This recommendation is based on the well-known pedagogical principles of Gagne. Gagne recommended a sequence of events that should be present in the teaching process in order for it to be successful and optimal. There is a specific order in the process of teaching: the beginning of teaching, interpretation, examination and the finish. In order to use the principle of adaptive teaching, the teaching process needs to be thus divided. The principle sets out events that should be present at each teaching unit (course, lecture, and lesson).

The adaptive support layers application on Gagne's theory can be demonstrated by Table 1.

The form of learning support will depend on the student's sensory perception type. Therefore, each framework will have sensory variants: one with a high volume of text (for verbal type of students), one with several images, graphs, tables and animations (for visual types), one with speeches, audio recordings, conversations and discussions (for audio types) and one with creative tasks, constructions etc. (for kinaesthetic types). The adjustment of these four options in accordance with the sensory forms of the framework will not cause a problem for the author.

Other variants will depend on the students' approach – in-depth, strategic, superficial, or "comprehension" adaptive. It is already known to all teachers that for some students ordinary interpretation is sufficient. However, others need the subject to be explained gradually, in more detail and with more examples. To maintain other students' attention, it is appropriate to provide additional information, following up on other subject issues. To create 3 variants of interpretations, varying by depth, will not be a problem for the author. Every depth is also interpreted in one of the above mentioned sensory variants.

Table 1. - Gagné's theory applied on an adaptable study support (Kostolányová, 2011)

Event (according to the Gagne's theory)	Framework layer in adaptive support
Gain attention	Motivation layer
Inform learners about objectives	Goal layer
Stimulate recollection of prior learning	Entry knowledge testing, eventual demands of the framework
Content presentation	Theoretical layer
Provide "learning guidance"	Semantic layer
Elicit performance (practice)	Practical examples
Provide feedback	Auto testing – layer of questions and tasks
Assess performance	Test results, key to unsolved tasks
Enhance retention and transfer to the job	Fixation layer

Teaching style is, however, affected by many other characteristics. It is not possible to add up every possible variant. Let's consider then how the instruction differs for these other characteristics.

Theoretically, a well prepared study type will prefer usual interpretation (theory – explanation – exercises) and check (control questions – tasks). Non-motivated students will first need motivation in the form of practical exercises – then principle explanation – and finally, theory – control tasks. Students without the ability to auto-regulate will need detailed instruction, direction for what to study, what to do first, and what to do after. Holistic students will first need a brief overview about the whole chapter and only then a gradual navigation toward detailed information.

Note that the instruction for all of the examples of types of students differ mainly in the sequence of instruction components within each option. Let us call these components variant layers and further analyse types of occurring layers.

Learning support must be structured in detail to adapt the teaching style to the level of students with a suitable choice of teaching options and a suitable order of individual layers. (Kostolányová, 2010b)

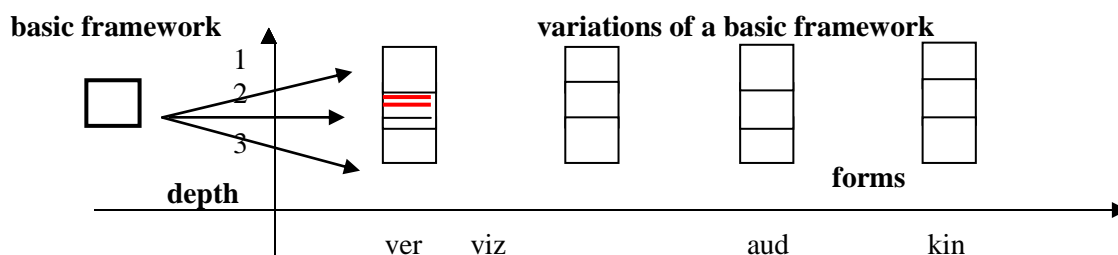


Figure 1. Framework variations

Framework variations are different methods of explaining and verifying (testing) the same material.

On the basis of considerations arising from conclusions in the previous paragraph, we propose up to four variations based on the preferred sensory perception of the student (also referred to as four sensory

forms of variations) and up to three variations in terms of depth of explanation. Thus a total may be $4 \times 3 = 12$ variations maximum in two “dimensions”.

It is not necessary to always employ all variations. It is up to the support author to cover sensible variations, or not to use certain ones if they are not suitable, or necessary.

Framework variation based on sensory form:

From the aspect of form, we divide variations into the aforementioned four types (variations column in the diagram above):

- Verbal – variation containing mainly text,
- Visual – variation containing mainly images, graphs, animations, etc.
- Auditive – variation containing lots of spoken words, sounds, video lectures, etc.
- Kinaesthetic – variation containing lots of interactive educational programmes, etc.

The depth of instruction indicates the level of curriculum detail and specifies the detail of the presented teaching information. We have defined three levels of depth – basic (the most frequently used depth interpretation), further detailed instruction (with easier and increasingly advanced exercises) and extended depth (containing interesting facts, details and news).

Variants differing only in their form and depth of instruction cannot cover all of the differences in the style of instruction that are necessary. By analysing these student characteristics, it has been concluded that instruction also differs in the sequence of parts of the instruction and ongoing testing, or organisational information.

Adapting a framework instructional style can allow us to divide the framework into partial components, or layers. Framework layers are called the homogenous part of the framework in terms of teaching process phases (theory presentation, explanation, fixation, knowledge verification, motivation and teaching management). (Kostolányová, 2010b)

Types of layers:

- Explanatory– group of layers containing explanation of the covered material itself. This concerns the following layers:
 - T Theoretical – containing theory: definitions, terms, rules, algorithms, etc. In terms of education, this is the most important type of layer.
 - S Semantic – explaining the introduced terms, formally described theory containing additional information to the theoretical layer, explaining correlations arising from the theory, etc.
 - F Fixation – with the aid of reviews, other formulations and alternative concepts, it can be implemented into the wider context to facilitate a better acquisition of the theory.
 - R Resolved examples – contains examples for applying theory and resolved “textbook” examples. For students, they institute examples for resolving their presented assignments.
 - P Practical – contains the resolution of practical examples using theoretical knowledge.
- Testing – a group of layers for regular testing of acquired knowledge which implants this theoretical knowledge with the aid of tasks, or assignments to be resolved. This concerns the following layers:
 - OQuestions – theoretical questions based on covered material. Questions may serve only for student feedback, or may be used by the adaptive algorithm for control of the following instruction.
 - UExercises – “textbook” exercises to be resolved.
 - XPractical exercises – exercises from practice.

- Other layers

MMotivational – motivational information on the subject, lesson or framework, which would justify the benefit of study to an unmotivated student.

NNavigational – didactic or organizational information, a kind of guide for lessons of covered material, recommended study methods, etc.

Information about the form and depth of instruction and the layer type needs to be recorded in the metadata. By using metadata, the system can choose and manage the correct sequence of teaching.

BASIS OF ADAPTIVE ALGORITHMS – RULE PROPOSAL

The rules for personalization of electronic materials are described as follows. Each rule tells us exactly how the teaching style will be altered for students with certain characteristics. Each rule has conditions and conclusions. In conditions there are different student characteristics. In conclusions there are different material properties: sensitive form of the variant, depth of the given type of layer and layer sequence. For example, if a student is not motivated, use depth 3 motivation layer at the beginning of the framework.

To make the rule creation easier, we have categorized the student's characteristics level into three values: high, low and regular. Now we are going to describe the rules for some of the student's characteristics. The complete rule description is in. (Takács, 2011)

Sensitive Perception

Material adaptation to the student's sensitive type is realized by assigning the most similar variant to the student. This is the only student characteristic where we do not use rules to describe the material adaptation. The sensitive perception of the student and variant is described by four values: vis, aud, ver, kin. The number of these values describes how close the student, or the variant, is to the visual, auditive, verbal and kinaesthetic type. All numbers range from 0 to 100, where 0 means that a student, or a variant, is not the given type and 100 means that it is the given type.

We assign the most suitable variant to the students by calculating the Euclidian distance (dist) between the student sensitive type and variant sensitive type with the following equation:

$$x = (vis_frame - vis_stud)^2 + (aud_frame - aud_stud)^2 + \\ + (ver_frame - ver_stud)^2 + (kin_frame - kin_stud)^2 \\ dist = \sqrt{x}$$

After the distance calculation for each variant, the variant with the lowest distance is chosen for the student's sensitive type.

Motivation

The adaptation with regards to the motivation is done by altering the depth of the motivation layer. For students with low motivation we need to use the depth 3 motivation layer and display the motivation layer first in order to get the student's attention right from the start of the frame. For students with high motivation we use depth 1, and for regular motivation, depth 2. These statements can be formally described by the following rules:

- if the student has low motivation, then use the motivation layer of depth 3 and display it to the student first;
- if the student has high motivation, then use motivation layer of depth 1;
- if the student has regular motivation, then use motivation layer of depth 2.

Deep, Strategic and Surface Approach

Based on this characteristic we alter the depth of the explanatory and testing layers. Ordinary material can get boring for students with a deep approach, which is why we offer them some additional content

and more challenging questions and tasks contained in depth 1.

Students with surface learning approach can sometimes try to just remember information they don't understand instead of trying to understand it. That is why the information is presented to them more carefully and depth 3 is used with more detailed explanations, simpler exercises and increasingly complex examples.

For students with the strategic approach we use depth 2 of explanatory and testing layers. From the above mentioned, we can state the following rules:

- if the student has the deep approach, put after every explanatory and testing layer (T, S, F, R, P, O, U, X) of depth 2 the same type of the layer of depth 1
- if the student has the surface approach, put before every explanatory and testing layer (T, S, F, R, P, O, U, X) of depth 2 the same type of the layer of depth 3
- if the student has the strategic approach use depth 2 for every explanatory and testing layer (T, S, F, R, P, O, U, X)

CONCLUSION

The introduced teaching system makes it possible to customise teaching contents to fit the learning style of each student, and therefore improve their learning. The system can only be achieved by preparing study materials and arranging these in several variations. Individual variations differ in the media used (text, images, audio) and in the focus (ordinary students, students with high interest, and students who have difficulty to understand the subject).

Another important part of this system is the virtual teacher, which selects the most suitable material from the available options, to match the corresponding student characteristics. The virtual teacher's activity is set by rules that select a particular material variation for a particular student's characteristics. The basic versions of these rules have been introduced here and may be easily changed or extended. The first version of this teaching system has already been created along with several parts of subjects prepared in the adaptive format. The next phase of adaptive teaching will take place in this system with a small number of students. Based on their feedback, the system - mainly the rules for virtual teaching - will be further modified.

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SUPPORTING TUTORS WITH THEIR FEEDBACK USING *OPENMENTOR* IN THREE DIFFERENT UK UNIVERSITIES

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Alejandra Recio Saucedo

ABSTRACT

Assessment has been identified as one of the major challenges faced by Higher Education Institutions (Whitelock, et al, 2007). As a response to the challenge, in a project funded by the Joint Information Systems Committee (JISC) the Open University developed Open Mentor (OM), a learning support tool for tutors to help them reflect on the quality of feedback given to their students on assignments submitted electronically. It was developed on the fundamental theory that there was convincing evidence of systematic connections between different types of tutor comments and the level of attainment in an assignment (Whitelock et al 2004).

The work initiated by the Open University is being continued at the University of Southampton and King's College London through the JISC-funded Open Mentor technology transfer (OMtetra) project. OMtetra aims at taking up OM and extend its uses by developing the system further and ultimately offer better support to tutors and students in the assessment process.

The findings to date from the preliminary testing suggest that changes are required to the algorithm used in the analysis of feedback comments together with the introduction of a module for user authentication that would facilitate integration within any university system. In addition, changes to the types of assignments processed by OM have been also suggested by tutors who assess marked assignments as well as essays written by post-graduate students which do not necessarily need to have a mark but require complex feedback that allow students to enhance academic writing skills.

OMtetra is an on-going project with high potential. We believe that the tools that result from the development and trial implementations of OM will contribute highly to the area of assessment and feedback in Higher Education Institutions (HEIs) since it is an open source tool that will have wider applicability through the customisation process that is currently being undertaken.

KEYWORDS

e-feedback, technologies for Education, assessment, tutors' feedback, Bales categories

BACKGROUND

One of the major challenges for Higher Education today is that of assessment. This is due to a tension between the demand for institutional reliability and accountability on the one hand and a move towards a more social constructivist approach to learning on the other (Whitelock & Watt, 2007). The main thrust of this latter work has come from the cultural historical perspective (Cole, 1990; Vygotsky, 1978). Within this socio cultural perspective one of the most important premises is the recognition that individuals shape the cultural setting which in turn alters and shapes the development of individual minds (Wells & Claxton, 2002). This is an important consideration when tutors are trying to shape students' learning behaviours through the use of pertinent and salient constructive feedback.

Technology has a role to play in enhancing the assessment feedback cycle but only if it has been designed to improve the effectiveness of the assessment from a learner's point of view. The call for a pedagogically driven model for e-assessment was acknowledged as part of a vision for teaching and learning in 2014 by Whitelock and Brasher (2006). Experts believe that such a model will allow students in Higher Education to take more control of their learning and hence become more reflective,

but how can this be supported with tutor feedback? One of the problems with tutor feedback to students is that a balanced combination of socio-emotive and cognitive support is required from the teaching staff. One approach adopted by Whitelock et al (2004) to solving this problem was to build an electronic tool to support tutors with the feedback process. This tool, known as OpenMentor (OM), analyses and displays the different types of comments provided by the tutor as feedback to the students. It then provides reflective comments to the tutors about their feedback practice. This tool was designed by and used within the Open University. However, there is interest in improving the feedback given to students in Higher Education (HE) throughout the UK. This interest was prompted by the annual Student Survey and has led to an awareness of how OM might assist other institutions in supporting tutors with their feedback to students.

In response to the interest, a project was set up to transfer OM to external institutions, the University of Southampton and King's College London. This paper reports the OpenMentor Technology Transfer (OMtetra) project's progress to date and addresses the following research questions:

- Would tutors who were not trained by the Open University accept the comments given to them about their feedback to students produced by OpenMentor based on Bales taxonomy? And if so, how would tutors incorporate their learning experiences after using Open Mentor?
- What changes would be needed to facilitate cross institutional use of OpenMentor?
- What would be the strengths and limitations of OpenMentor as a tool used for training purposes?

The findings should assist the project in producing an open source tool to enable the software to be easily deployed and freely used without licensing costs.

THE IMPACT OF FEEDBACK ON STUDENTS' LEARNING

In discussing the impact and importance of feedback on learning, it is useful to outline a view of education, learning, and teaching in which feedback plays a central part. Education may be characterised as the alignment of learning with intended outcomes or objectives, and the role of a teacher (which includes the learner when their activities involve self-study, self-teaching, or self-evaluation) as comprising three components: providing materials to support learning; asking learners to undertake learning activities; and providing feedback. This produces a model which has the potential to change student's behaviour. In this model, feedback is characterised as the consequences of behaviour which lead to learning. This conceptualisation of feedback places it at the centre of education, learning, and teaching; and assumes that without effective feedback, the learner is most unlikely to achieve their intended outcomes or objectives.

This model of education and the essence of the learning and teaching situation as shown in Figure 1 has been called the "learning transaction" (Gilbert, Sim, & Wang, 2005; Gilbert & Gale, 2008). Draper (2002) and others emphasise the role of the learner in providing their own, internal, feedback about their performance, and this view is entirely consistent with the learning transaction and the model of education which contextualises our discussion.

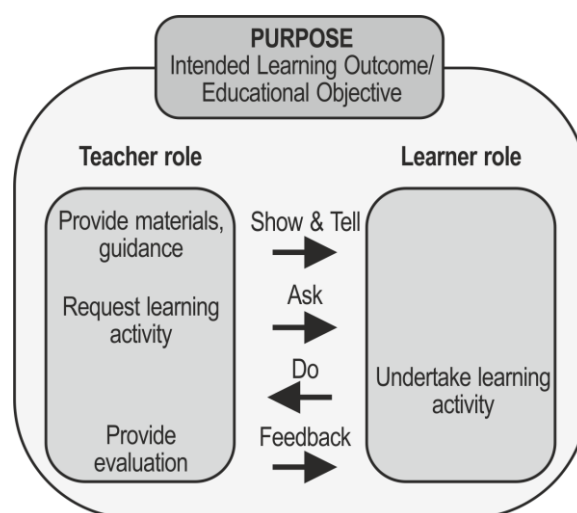


Figure 1. The learning transaction (adapted from Gilbert & Gale, 2008)

A useful distinction is often made between formative and summative assessment (Bloom, Hastings & Madaus, 1971). In this distinction it is important to note that feedback is not a necessary component of summative assessment, but an essential component of formative assessment. Nicol and Macfarlane-Dick (2006) have identified seven features of effective formative feedback (see Table 1). These features have to be in tutors' minds when constructing their feedback in order to provide a balanced view of the students' performance on a given assignment.

Table 1. Nicol & Macfarlane-Dick's features of effective formative feedback

<ol style="list-style-type: none"> 1. Facilitates the development of self-assessment (reflection) in learning. 2. Encourages teacher and peer dialogue around learning. 3. Helps clarify what good performance is (goals, criteria, and expected standards). 4. Provides opportunities to close the gap between current and desired performance. 5. Delivers high quality information to students about their learning. 6. Encourages positive motivational beliefs and self-esteem. 7. Provides information to teachers that can be used to help shape the teaching.
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Turning to the provision of feedback within an e-learning and e-assessment environment, it is useful to note the recent reports of Szwelnik (2010) and Gilbert, Whitelock, and Gale (2011) which explore the use of technology in the provision of what we might call e-feedback. These reports emphasise the fact that successful e-feedback lies with the pedagogy rather than the technology itself. The technology is an enabler and it is the pedagogically-informed design of appropriate and constructive feedback which underlies the success of e-assessment. Additionally, Gilbert, Whitelock and Gale (2011) emphasise that staff development and support are vital when introducing and developing e-assessment and e-feedback. These findings form the basis of the Open Mentor application and of the OMtetra project.

OPEN MENTOR

The Open University developed OM (Figure 2) as a response to the challenge of delivering meaningful and learning-conducive assessment to students. Under such premise, OM was created as a learning support tool for tutors to help them reflect on the quality of the feedback they give their students on assignments submitted electronically. Underlying the construction of the tool is the fundamental notion that there is convincing evidence of systematic connections between different types of tutor comment and the level of attainment in an assignment (Whitelock et al., 2003).

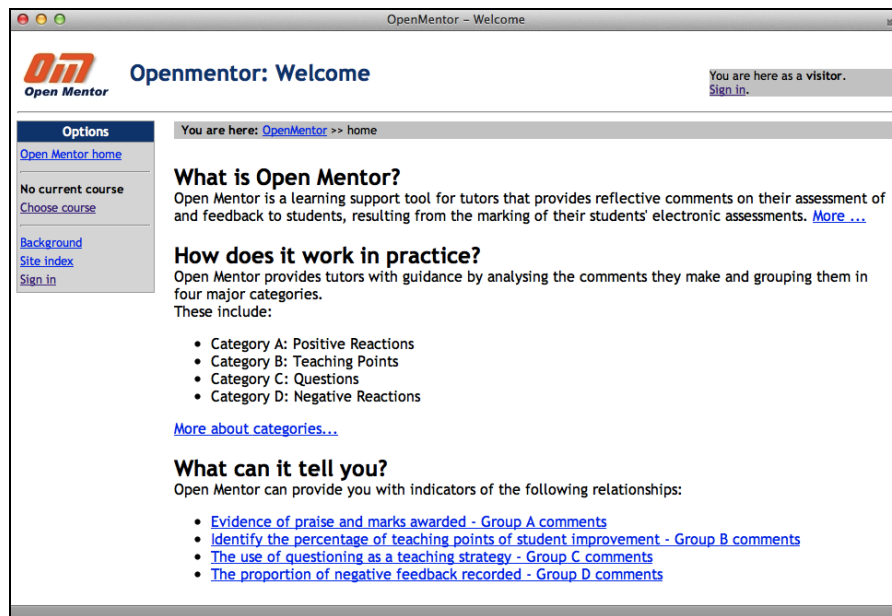


Figure 2. Open Mentor welcome screen

BALES FRAMEWORK FOR FEEDBACK CATEGORISATION

OpenMentor is based on Bales (1950) interactional categories which provide four main types of interaction, namely positive reactions, negative reactions, questions and attempted answers. These interactional categories illustrate the balance of socio-emotional comments that support the student. Table 2 provides examples of classified feedback following the main interaction categories. The algorithm of OM analyses tutors' feedback under Bales categorisation and produces graphic reports using the four interaction types. These reports can be studied by tutors to understand and potentially enhance tutors' feedback styles.

Whitelock et al. (2003) found that tutors use different types of question in different ways, both to stimulate reflection, and to point out, in a supportive way, that there are problems with parts of an essay. These results showed that about half of the Bales interactional categories strongly correlated with assessment grades in different ways, while others were rarely used in feedback to learners. This evidence of systematic connections between different types of tutor comment and the level of attainment in assessment was the platform for the current work.

The advantage of the Bales model is that the classes used are discipline-independent. Whitelock et al. used this model to classify feedback in a range of academic disciplines and it proved successful in all of them. An automatic classification system, therefore, can be used in all fields, without needing a new set of example comments and training for each discipline.

Others (see for example Brown and Glover, 2006) have looked at a range of classification systems, including Bales. From these systems, Brown and Glover developed their own classification system to bring out additional aspects of the tutor feedback, specific to science training. In practice, no (useful) classification system can incorporate all comments given by all tutors. Whitelock et al. selected and still prefer Bales system because of its relative simplicity, its intuitive grasp by both students and tutors, and because it brings out the socio-emotive aspects of the dialogue, which is the one aspect tutors are often unaware of.

Table 2. Bales categorisation of interaction

Categories	Feedback structure	Feedback comments examples
Positive reactions		
A1 – Shows solidarity	Jokes, gives help, rewards others	Very Good section, applying Rowntree's Table 1.3.
A2 – Shows tension release	Laughs, shows satisfaction	Conflicting ideas that have been resolved elegantly, well done.
A3 – Shows agreement	Understands, concurs, complies, passively accepts	Yes. They often also have a conflicting interest.
Teaching points		
B1 – Gives suggestions	Directs, proposes, controls	You need a date here to link it to the reference list.
B2 – Gives opinions	Evaluates analyses, expresses feelings or wishes	I like the way you've used footnotes to explain your acronyms. Good idea.
B3 – Gives information	Orients, repeats, clarifies, confirms	Page 10 of the Assignment Guide shows how to write out these kinds of references.
Questions		
C1 – Asks for information	Requests orientation, repetition, confirmation, clarification	Here you should have a citation. Did you get this from a particular report?
C2 – Asks for opinion	Requests evaluation, analysis, expression of feelings or wishes	If you hadn't specified computers, would it have been clear what you were asking? What other facilities might there be?
C3 – Asks for suggestions	Requests directions, proposals	What do you think you should do about that?
Negative reactions		
D1 – Shows disagreement	Passively rejects, resorts to formality, withholds help	It is not too clear to me that you addressed the second part of the question.
D2 – Shows tension	Asks for help, withdraws	I might not agree entirely with your argument. Perhaps you can elaborate on it further?
D3 – Shows antagonism	Deflates others, defends or asserts self	Adding more evidence to support your view will strengthen your argument, regardless its rather controversial nature that some would point out

The following sections report on the pilot studies that have taken place in the participating institutions and how these were organised. The aim was to evaluate the use of OM by local tutors, to document the user experience, and to establish whether any development work would need to be carried out for the next phase of the OMtetra project.

TRANSFERRING OPEN MENTOR

Open Mentor was introduced to tutors of the three participating institutions of the OMtetra project in October 2011. Tutors were invited to use the system to analyse the feedback provided in their assignments and report their experiences. In order to collect their views on the system a questionnaire (See Appendix A) was prepared and used across the three institutions (including the Open University as the system was re-adopted within a module of technologies for learning and teaching). In order to accommodate the particular working patterns of each department the questionnaire was slightly modified by members of the research teams.

The number of tutors involved in the first stage of the project varied per institution. Also, the system was presented to tutors in various ways, including face to face short training sessions and/or use of materials and resources available from the webpage for on-line training, with continuous support via email or chat.

RESULTS

This section presents details of the participants and results from the analysis of the data collected through the questionnaire and interview study. This is followed by the features identified by all participants as recommendations for an improved version of OM⁷.

King's College London

The original version of OM was used by three tutors (two academic developers from King's Learning Institute and a lecturer from the Department of Education and Professional Studies). Two of them were interviewed (on average one hour length) and gave feedback and discussed their generated reports. Feedback was received from twenty five e-learning experts during the college Technology Enhanced Learning forum who gave feedback on the functionality of the system together with tutor and student requirements of OM, after a demonstration of the system.

Tutors at King's were very positive about the opportunity they were given to receive comments about their feedback practice, as they had not received this type of feedback before in a structured fashion. Feedback on assessment practices which is given to assignments is received at tutor team meetings and sometimes at programme exam boards but not consistently.

The tutors did not experience usability issues and they appreciated the induction that was offered to them, however one of them pointed out that uploading the assignments was laborious and potentially time consuming for which they thought it would be useful to have administrative support to complete this task. This task however may be integrated into the marking exercise which will ultimately streamline the process, counteracting the seemingly laborious task of uploading assignments with the benefits of providing quality feedback to students.

They were appreciative of the multidisciplinary aspect of the system, however one of them commented on the particular idiosyncrasies of disciplines that might make evaluating feedback across different disciplines difficult. They would like the system to have a purely formative function, which they claimed would be useful for feedback on draft assignments and where the summative aspect could be 'switched off' (e.g. in feedback given to PhD students). Only one tutor thought that some of the system classifications were inaccurate, e.g. in teaching points and questions. She also pointed out that she would like to see the system advise whether the comments are synchronous with the grade⁸.

Tutors were happy with sharing the feedback from the system and the Bales' categorisation outcomes with their students and colleagues. They thought that in both cases this would lead to useful discussions that would allow establishing common views about what constitutes constructive and supportive feedback. One of the tutors (who is the Programme leader of the Postgraduate Certificate in Academic practice, a King's programme, whose target audience is probationary lecturers and inexperienced tutors) highlighted that a system such as Open Mentor could be a very useful peer review tool in face to face workshops. She also recommended the tool for novice tutors who would appreciate feedback on their assessment practice.

⁷ The features and overall feedback were used to plan a further development of the system which is now being implemented and trialled as the second stage of the OMtetra project.

⁸ In order to facilitate understanding of reports generated by OM, the results tables were slightly modified during the development stage of the project.

Overall, improvements in the system tutors would like to see included:

- access from everywhere (inside and outside the College, not the case for King's when the pilot study took place, so there needs to be implemented before further tutor engagement)
- Enhancement of narrative in reports as quite often the graphs were not easy to interpret, without supporting explanations.
- Renaming 'negative' comments to 'areas for improvement' or similar, as they thought current trends in assessment avoided terminology of this kind and the term might alienate students. It must be noted that an alternative name for the category was not proposed, as a result, a decision was made to preserve the labels under Bales taxonomy and discuss this issue in further work.
- A purely formative function to be used in commenting on drafts.
- Developing the route that would help tutors to move towards the ideal 'state', which they thought was not explicit in current version.

Southampton

The original version was used by three tutors. The three participant tutors were sent a questionnaire regarding OM. Two of the tutors who responded the questionnaire were also interviewed.

The evaluation of OM by the ECS lecturers involved in OMTetra resulted in the realisation that the framework used to analyse tutors' feedback was only able to offer a partial perspective of the qualitative value of tutors' comments given to a student in a particular assignment. Tutors in ECS focus their feedback in two major aspects including the structure of an essay and the skills associated with the subject under study, like for instance, programming skills, mathematics analytical skills or reasoning skills underlying the creation of algorithms and software design. Lecturers found that Bale's approach as implemented in OM was extremely useful in the assessment of students' academic writing but less helpful for the analysis of feedback regarding how a programming language was used in the development of a system (e.g. for a student to develop programming skills in a particular language, all syntax errors in a program need to be marked as *errors*. In programmes written by undergraduate students who are in the process of developing programming skills will present cases where a single programme may have a large number of errors. Tutors evaluating assignments which include the writing of a programme would comment those mistakes as errors only. As a result, OM reports would show an imbalance between the ideal number of comments classified as negative and those actually given by the tutor, however, in this case, the imbalances do not need to be corrected).

The conclusion of the tutors was that the algorithm used to evaluate tutors' feedback is appropriate for determined situations but not generalisable to other contexts or subjects.

The Open University

OM was evaluated by three distance education tutors using the questionnaire prepared for all three sites. Feedback and discussions took place by email. OM was implemented within a module of 113 students in a Masters course focussing on Innovation in eLearning and 5 tutors.

Student enrolled in the course sent feedback on OM by email. These contributions were spontaneous and were not initiated by the researchers. The feedback received centred on technological issues found whilst interacting with OM. These were considered during the development of the enhanced version of OM.

ENHANCING Open Mentor

A feature we identified for improvement of OM was the analysis algorithm. Originally, OM classified tutors' comments into four categories by applying a naïve text-matching algorithm. This involved building a substantial collection of comments, manually categorizing them, verifying inter-coder reliability, and then generalizing to a set of static patterns – implemented as regular expressions. The analysis algorithm simply works through the patterns to find the best category match. This is technically complex to maintain, and fragile. The ideal analysis algorithm should require minimal maintenance, and

where possible, any maintenance should be implemented to take place automatically through the tutors' use of the system.

Classifying comments is a challenge because there is a comment genre – comments have a form that is distinct from their topic. Positive comments on philosophy essays are similarly structured to positive comments on business essays. It is this aspect of form that allowed the pattern-based approach to work as well as did. A successful analysis algorithm will need to be sensitive to the form of the comments, without being confused by changes in topic. In practice, this means it needs to use structural features (e.g., word orderings, punctuation) as well as linguistic ones (Dewdney et al., 2001; Watt, 2009). A simple 'bag of words' classifier is not sufficient. Genre-based classifiers typically require more complex feature identification – and this is a strength of the pattern-based approach.

Allowing tutors to provide feedback to the classifier through the OMtetra interface would also be a significant improvement. Then, as the number of users grows, so will the quality of the analysis process, making it more comprehensive and intelligent as the precision of the classification improves. However, this is a challenge – it is important that as tutor feedback is incorporated, any changes to the classification still comply with Bales Interaction Process model.

There are a number of classification algorithms that are amenable to this approach, and that can incorporate feedback through manually classified exemplars. Support vector machines generally perform well in text categorization, as do case-based classifiers (Watt, 2009). Both approaches typically offer better accuracy than a pattern-based approach, and are more maintainable. Some empirical work will be required to provide a definitive recommendation – and it is possible that both approaches are made available, with the option to select configurable by a local administrator.

One important enhancement to OM was identified as its capability to integrate with existing information management systems in different academic institutions. OM has already utilised a built-in database where students, tutors and course information are saved. But the user management component in the backend of OM is left open, which allows OM to integrate with existing user management systems in different academic institutions, where data sources for student, staff, course lists and assignment content are provided. However, these functions still require a lot of further development under the current implementation. Grails builds on Spring Framework and many functions mentioned above are supported out-of-the-box. Under Spring Framework we can divide the input resources of into a number of individual components. One institution could integrate its own resource of users and courses into OM. We also use Spring Security Framework to provide support of various authentication systems with some configuration, such as Lightweight directory Access Protocol (LDAP) and Shibboleth. In this case, OM only refers the authentication information in existing systems and the users and course information in other management system will not be duplicated in OM's own database. In this way, the modules in OM can reuse the existing resources from external systems.

CONCLUSION: TOWARDS AN ENHANCED OPEN MENTOR

Innovative use of ICT tools and technologies can facilitate the provision of timely instant feedback to students in tertiary education. It can also help students to evaluate the quality of such feedback. The pilot testing has revealed that tried and tested pedagogical strategies in a number of disciplines can be enhanced by the use of automated feedback. The main findings from the pilot study addressed the research questions as follows:

- Open Mentor's theoretical framework was robust enough to facilitate and encourage dialogue and reflective activities for the participating tutors. Tutors from the partner institutions were positive about the system's functions to support provision of feedback.
- The changes needed to facilitate cross institutional use of Open Mentor included the development of a module for user authentication and management; enhancement of the user interface

to allow some level of customisation to the look of the system; and most importantly, the development of OM reports to help tutors to progress towards the ideal ‘state’ of feedback provided.

- There was agreement that Open Mentor could be used for training purposes as an academic development tool. The project needs to explore ways of how to support this type of activity.

There is a growing consensus in the field of assessment that times are changing and that assessment needs to become more embedded/central in the teaching learning cycle (Hatzipanagos & Rochon 2011). However the provision of feedback that students will actually respond to which is timely and pertinent is indeed a challenge. This project provides another phase in this type of research where the balance of socio emotive content contained in feedback cannot be ignored (Draper, 2009). Feedback that encourages the student to actively change their ideas and ways of organising their answers and discourse within a given subject domain is what is required and advocated by Whitelock (2011) as “advice for action”. There is still much work to be done but if the tools are under-pinned with appropriate learning and assessment strategies we are on the way.

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Appendix A

Tutor interview

Part 1: Open Mentor interface

1. Is Open Mentor easy to use?
2. Approximately, how much time did it take to 'learn how to use the system' to upload and analyse assignments?
3. Was the guide provided in the project website (or emailed/given to you) useful?
4. Is it easy to enter course information, lists of students, tutors and/or uploading assignments into Open Mentor?
5. What features would you change/add?
6. On a scale of 1 to 10 (1 the least, 10 the most) how would you rate Open Mentor:
7. design quality?

Part 2: Open Mentor usability

1. Did you find the reports the system gave you useful?
2. Were the points the report made relevant to your assessment practice and module. Did the reports have an impact on your feedback?
3. On a scale of 1 to 10 (1 the least, 10 the most) how would you rate Open Mentor:
 - a. Usefulness?
 - b. Appropriateness of criteria used to analyse the feedback considering your students and the module you teach?
4. Open Mentor makes some assumptions about what is good feedback and its comments point towards these directions. Did you find those comments useful and relevant to the assessment for this module?
5. Open Mentor made some assumptions about generic principles of feedback that might also be applied to the King's College generic marking criteria? Were these assumptions true?
6. How would you feel about discussing the reports on the analysis of your feedback with colleagues, other students?

Student questionnaire

Your tutor's participation in a research study to analyse the feedback given in assignments has ended, and we would like to know your opinion and perceptions on the usefulness of the feedback received in the module _____ compared to feedback you receive in other modules or that you have received in the past.

- Did you find the feedback that you received from the tutor participating in the research study
- a. more/equal/less useful than feedback received in other modules/in the past?
 - b. more/equal/less structured?
 - c. more/equal/less clear and easy to understand and follow?
 - d. more/equal/less conducive to improvement?

Would you recommend the use of feedback analysis tools?

DIALOGICAL INTERACTIONS CONCERNING THE SCIENTIFIC CONTENT THROUGH FACE TO FACE AND DISTANCE COMMUNICATION USING WEB 2 TOOLS

Z. Smyrniou, E. Varypari, E. Tsouma

ABSTRACT

The existing literature points to an array of issues related to science inquiry and dialogical interactions between students trying to resolve a scientific problem. The objective of this paper is the study of how students interact face to face as well as distant in the modern shared screen of the Metafora Platform when using Web2.0 tools (Planning Tool, Argumentation Tool) in which students learn how to learn together, argue and construct plans to resolve problems concerning scientific matters. Those tools include visual language based on the theoretical structure of inquiry, as well as based on the theoretical structure of constructionism and of argumentation theory as part of the Metafora Platform. This study contributes to the knowledge basis regarding the communication and the cooperation between students in an attempt to resolve two common challenges. The results of this study demonstrate that dialogical interactions promoted effectively the abilities of science inquiry.

KEYWORDS

Dialogical interactions; Modern learning platform; Planning tool; Argumentation tool (LASAD); Physical sciences

INTRODUCTION

Scientists are interested in the role dialogical interactions play in learning new scientific concepts as well as in the acquisition of skills. For the present pilot study of the Physics challenge-based scenario, 12 students will, work in subgroups of two, each one on their own computer. The communication among the subgroups will be synchronous through the Metafora platform. The factors that influence learning through collaborative activities are numerous: personality of students, relations, ability to express their opinion and support it etc. (Dillenbourg, Baker, Blaye & O'Malley, 1996). These factors, however, are numerous and interact with each other in such a way that one can not ascertain a-priori results.

In particular, we are interested in the way Greek students of the the 8th class (13-14 years old) interact when using two pedagogical tools (Planning Tool, Argumentation Tool) which include visual language based on the theoretical structure of inquiry as far as the first is concerned, as well as based on the theoretical structure of constructionism and of argumentation theory regarding the second. The mission of the two subgroups is coping with a common challenge (Main Challenge) in the 3D juggler microworld (Figure 1), which is interactive educational software of physics. By adjusting the various variables of this software such as Sphere mass, Sphere Size, Shot Altitude, Shot Azimuth, Gravity pull and Initial velocity (Power), students have the opportunity to study the phenomenon of "Shot". In order to communicate, they use the Argumentation tool (LASAD), which includes cards such as "Comment", "Microworld idea", "Microworld Action", "Sharing thoughts", etc. In addition, they use the Planning tool for the construction of the joint plan, that includes cards such as "Find hypothesis", "Construct a model", "Conclude", etc.

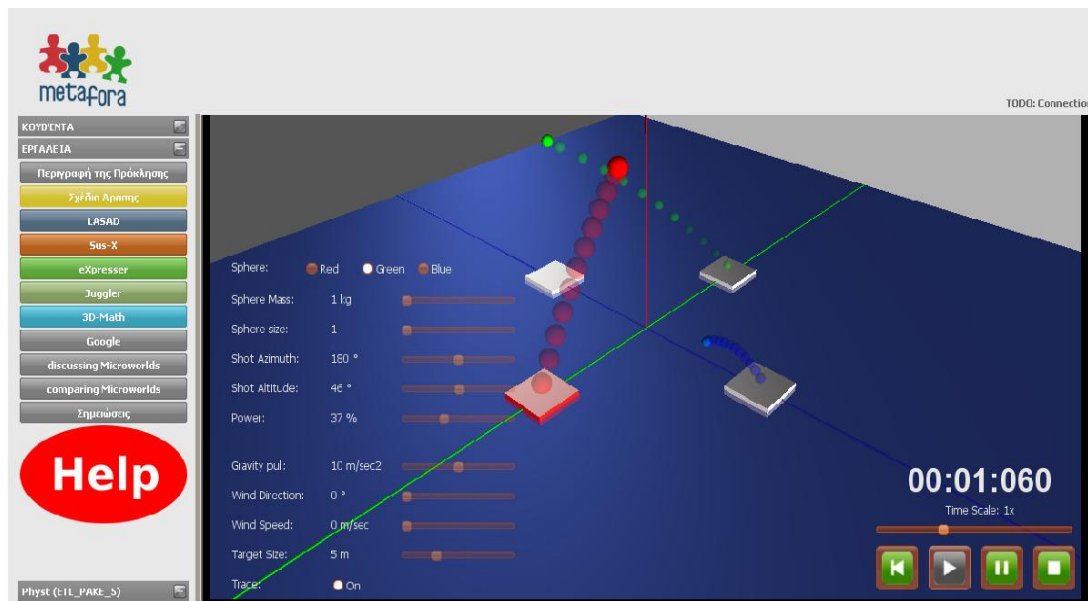


Figure 1. 3D Juggler Microworld

THEORETICAL FRAMEWORK

Inquiry based learning is the main point concerning LASAD and Planning tool. What needs to be highlighted is the modern theoretical framework that includes the scientific process or exploratory learning and attempts to describe the complex processes of the learning process but also the skills to be acquired by students. There are various forms of inquiry (Zacharia, 2007), including: reflective enquiry (Kyza & Edelson, 2003), scientific inquiry-based learning context (de Jong, 2006), dialogical processes of enquiry (Grandy & Duschl, 2007). Five different approaches describe inquiry-based learning in Metafora Learning (Wegerif & Yang, 2011): personal inquiry framework (Scanlon et al. (In press), generic inquiry cycle (Shimoda et al., 2002), case-, problem-, and project-based inquiry learning (Schwartz et al., 1999), constructivist inquiry cycle (Llewelyn, 2002) and progressive inquiry (Hakkarainen, 2010). Challenge based, which we have already mentioned, is embedded in inquiry-based learning and so does modelling as a process of thinking, reasoning and expression (Smyrniou & Dimitracopoulou, 2007 Petridou et al., 2009).

Both challenge and modelling are related to the actions of students in the domain tool of Metafora, the Physics microworld, 3D juggler. In this environment, students will construct their model in an attempt to find the solution to the challenge. Their discussions will change from general into specific. To a smaller or greater extent they will follow the constructionist ontology (Yiannoutsou et al., 2011). There, they will select the objects, their attributes, and relationships among them. They will construct and deconstruct their microworlds, they will test them through visual feedback (Kynigos, 2007).

Three factors seem to affect the solution of a problem when students work in teams (in the context of collaborative learning): their prior knowledge, the roles they adopt and the information they exchange. (Dillenbourg, Baker, Blaye & O'Malley, 1996). These three factors seem to determine their dialogical interactions and scientists have proposed cognitive forms of dialogue in order to analyze the dialogical-verbal students' interactions (Kneser & Ploetzner, 2001). In Metafora Learning, the use of the Visual Language is a main factor and strongly suggested (Wegerif & Yang, 2011).

In Physics, the knowledge of the scientific content students acquire is the factor we are mainly interested in (Psillos & Niedderer, 2002). It is known from relevant research that the creation of scientific meanings starts from the intuitions (Anastopoulou et al., 2011), the initial representations of

students (Driver, 1989), the phenomenological descriptions, the descriptions of actions or events perceived as scientific concepts and relationships between concepts (Smyrnaiou & Weil-Barais, 2005).

During the pilot phase there will not be any guidance from the Metafora system but there was a short guidance by a teacher or researcher. This may be deemed necessary at a later stage. Individual behavior and group behavior need to be distinguished in order to understand collaborative learning experience, since different collaboration styles are adopted by different individuals throughout the collaborative project. Content analysis is suggested to be conducted concerning the individual discourse to characterize the topics and key words of the messages and trace individual learning trajectories in the group (Wegerif & Yang 2011).

According to the theory of inquiry, of constructionism as well as of dialogical interactions, we created a framework to analyze our experimental data.

DESCRIPTION OF THE STUDY

In this study we are interested in students' interactions in their attempt to resolve the scientific problem. In particular, we examine their discussions when trying to construct a plan of resolving the problem and when trying to explain with arguments the entire procedure to their classmates, not only to the same subgroup through face to face communication, but also to their classmates of the other subgroup by distance communicating through the shared screen of the platform. The previous dimensions become more interesting when students use tools, like planning tool, argumentation tool and constructionist tool to resolve the challenge in Metafora Learning. Within this conceptualization and implementation, the present study examined how school students designed a planning process or an inquiry process, construct a model to answer the challenge (or challenge-based questions) and argument on these using the Metafora system. Another important consideration relates to the fact that LASAD and Planning tool include cards that must be completed.

This challenge-based study explores three research questions:

- What is the role of dialogical interactions in creating scientific meanings through Planning tool and Argumentation tool?
- What are the characteristics of the dialogues emerged from the use of the tools?
- What are the roles of the tools to stimulate and sustain the dialogues?

Taking into consideration the theoretical framework presented before, we will present the factors based on which we will analyze the plans that will be designed by each subgroup in the pilot study. Their discussions will be analyzed according to five dimensions as presented below: inquiry, constructionism, computer-supported collaborative learning, scientific content, argumentation.

RESEARCH METHOD-PROCEDURE

Students were divided in three groups of four, each of which was divided in subgroups of two in order to cope with a common challenge related to the "Shots". In order students to be familiarized with the three tools: LASAD, Planning tool, 3d Juggler Microworld of the Metafora Platform, they were asked to navigate to them in order to understand their functionalities. Then, they were given a warm-up challenge, as presented below: "Keeping the blue and the green balls still, shoot the red ball vertically upwards".

The two subgroups tried to resolve together the challenge, discussing through LASAD, stating their ideas and explaining their moves. They also had to construct a common plan in Planning Tool with the moves that led to the solution of the challenge. The two subgroups tried to resolve together the challenge, discussing through LASAD, stating their ideas and explaining their moves. They also had to construct a common plan in Planning Tool with the moves that led to the solution of the challenge.

Once familiarized with the three tools in the stage of the warm-up and figured out which sliders regulate and how they do so, they followed the same procedure to resolve the main challenge, as presented below: “The red ball should hit the blue ball’s base”.

In this study we focused in one group, because it was pilot and we were interested in the detail of what was told as well as done, in order to draw conclusions for the design of the main study which will be carried out in the next phase.

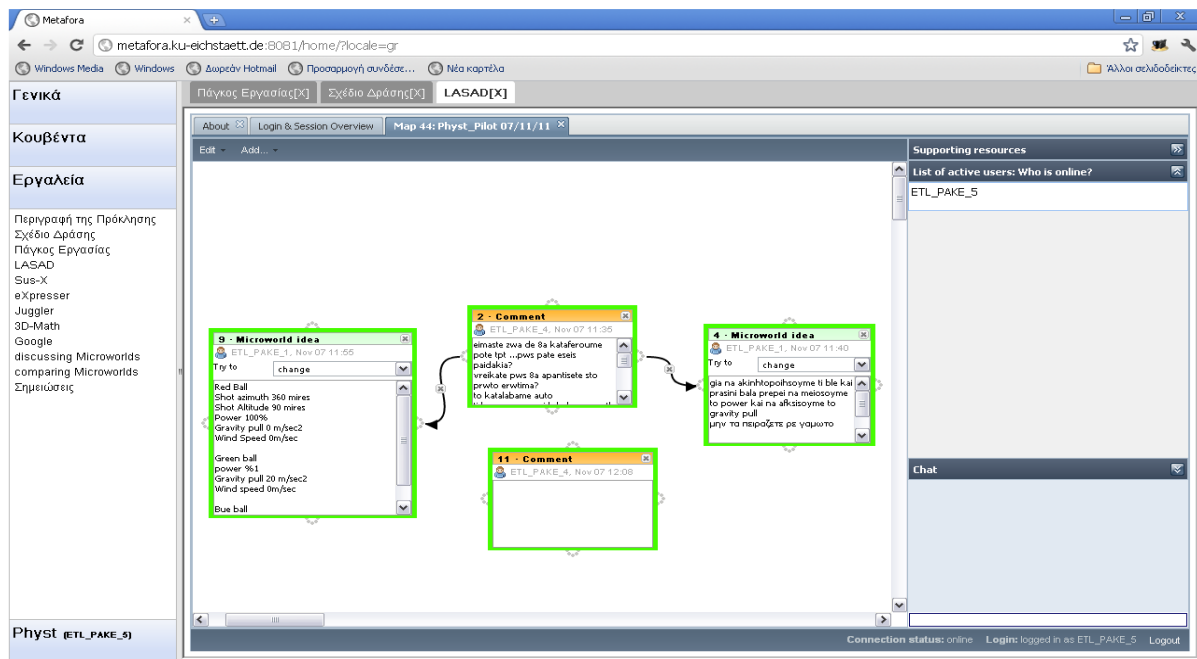


Figure 2. LASAD

RESULTS

The analysis of the student’s dialogues reveals that during the warm-up the two subgroups, communicated with each other through LASAD in order to resolve the challenge after exploring juggler and after deciding how to resolve the challenge. Then, in order to construct the joint plan with the moves that led to the solution of the challenge, students used Planning tool. The dialogue that takes place in LASAD relates to their moves in the Planning tool. What is more important to highlight in this point is that LASAD was necessary for the communication of the subgroups since there was no other means of communication (students were far apart). It is also important to note here that even though subgroup B worked creative with no problems, subgroup A had many disagreements and was more competitive in the whole challenge, since it does not provide any answer to the other subgroup.

At the same time subgroup A was unwilling to share its ideas, in spite of starting the discussion. On the other hand, subgroup B willingly shared its ideas as well as information concerning the successful changes of the variable values when solving the challenge. It is furthermore obvious that subgroup A was constantly in an attempt to take a leading role in constructing the plan, assuming that they work better than the other subgroup. Overall, subgroups manage to construct a joint plan in the Planning tool with the moves that led to the solution of the challenge. It is obvious, though, that subgroups argue about the fact that each one of them changes or puts in row the cards of the other subgroup.

At the same time the analysis also showed that in the Planning tool subgroups tried to record their assumptions regarding the way they could resolve the challenge. Their cooperation seems really well, since they complement each other in their attempt to create a joint plan. It furthermore becomes obvious

that the scientific method was properly approached as illustrated by the cards chosen and the order in which they were placed in the Planning tool (Figure 3).

As also evidenced subgroups confronted a problem of understanding in the middle of the process, so the students of subgroup B deleted all the cards from the surface of the Planning tool, assuming that subgroup A deleted some of the cards that they had written. However, this problem was overcome and the two subgroups construct the joint plan.

Data indicate that overall the cooperation between the two subgroups is evolving well, since they discuss on the alterations of the values in the variables. Even though subgroup A seems initially to question the values that the other subgroup gave to some variables, subgroup B does not disagree but argues that the values they also gave to the variables, can resolve the challenge. Subgroup B seeks cooperation since it requests to contribute in the construction of that plan, with ideas about what they could note on each card.

The analysis also revealed that, the two subgroups record their assumptions concerning the solution of the challenge. Based on the observations, even though initially, the cooperation of the two subgroups was not successful, since they chose cards with the same title and they note different data, later they seem to cooperate pretty well. Subgroup A corrects the content of some cards afterwards with the participation of both subgroups, they construct the joint plan.

It is further indicated that according to the choices students made regarding the cards and their order, they have approached correctly the scientific method. Overall, the cards of the Planning tool contributed to the construction of the joint plan, while the dialogues were not stimulated and sustained by the wrong choices regarding the cards of LASAD.

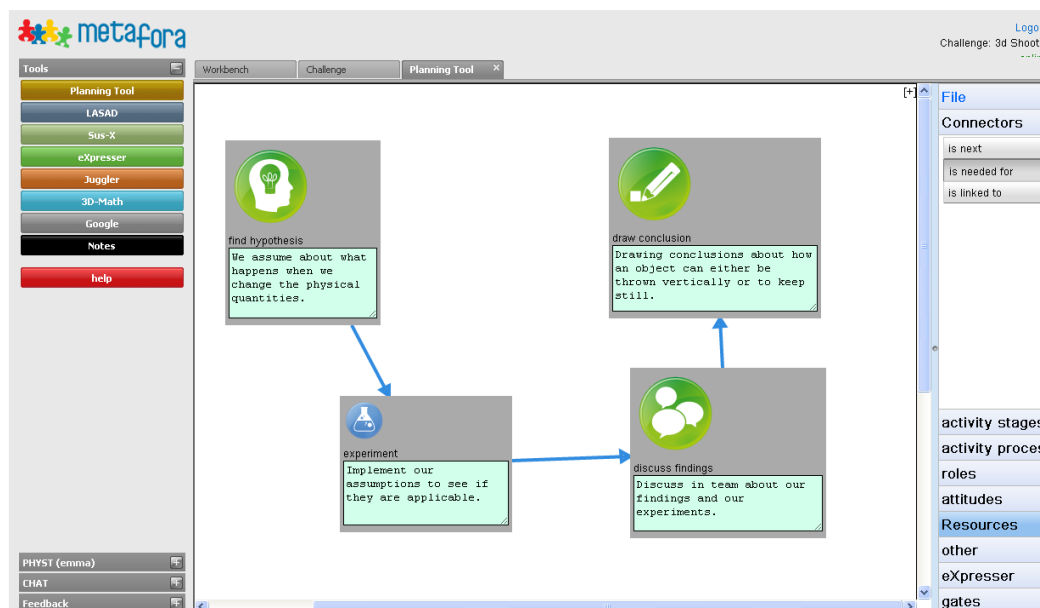


Figure 3. Planning Tool

CONCLUSIONS

The results of the analysis suggest that students became able to plan procedures for investigation, build models using technology-based learning environment, record results and draw conclusions. The largest gains were obtained for the skills of planning, modeling and drawing a conclusion.

Concretely, even though in the stage of the warm-up, LASAD was not exploited effectively by the two subgroups, in the stage of the main challenge, it was used more, since both subgroups contributed with

their ideas in order to resolve the common challenge by expressing their ideas and thoughts. However, this implication did not happen in the stage of constructing the plan, since students did not use LASAD as means to communicate.

More specifically, LASAD contributed to the solution of the challenge, since subgroups could exchange of views and for constructing a common plan in the Planning Tool. Another important implication is that LASAD was exploited so as to ask questions, express agreement or disagreement and report the values that were given to the variables to resolve the challenge.

Additionally the students of our study used Planning Tool exclusively for the construction of the joint plan by in which their moves were recorded regarding the way through which they reached the solution of the challenge.

Overall we contend even though the two subgroups in the initial stage did not cooperate effectively, in the later stage they seem to cooperate well. We also argue that they have approached properly the scientific method taking into account the cards students chose. In addition planning tool led subgroups to the creation of scientific meanings. This conclusion is not apparent, though, for LASAD. As a final conclusion of this study, inquiry-based and modeling-based instruction promoted effectively the interactions between the students.

ACKNOWLEDGEMENTS

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CONFRONTING CHALLENGES REGARDING GLOBAL ENERGY POLITICS IN A MULTIPLE PLATFORM OF TRANSMEDIA STORYTELLING TO IMPROVE ENGLISH

Z. Smyrniou, E. Tsouma

ABSTRACT

Current pedagogy fails to engage learners of English as a foreign language with the study of complex issues concerning global energy politics in a meaningful way. As a consequence, young foreign learners lack the needed skills and competencies to cope with issues of energy politics in the target language. To address this problem foreign language education research needs to approach new trends and concepts of learning, and utilize new pedagogical tools to support students in developing skills and abilities for resolving complex social issues. This study examined the dialogues conducted between students using a modern multiple platform of transmedia storytelling. Specifically, the objective of this paper is the study of how learners interact, collaborate and express themselves to create notions in English regarding complex issues surrounding global energy politics. Findings indicate that game-based and transmedia storytelling instruction promoted effectively the abilities presented before. More specifically, students of this study managed to communicate effectively in order to resolve the challenges as a starting point, and after to create meanings concerning the scientific concepts of the game in the English language.

KEYWORDS

Collaboration, face to face interaction, global energy politics, creation of meanings, English as a foreign language, multiple platform of transmedia storytelling, Collapsus

INTRODUCTION

Literature of educational gaming indicates that science gaming has offered learners increasingly learning opportunities but we support that digital games and transmedia storytelling can improve face to face communication and collaboration between learners of English as a foreign language. We focus in the technology of a modern platform of transmedia storytelling that blends interactivity, fiction, animation and documentary.

More specifically, this platform places users in crucial moments in time and be taken to a series of location provides the opportunity to decide their own future and also to observe the consequences of their choices. They look into the near future and how the imminent energy transition will affect people who appear to be caught up in an energy conspiracy. The users have also the opportunity to broaden their perspective by listening to the experts and of course by observing the consequences of their decisions. For this study, students will work in groups each one on their own computer in order to confront the challenges communicating face to face with other classmates (a small number of students).

This paper describes the role of dialogical interactions and transmedia storytelling in learning English as a foreign language. In particular, we are interested in the way Greek learners of the 11th class interact when using the multiple platform of transmedia storytelling “Collapsus”(Figure 1), cooperate and express themselves to create meanings in the English language regarding issues surrounding global energy politics.

More specifically, we will present findings concerning dialogical interactions and development of communicative skills (speaking, listening, writing) as well as the impact of transmedia storytelling in creation of notions between foreign learners of English when trying to resolve challenges regarding global energy politics. The mission of the groups is coping with common challenges in the interactive game of the platform and applies their scientific knowledge.



Figure 1. Collapsus

THEORETICAL FRAMEWORK

As Rosenbaum et al. (2007) state, the factors that constitute computer games effective, are the motives they provide as well as the creation of a context in which students experience that their actions affect the outcome of the game. Nowadays, several digital games can contribute to the construction of an appropriate context of social exchange, interaction and work in groups among players by offering multimodal channels of communication, collaboration and experience (Williamson & Facer, 2003). It is argued that digital games can assist in the generation of new meanings since they are objects that represent particular ‘realities’ (Gee, 2003).

According to Jenkins et al.(2009), foreign language learning is intensified through a transmedia storytelling process as well as the creation of meaning beyond language through the building of a digital story. Based on the theory of convergence culture (Jenkins, H. 2006), convergence is defined as the elimination of distinctions between media. Thus, the different media platform uses are not isolated but related so the player does not focus on specific characters and plot but on an entire imaginative world. This link between those media makes games of transmedia storytelling interesting and cause students to learn more and explore the game in depth, since they become part of the story, experience and understand in order to succeed in the game. The main characteristic of transmedia storytelling and interactive games is the increased engagement and thus the experience becomes more meaningful and fun and creates a unique learning environment through which students become able to export information and incorporate them into their cognitive structures, developing their mental models. Moreover, through this platform incidental learning concerning the English language occurs. As noted, every time someone plays a game, learning occurs constantly either they know it or not (Prensky, 2002).

The concepts that trigger dialogical interactions in the English language are imagination, challenge and curiosity. Challenges are incorporated in the interactive game of the platform. Students communicate face to face and attempt to find solution to the problems. They select types of energy and they take into consideration their attributes and their relationship between them. The imaginative game content through the challenges and the movie/animation, intensifies the excitement of the players and the challenges to be overcome make players active. The social activities of play are considered of prime importance for the development of the imagination of children to Prensky (2009). At the same time Prensky (2001), calls attention to the fact that the game requires response and engagement from the players as well as active participation.

The solution of the challenges in our study will be in groups since we talk about complex issues both in nature and in resolution. The form of collaborative groups is supported by many science educators (McNeill et al.2006) as a way to promote more effective scientific argumentation in a context of challenges. It is also worth noting that this kind of games aim to different types of learners and the cooperation between them is essential to understand the story (Jenkins, 2007).

AIM AND RESEARCH QUESTIONS

The present study takes its point of departure in the assumption that using a multiple platform of transmedia storytelling new conditions of dialogical interactions between learners of English as a foreign language when trying to resolve scientific problems and when trying to face to face communicate are created. The next important assumption is that transmedia storytelling like animation, film and documentary (Figure 2), creates authentic conditions of learning English as a foreign language as well as the ability to make learning a natural experience.

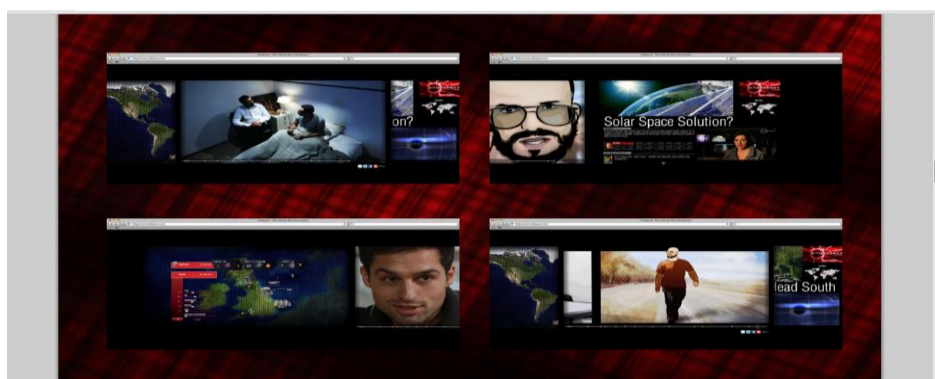


Figure 2. Multiple Representations

Within this conceptualization, the underlying aim of this study is to examine how Greek learners of English are involved in a digital game, named Collapsus, which uses a specific context as well as how they communicate and learn about global energy politics in the English language in their attempt to make choices and decisions and to apply their scientific knowledge collaboratively, and in the process of making their understanding explicit.

This design-based study explores three research questions:

- At what extent do dialogical interactions influence the development of communicative skills in English as a foreign language?
- In what ways does a multiple platform of transmedia storytelling when integrated in a learning environment influence the development of communicative skills in English as a foreign language?
- At what extent do the different media of transmedia storytelling lead to the creation of meanings about global energy politics and cause the engagement and the collaboration of foreign learners of the English language?

FRAMEWORK FOR THE ANALYSIS OF THE DIALOGICAL INTERACTIONS

Taking into consideration the theoretical framework presented before, we will discuss the framework which we constructed in the context of this study in order to analyze the dialogical interactions and generally the moves between the students developed in the pilot study.

The types of dimensions of most interest to us we assume that will be included in the learners discussions in their attempt to resolve the challenges of the interactive part of the game will be different

and are connected to the English language, collaborative learning, digital game. These three different dimensions will be considered in the present study.

METHODOLOGICAL RESEARCH-PROCEDURE

The main aim of the methodological consideration in this study has been to find a research method that focuses on, and make it able to examine the influence of transmedia storytelling when integrated in a lesson of English as a foreign language. In order to come close to the research questions discussed before, the participating students were given opportunities to consider and interact about global energy politics as well as reflect upon their final decisions regarding the global energy production of different countries.

More specifically, this study took place in an 11th grade class located in Athens. There was a small number of students because we were interested in the detail in order to draw conclusions for this kind of technology used in learning. In order to collect data we chose to record the moves of students through camstudio. The participatory observation as well as the narrative report students wrote played an important role. We selected this particular class because they did not have any experience with this technology used in learning before. However, they had used digital games and generally computers much to this point.

This study was designed to engage students in scientific matters of energy and to communicate in the English language. Central to this perspective was the comprehension of the complex issues around global energy politics concerning both the causes and the solutions. We selected those students to work in groups in this study because we wanted to interact face to face in order to cope with the common challenges of the game. The students had to complete several tasks from a worksheet given meanwhile as well as after playing in the platform. Clearly, the students after familiarized with the platform, should discuss face to face, express their ideas and explain their moves in order to resolve the challenges of the interactive game.

RESULTS

One important aim of this study is to analyze and describe in what ways this transmedia storytelling platform influences learners of English as a foreign language to be involved in dialogical interactions so as to develop communicative skills in English in order to resolve important challenges. This means that the aim is to describe to what extent are the different media able to help foreign learners of English to create notions about global energy politics as well as to engage students to cooperate in English.

The analysis revealed that the students, to a considerable extent, in the initial phase of this study communicated a lot with each other in order to find out the topic that was presented in the platform. What is more important to highlight in this point is that learners were able to communicate sufficiently in the English language using either scientific concepts on the basis of a relevant scientific language used the platform or everyday words. At the same time they managed to improve their communicative skills, since they correlated properly the questions with the answers, comprehended, expressed their opinion, mostly expressed different opinion after the interaction as well as created meanings in the English language concerning the concepts of the game.

On many occasions learners communicated in order to share their ideas and personal views regarding the changes in the variable values they thought appropriate to lead to the solution of the challenges. It furthermore became obvious that some students chose also to communicate during the film-animation as well as during the documentary regarding information that drew their attention as well as before completing several tasks in a worksheet given. This indicates that the information presented in the game led learners to interact with each other.

At the same time the analysis also showed that learners were able to use certain scientific concepts presented in the platform in a relevant and concise way. Most of the students as far as the digital platform is concerned, seemed to appreciate this game, since they characterized it as interesting, entertaining and full of motives and useful information. As also evidenced they did not confront any problem regarding the screen interface and the function of the platform. More specifically regarding the interactive game (Figure 3), students navigated and defined the challenge, analyzed the data presented, the requested, options, selected, changed the values of the options, decided and completed the changes, analyzed the results and reviewed. Based on the observation, we noticed that learners took advantage not only the film and the animation but also the documentary (Figure 4) as far as the multiple representations of the platform are concerned. On the other hand, students most of the times skipped the mini-games included in the film after spending some time trying to manage them.

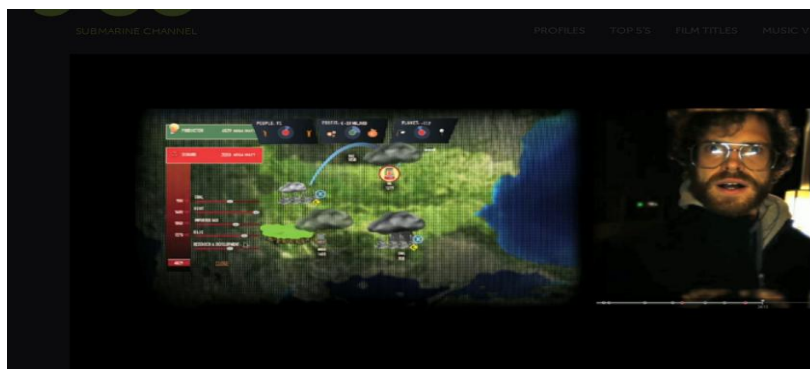


Figure 3. Interactive game

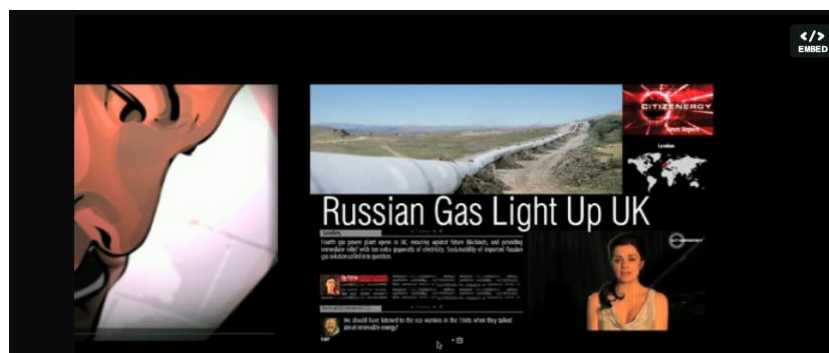


Figure 4. Documentary

A final observation notes that learners focused mostly on the challenges of the interactive game of the platform. Our observations concerning the promotion of collaborative learning through this platform suggest that students' dialogical interactions mostly included information, justification, request for evaluation, research, answer, evaluation, after-statement, agreement.

CONCLUSIONS

The results of the analysis suggest that the interactive game was the tool of the platform that challenged learners the most in order to interact and communicate in English. More specifically, this tool led to the expression of various opinions concerning science concepts in a contextualized and complex problem solving situation making the discussion creative. Another important implication is that even though interactive game caused most of the interactions between the learners, the feedback messages made learners acquire more information about the scientific concepts presented in the game. This conclusion is reinforced by the fact that the film and the animation (Figure 5) caused the excitement of the learners and made the procedure more creative and interesting as well as helped learners acquire information

about global energy politics. Additionally, the results display that documentary was exploited less by the learners, although some information was taken by that. In fact, the integration of transmedia storytelling created learning conditions of English as a foreign language similar to those of the target country.

Overall, we argue that the use of the multiple platform Collapsus contributed to the effective interactions as well as exchanges of opinions between the members of the groups which were crucial for resolving the challenges and subsequently for developing and improving their communicative skills in the English language. Concretely, the students of our study communicated face to face in order to ask questions, express agreement or disagreement and discuss the changes of the values that were given to the variables to resolve the challenges. We also contend that the opinions expressed were influenced by the interaction of the learners. The research observations indicated that the game created an intense learning situation, where students themselves communicated not only during the process of resolving the challenges but also while completing the tasks about the global energy politics. Their dialogical interactions resulted in the creation of notions with the scientific concepts presented in the interactive game.

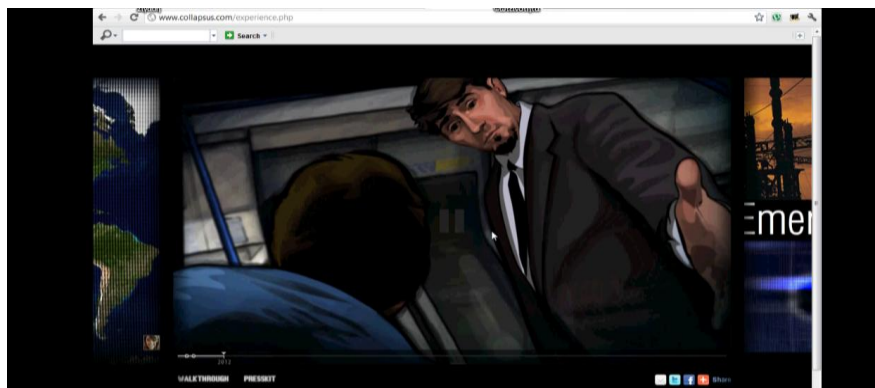


Figure 5. Film/Animation

DISCUSSION

As a final conclusion of this study, we argue that transmedia storytelling actually can contribute to create meaningful learning situations in English classrooms concerning science and can constitute important means that may facilitate learners to promote effectively the involved abilities presented above as well as make students use of scientific concepts of the platform explicit. We also contend that in this framework the vast majority of students used for this study developed their ability to ask appropriate questions and respond properly. This statement resulted in the development of communicative skills in English. Furthermore, they attempted and managed to discuss possible choices about global energy politics, investigate their moves, the consequences of those choices and draw conclusions using a technology-based learning environment. However, one implication for future studies in this field could be to use e-learning tools in order to analyze and describe how students actually act, how they apply scientific content in action using e-learning tools rather face to face.

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Collapsus: VRPO digital, Submarine channel

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LEARNING TO LEARN SCIENCE TOGETHER

Z. Smyrniou, R. Evripidou

ABSTRACT

The Metafora project offers a pedagogical proposal based on online social learning to address such challenges as the decay of Mathematics and Science teaching and learning in Europe. During our Pilot study we examined the role of the platform's tools in assisting students' engagement in meaning generation processes as regards motion in a 3d Newtonian space. Moreover, the tools' role seemed promising in promoting collaboration and metacognitive skills such as planning. Nevertheless, further research is needed regarding the potential of the platform's tools to enhance the learning climate with an emphasis in collaboration which seems to be missing from our schools.

KEYWORDS

Learning to learn together (L2L2), inquiry-based learning, modeling, science, constructionist learning, visual language

INTRODUCTION

The Metafora project, based on the Learning to Learn Together (L2L2) pedagogical concept, builds on Learning to Learn by shifting the focus on group, social, collaborative rather than individual learning. The use of the online platform's tools supports challenge-based learning, modeling and the constructionist approach in teaching and learning.

This qualitative study examines the role of these pedagogical tools in helping students engage in meaning generation processes regarding scientific concepts and methods. In our Pilot Study, 13-year-old students, with very limited prior knowledge of Physics, were asked to solve an open-ended challenge using three of the platform's tools.

They explored and built models of 2d and 3d motions and collisions, (de)constructing the 3d Newtonian space of the 3D Juggler microworld. It gave students the chance to operate in a complex, fun and engaging domain, working with complex 3D space concepts such as Azimuth, as they collaborated to address the challenge developing communication, strategic thinking and problem solving skills needed to build scientific meanings and concepts.

In Lasad, the platform's argumentation and discussion workspace, the students discussed their findings, negotiated and arrived at an agreed solution. Unlike common Web 2.0 social networking sites, Lasad helped them organize their learning and disseminate educational content, enhancing those social skills that pertain to intellectual growth.

To address the challenge, they collaboratively produced a plan of actions using the Planning tool. This plan, evidently demonstrating the use of the scientific method, helped them accomplish their tasks and provided valuable feedback for metacognitive, self-regulatory reflection.

Despite our findings regarding the role played by the tools in enhancing students' scientific meaning making the study showed that collaborative learning needs to be further cultivated in our schools before

the students can fully exploit the potential of these tools. Moreover, it seems that the fact that there were too many cards available for them to build their plan was rather confusing. This fact coupled with the limited time available for familiarization with the tools rendered it difficult for the students to cooperate as efficiently as was hoped.

THEORETICAL FRAMEWORK

Modeling has proven to be of great importance in enhancing students' reasoning and understanding of scientific concepts. Moreover, it is an inquiry-based learning process which coupled with the use of technology based educational tools can further contribute to this enhancement. These technology based tools can offer students the chance to explore, design and build personally meaningful computer models through which they realize their own conceptualizations and ideas as far as the scientific quantities and concepts studied are concerned. They have the chance to test their ideas using their models according to the constructionist approach. When created in collaboration with their peers, these models become the subject of discussion and reflection, a process which leads to further understanding of the scientific phenomena which lie behind them.

In our time and age computer gaming is a prevailing habit among students and an integrated part of their daily routine and interests. Game microworlds, specially designed to engage them in the study of academic subjects, take advantage of this reality in order to offer students the chance to learn in a way that is fun and familiar to them. Half-baked microworlds, as is 3D Juggler microworld, the one our students worked with in our study, are incomplete by design in order to work as idea generators and vehicles of scientific meaning making (Kynigos, 2007). This happens as the students using them can explore and (de)construct them according to their understanding.

Planning consists one of the three phases of cognitive regulation (along with monitoring and evaluation), and an element of self-regulated learning (SRL). As such, planning in science may be associated with the process of problem solving and in any case is a general domain metacognitive skill. There have been many research studies which have examined the self-regulated learning in a cognitive and social cognitive perspective. It is a process whereby learners think about their thinking (metacognitive process), take action in a strategic way (plan, monitor, evaluate personal progress) and therefore are motivated to learn. Emergent planning is of particular importance for researchers in the context of constructionist environments (Yiannoutsou et al., 2011). It is also considered a key tool which can guide students solve complex problems by finding strategic solutions (HUJI, Baruch). It is also seen as a means of representation, reflection, expression, communication and self-regulation.

In Physics we are particularly interested in what students learn as regards the scientific content and the scientific language besides problem solving. As far as scientific content knowledge is concerned, we know from relevant research that the scientific meaning making depends on the intuitions, the initial representations of students, the phenomenological descriptions, the descriptions of actions or events perceived as concepts and relationships between them.

RESEARCH QUESTIONS

The following Research Questions were examined in the study:

- What is the impact of the Metafora Platform/learning on students' ability to conduct science inquiry & constructionist and overall, modelling and to use the inquiry skills of questioning, planning, implementing, constructing a model, concluding, arguing and reporting?
- What is the impact of the Metafora tools in orchestrating learning to learn together (L2L2) meaning generation processes and, more specifically, Physical concepts and scientific methods?

RESEARCH METHOD-PROCEDURE

Use of the Metafora tools

After the short presentation of the tools, our students were given the Research Protocol (worksheet) with the warm-up and main challenges and were asked to “play” in the 3d Juggler microworld in order to familiarize themselves with it and be able to face the warm-up challenge first and the main challenge afterwards. They could use LASAD as a communication tool in order to discuss with the other subgroup of their team any issues needed in order to solve the challenge together. We briefly presented the discussion cards included in it. We emphasized that their ultimate mission was to work together on the Planning tool so as to present the plan they would follow in order to solve the challenge and showed them the different cards they could use in it to make their plan.

The two subgroups’ work stations were far enough from each other so as to exclude their face to face interaction and to make the use of LASAD and Planning tool necessary for their communication.

Warm-up and Main Challenge stages:

- Warm up: “Keeping the blue and the green balls still, shoot the red ball vertically upwards”.
- Main Challenge: “The balls should hit each other’s base in a circular manner” (e.g. the red ball should hit the blue ball’s base etc.)



Figure 1: The 3D Juggler microworld

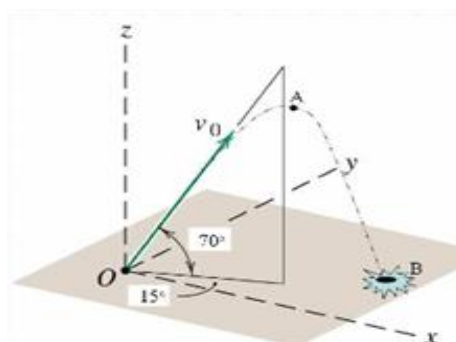


Figure 2: The role of the “Shot Altitude” and “Shot Azimuth” angles (70 and 15 degrees respectively in the drawing below) for the direction of the ball.

Data collection

The corpus of data includes a record of the students' interactions with the digital tools as well as their verbal interactions as they worked together with the use of screen-capture software, as well as audio files from voice recorders, the students' answers to the worksheets, their maps in Lasad and in Planning Tool and the researchers' field notes.

Description of the setting and participants in the pilot study

This study took place in a public school, the 2nd Experimental Junior High School of Ambelokipi Athens.

The students who participated in the pilot study were four 13-year old Junior high School students at their second grade, with very limited formal prior knowledge in Physics as they had not been taught kinematics and projectile motion yet.

Four teachers/researchers took part in this phase of the study. The researchers' intervention was as limited as possible with the intention of letting students work independently. In this way they were given the chance to discover for themselves how to manipulate the 3D Juggler objects and variables and build their communication using Lasad and the Planning tool without any external influence. However, the students had to be oftentimes reminded to use Lasad, the discussion tool, to inform the other subgroup of their findings, progress or planned moves. The researchers' intervention was more obvious than it was planned to be in cases when the students' attention had to be refocused on the given guidelines.

RESULTS

Although the students manipulated the microworld's objects to solve the challenges, in the beginning they did so without really realizing the physical properties and concepts present in it. An example showing this is the fact that they decided to “play” with “gravity pull” (gravitational acceleration) in order to manage to keep the blue and green balls still as asked. One would have probably expected them to work this out in a different way. They were expected to zero the balls' initial velocity by zeroing “power” instead. They also wanted to manipulate “wind speed” and “wind direction” in order to carry the red ball to the direction they wanted instead of using the “power” and “shot azimuth”, “shot altitude” to achieve this goal.

The students seemed confused by the fact that both the “Shot Azimuth” and “Shot Altitude” are measured in angle degrees and therefore couldn't discern which quantity each of them monitors. Moreover, they didn't realize that they needed to isolate each variable, by changing its value and leaving all others unchanged, in order to see which quantity it represents. They finally managed to do so after several efforts and disagreements. It is also evident that the students thought that the mass affects the

range of the shot. We assume this because we see that they change the value of the mass to achieve their goal probably thinking that the lighter the ball is the farther it will reach.

The students were unwilling to build a plan of actions before they really addressed the challenge in the microworld. Their plan was rather a report of actions they took to address the challenge. They communicated through Lasad during their efforts to address the challenge and afterwards in order to build their plan. Their comments on the cards of the Planning Tool show that they had realized the role of the physical quantities in the microworld and more specifically they had worked out that the direction of the ball on the horizontal level was defined by the value of "shot Azimuth", and that the combination of the Shot Altitude angle and the Power (initial velocity) defines the range of the ball. The cards they chose and the order they used them with shows that they approached the scientific method properly (Observe, hypothesize, experiment, conclude, etc.).

The collaboration between the subgroups was not always smooth. Subgroup B ignored subgroup A's comments although they later responded and finally managed to cooperate.

CONCLUSIONS / DISCUSSION

The students had to work with and understand deeper the physical concepts and quantities which have to do with projectile motion in a Newtonian space in order to address the challenges. Due to the fact that the microworld was a 3D environment they were able to generate meanings about simple Physical concepts and quantities e. g speed, power as well as complex ones e. g Azimuth. The students engaged in the (de)construction of the microworld while at the same time they were offered open-ended challenges. Their approach to the challenges was creative and alternative. For example, when one of the subgroups managed to address the challenge by making the red ball hit the blue ball's base following linear motion on the horizontal level, they decided to reject it because they didn't consider it spectacular enough. They wanted to make it "fly" towards the target (projectile motion), which they eventually achieved.

The two subgroups were led to reconciliation and collaboration after they had erased each other's cards on their Planning tool map and destroyed the whole map. They rebuilt their plan together and started all over from the beginning. This incident shows that the tools rendered their collaboration absolutely necessary and gave them the chance to realize its importance.

They gained deeper understanding of scientific concepts and the relations between them by experimenting with motion in the 3D Newtonian space of the 3D juggler microworld's environment.

Consequently, they had the chance to Learn to Learn Together (L2L2): how to collaborate, how to plan their moves, how to argue, scientific concepts and physical quantities, scientific methods and approaches

Nevertheless, there are some findings that pose questions and considerations as regards possible changes and improvements to be employed in the future main study:

First of all, the students seemed reluctant and unwilling to share their findings with their mates and in many cases did so only because they were asked to do so by the researchers. The admittedly great number of cards in the Planning tool seemed to cause confusion about which of them to use to construct their plan. They could not plan their actions ahead before actually experimenting and addressing the challenge first. They used the same cards repeatedly and in some cases, added text the content of which was irrelevant to the cards label.

Taking the above into consideration, we will have to address these issues in the future main study by taking the following steps:

We will allocate more time for the familiarization session during which we will give students readymade sample models of both argumentative discussions and plans in Lasad and Planning Tool respectively. This will hopefully help them realize the use of each card in them. The issue of collaboration and feeling comfortable with sharing questions, findings etc. with others may also have to do with the lack of a school culture of collaboration. Admittedly, our schools encourage competitiveness more than collaboration. This fact makes it even more necessary and urgent to introduce such tools as the ones our study presents, in order to help emphasize the need for collaboration and togetherness in learning.

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DESIGN OF AN INNOVATIVE ON-LINE INQUIRY-BASED LEARNING ENVIRONMENT FOR "ANTIBIOTIC RESISTANCE OF BACTERIA"

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ABSTRACT

This paper reports on an ongoing research project that focuses on the design, development, research-based validation and refinement of an on-line inquiry-based learning environment. This learning environment is situated in a topical socioscientific issue, namely antimicrobial resistance, and is intended to promote, in an integrated manner, reasoning skills (argumentation skills) and conceptual understanding of fundamental ideas pertinent to this issue. In this paper we seek to describe the rationale underlying the project and provide an outline of the learning environment, its learning objectives and the technological tools it embodies.

KEYWORDS

Collaborative inquiry learning environment, socio-scientific issues, argumentation

INTRODUCTION

Socioscientific issues are becoming a common and significant component in modern societies (Sadler, 2004; Sadler & Zeidler, 2005). These issues typically integrate scientific, technological, and social dimensions and tend to generate dilemmas at a personal level or controversies at a more global level. Socioscientific issues hold an important role in science education in two ways. First, the ability to effectively deal with such issues (e.g., by following the public debate and formulating an informed position with respect to how those issues are tackled) is considered a vital skill for citizenship and a significant learning objective of science teaching (AAAS, 1993; Aikenhead, 1985; Bybee, 1987; Jenkins, 1994; NRC, 1996). Second, socioscientific issues are considered to provide an effective and productive organizing theme for science teaching. In this paper we report on a research project aiming to develop a research-validated, on-line learning environment that demonstrates both roles of socioscientific issues in science teaching. The learning environment is focused on a topical socioscientific issue (i.e., antibiotic resistance of bacteria) and is intended to promote, in an integrated manner, two learning objectives. The first includes conceptual understanding of fundamental ideas pertinent to this issue (e.g. bacteria, viruses, immune system and antibiotics). The second the development of argumentation skills; this is considered an important aim of science teaching, directly related to the objective for the development of the ability to productively engage with socioscientific issues. In this paper we briefly outline the rationale, the objectives and the main components of this project.

Background

The project draws from four main research areas, namely Socioscientific Issues (SSI), Argumentation, Computer Supported Collaborative Learning (CSCL) and Design Based Research (DBR). SSIs have acquired a central role in science teaching. They could serve as organizing themes for designing teaching/learning activities that could promote, in an integrated manner, significant learning objectives

of science (e.g. conceptual understanding, reasoning strategies and understanding of NOS). At the same time, organizing science instruction around topical SSIs could also serve to address important challenges relevant to science teaching, including, for example, the lack of relevance to students.

Argumentation is an essential skill, which constitutes an important objective of science teaching (Jiménez-Aleixandre, & Erduran, 2007). However, despite this wide recognition, this learning objective does not typically receive systematic, explicit attention in science teaching. This, in conjunction with research findings illustrating, first, that argumentation skills do not emerge spontaneously (Kuhn, 1992; Hogan & Maglienti, 2001), and, second, that providing students with sufficient opportunities to engage in argumentation in a systematic manner could indeed lead to substantial learning gains in this respect (Kuhn, 2003), underscore the need for further research on the development of relevant teaching innovations.

Computer Supported Collaborative Learning is an emerging educational paradigm that, in its simplest form, studies how computers contribute to peoples' learning. The term CSCL emerged by combining two ideas, technology-enhanced learning and collaborative learning. CSCL research focuses on the development of learning environments that facilitate the collaboration around and through computers (Lehtinen, 2003). Learning around the computer is based on the interaction between the teacher and the students and among the students. Students learn by posing questions, supporting each other and exploring each other's reasoning. On the other hand, learning through the computer refers to the interaction among students through the various online tools that web-based environments accommodate. It is widely believed that CSCL has the potential to support teaching innovations purporting to help students engage with inquiry (Bell et al., 2012; Stahl et al., 2006)

The project draws on the paradigm of *Design-Based Research* (Brown, 1992). Design Based Research Collective (DBRC) (2003, p.5) characterizes design based research as a research paradigm that "blends empirical educational research with the theory-driven design of learning environments". DBR offers many advantages compared to other methodologies (DBRC, 2003). Firstly, DBR addresses and solves practical problems through successive enactments of the intervention, thus providing a mechanism for bridging the gap between research and practice. Furthermore, DBR utilizes mixed methods to analyze an intervention's outcomes and refine the teaching material. Recently, researchers in educational technology argued in favour of design based research to support the development of technology based innovative learning environments (Reeves et al., 2005; Wang & Hannafin, 2005).

Overview of the project and its objectives

The aim of the project is the design, development and validation of a web-based learning environment based on open inquiry. The learning environment is situated in the topic of antimicrobial resistance and is targeted at students aged 14-16 years old. The learning environment will be developed using the web-based platform STOCHASMOS. The collaborative inquiry based learning environment is seeking to promote combined (a) reasoning skills and (b) understanding of basic concepts.

The project will be implemented in three stages. The first stage is concerned with the formulation of the theoretical background that will support the initial design of the teaching/learning material and the design or adaptation of the assessment tools. Thus, the first phase is the critical review of the available literature to determine the existing knowledge in relation to a) teaching and learning approaches regarding the learning objectives of the project (cultivation of argumentation skills and conceptual understanding (e.g. microorganisms, the immune system, antibiotics, etc.) b) appropriate tools for assessing students' attainment of the learning objectives and c) design principles for the development of web-based collaborative learning environments. The second stage involves the design and development of the inquiry learning environment and the design (or adaptation) of the corresponding assessment tools. Regarding the development of the inquiry environment, information from the literature originating from authentic scientific debate will be incorporated in the environment after they have been modified to make them suitable for processing by high school students. The third and final stage involves the evaluation and refinement of both, the learning environment and the assessment tools. The evaluation will be based on two cycles of implementation- evaluation and refinement in authentic

classroom environments. During each cycle, we will collect empirical data on students' learning gains, using the assessment tools, so as to, firstly, explore and document the potential of the learning environment to promote the learning objectives it has been designed for and, secondly, guide the refinement of the learning environment by indicating aspects that do not seem to function effectively.

Summarising, the general objectives of the project include:

- the design, development, evaluation and refinement of a collaborative inquiry learning environment, investigating the topical SSI of “antimicrobial resistance”
- the development (or adaptation of existing) assessment tools for investigating students achievement and for evaluating the learning material
- the study of the effect of the implementation of a web-based collaborative learning environment based on open-inquiry of a SSI in the development of evidence-based argumentation.

The socioscientific issue under consideration

Antimicrobial resistance presents a topical socioscientific issue that has received much attention within the scientific community (Salysers & Whitt, 2005; Wax et al., 2008). The increasing number of casualties reported in the last decade due to the resistant mutations of bacteria has brought the problem at the centre of attention of the scientific community (physicians, drug researchers, etc.) stakeholders (e.g. pharmaceutical industries, health agencies) but also (to a less extent) lay people, more broadly. Specifically, in 2011 the World Health Organization (WHO) decided to devote the World Health Day (celebrated on 7th April) to “antimicrobial resistance and its global spread”. In spite of the actions taken so far (e.g. mostly by Non Governmental Organizations), the general public appears to have limited knowledge regarding this issue and the possible solutions.

Furthermore, antimicrobial resistance is a subject of great interest to Cyprus, which happens to be the second country in the European Community in antibiotic consumption (ESAC, 2009), one of the main factors contributing to the development of resistant bacteria. Hence, antimicrobial resistance seems appropriate and relevant for the context of Cyprus.

Finally, the issue of antimicrobial resistance offers the advantage of the combined development of conceptual understanding and argumentation skills. The scientific content covers concepts from biology and chemistry (e.g., microorganisms, immune system, antibiotics and function of antibiotics). Students also have the opportunity to explore real scientific data (often presented in a simplified form), organise and evaluate them, using higher order cognitive skills. At the same time, they explore the social, economic and environmental implications of the problem.

Overview of the learning environment

The design of this on-line learning environment largely relies on two tools that have been developed by our research group, STOCHASMOS⁹ and SCHEDIA¹⁰. Stochasmos is a web-based learning platform intended to host on-line, inquiry-based, data-rich, problem-based learning environments. Stochasmos platform was created to support and promote inquiry and self-regulated learning and accommodates a plethora of tools for this purpose. The platform consists of two main environments: a) the inquiry environment and b) the reflective WorkSpace environment. The platform also enables synchronous and asynchronous communication through other spaces, the ‘Workspace Sharing’, the Forum and the chat tool.

Studies have shown that students have difficulty in understanding what constitutes an explanation in science and to back-up their explanations with evidence (Sandoval, 2003). Stochasmos scaffolding and reflection tools such as hints (added on demand in the inquiry environment by the designers to guide

⁹ Stochasmos was funded by the Cyprus Research Promotion Foundation (grants SYNERGASIA and STOCHASMOS) and the European Commission (grants CoReflect and Reflective Inquiry) (www.stochasmos.org)

¹⁰ Schedia was funded by the Cyprus Research Promotion Foundation (www.schedia.org)

students' investigation), the data capture camera (students can capture segments of data and organise them as they judge fit in the Workspace environment; helps students to collect, organise and evaluate data), the notebook (students keep notes during their investigation, it is accessible from both environments, inquiry and workspace) the template pages (space customised by the designers with articulation prompts and data-storage areas; help students externalise their thinking and build consensus and to link evidence to claims), etc help students in handling, interpreting and evaluating data but also in constructing explanations and backing them up with evidence.

Schedia is an on-line environment intended to support and facilitate teachers in developing learning environments using Stochasmos (even though it could be also used independently of Stochasmos). To support teachers in this process the environment provides various tools in the form of on-line applications. The key tool is the Design Guide, an interactive step by step sequence for the development of inquiry learning environments. This tool provides a theoretical framework to guide teachers/designers through the complex process of design and development of inquiry learning environments. The purpose of this guide is not to restrict the designers but rather to propose certain principles that underpin inquiry-based learning design. The theoretical underpinnings of inquiry-based learning integrated in Schedia are: a) students learn from each other (Vygotsky, 1978), b) learning is an active and reflective process (Bell & Linn, 2002), c) learning is situated in inquiry-oriented frameworks (Chin & Malhotra, 2002) and d) students need appropriate scaffolding to accomplish complex tasks (Quintana et al., 2004). The design process is also supported by a series of reflection tools, such as the Reflection Comments, the Reflection Diary (both serve the same purposes, clarification of ideas and reflection) and tools for the asynchronous communication of the members of the design group, the Reflective Wall (comments, notes, reflections can be made public through this application) and the Forum.

The 'inquiry environment' of the 'bacteria resistant to antibiotics' learning environment will be structured under the following four headings (tabs), namely 1) Your mission 2) Communication Campaign Strategies 3) Antimicrobial Resistance and 4) Information Library. The last three tabs are not intended to be processed by students in a sequential manner. Instead they are expected to move back and forth between these tabs, as they see fit with their purpose and goals. The mission page, at the very beginning will present the discovery of a new superbug strain of gonorrhea, which is resistant to all known forms of antibiotics. The presentation of the case of the new strain of the sexually transmitted disease is expected to stimulate students' interest. Then, students will engage in a scenario and they will have to undertake the role of employees at a local campaign office and organise a campaign targeting at communicating the main issues associated with antimicrobial resistance to stakeholders (e.g. physicians, pharmaceutical industries, etc.) but also to the general public. In preparing for this campaign, they are expected to formulate claims, justify them with appropriate evidence-based reasons, anticipate possible counterarguments and prepare corresponding rebuttals. Under the second tab, entitled 'Communication Campaign Strategies', students will find information on how to lead a successful campaign. The third tab contains a rich set of data associated with the main aspects of the discussion taking place within the scientific community on antimicrobial resistance. This information will be presented in diverse forms, including textual, graphical, tabular etc. Students will have to process the information so as to organize it and identify evidence they could use to support their claims. Finally, the last tab is intended to help students appreciate the main ideas relevant to the subject matter of microbial resistance. Thus, this tab will include fundamental conceptual ideas drawn from biology and chemistry (e.g., bacteria, viruses, immune system and antibiotics). As students will go through the data under the 'antimicrobial resistant' tab they will have to refer to the 'information library'. While reviewing and processing the information in the various tabs, students will be scaffolded through specially designed template pages. These templates will be pre-structured forms to be completed by students. Their structure is intended to help students organize the information they identify in certain ways and draw important distinctions (e.g. between evidence and claim)

DESIGN, DEVELOPMENT, IMPLEMENTATION & EVALUATION

As already mentioned, the design and development of the inquiry learning environment will take place in two distinct web-based environments, Schedia and Stochasmos. An initial version of the learning environment will emerge as the result of the combined efforts of science teachers and science education researchers, in an attempt to bridge the gap between theory and practice. Stochasmos has hosted in the last few years a number of inquiry based learning environments and our aim is to extract all the valuable elements; to take into account in our design the results produced in previous research efforts. The inquiry based environment will employ various scaffolds to help students overcome inquiry challenges (Linn, 2003). The content of the inquiry environment will include scientific data from multiple sources and forms (text, graphs, tables, etc.) which will be adapted to be suitable for interpretation by high school students. Students should explore, explain and demonstrate, based on interpretation of available data, the phenomenon of bacterial resistance to antibiotics.

Following the DBR framework, the initial version of the learning environment will be implemented in real classroom settings. The findings from the first implementation will feed back to the process of the refinement of the learning environment. The design, implementation, evaluation and refinement cycle will be repeated once more to produce a refined version of the learning environment. During each implementation, we will collect video data from students while working in their groups so as to analyze a) students' interaction with the learning environment and b) students' social interaction inside the group and between groups. Additional data will be collected using assessment tools, which will be decided after reviewing the relevant literature. The assessment tools will include activities in order to evaluate students' conceptual understanding and development of argumentation skills. For the analysis of the collected data a combination of qualitative and quantitative methods will be used.

IMPORTANCE OF THE CURRENT STUDY

The primary objective of the project includes the development of a web-based collaborative learning environment. The learning environment will feature an authentic problem, the contemporary socioscientific issue of antimicrobial resistance. The learning environment will be rich in authentic data that will have to be processed and synthesized by the students in order to formulate valid arguments. Furthermore, the teaching /learning approach used will be based on the involvement of students in structured argumentation at different levels, (individual students, group of students and between groups). The requirements mentioned above are directly related to the needs and challenges faced by science education in the modern society, including explicit teaching for the development of argumentation skills and processing of socioscientific issues. In addition to the development of an innovative teaching material that satisfies the above requirements, the current study is expected to enhance the existing research on the teaching and learning of argumentation skills in the context of SSI.

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A WEB-BASED LEARNING ENVIRONMENT ON GLOBAL WARMING FOR THE DEVELOPMENT OF ARGUMENTATION SKILLS

Elena Siakidou, Nicos Papadouris & Constantinos P. Constantinou

ABSTRACT

Argumentation holds a central role in Science Education and has attracted much attention in the research literature. We set out to design and evaluate a learning environment for promoting argumentation skills. In this paper we seek to explore the impact of a web-based learning environment on students' argumentation skills. The study sets out to investigate the extent to which high school students are able to effectively engage in argumentation and to what extent this can be improved through a specially designed learning environment, on the STOCHASMOS platform. The learning environment was situated in the context of global warming and the debate regarding what causes this phenomenon (human activities or natural processes). We have used the learning environment to guide the teaching intervention in one high school classroom. Participants were 23 students aged 15-17. The intervention involved 12 (110-minute long) sessions. We collected data on students' argumentation skills through written-open ended tasks administered prior to and after the enactment. The findings suggest significant improvements in students' ability to engage in argumentation.

KEYWORDS

Argumentation, web-based learning environment, STOCHASMOS platform

INTRODUCTION

Argumentation is an important aspect of scientific reasoning. The ability to engage in argumentation is widely recognized as an important skill for citizenship and also a significant learning objective of science teaching (Erduran, Simon, Osborne, 2004; Jimenez – Aleixandre, Rodriguez & Duschl, 2000). The ability to effectively engage in argumentation over a socioscientific issue posits conceptual understanding with respect to the main ideas involved (Jimenez-Aleixandre et al., 2000) but also skills associated with formulating convincing arguments and critiquing arguments made by others (Erduran et al., 2004). Argumentation has attracted much attention in science education research literature because it constitutes an important educational goal while it could also serve to provide an effective instructional context (Osborne, Erduran & Simon, 2004). Despite the important insights that have emerged so far, there is still a need for more research on the development of teaching innovations for integrating this learning objective in science teaching environment. The present study is directly related to this need; it sets out to design and evaluate a learning environment for this purpose. Specifically, this study focuses on the design of a learning environment for promoting argumentation skills in the context of a topical socio-scientific issue, namely global warming.

THEORETICAL BACKGROUND

Argument and argumentation in Science Education

Argumentation holds a central position in the development and justification of scientific claims and, hence, the evolution and elaboration of scientific knowledge (Driver, Newton, Osborne, 2000). Kuhn and Udell (2003) stated that the argument is used as a product, which refers to the results where an

individual or a group of people are asked to justify claims, whereas argumentation refers to the process of constructing arguments. Argumentation is a social, intellectual activity serving to justify or refute an opinion. In general, argument describes students' artifacts with which they justify their claims and argumentation refers to the complex process of constructing those artifacts (Osborne et al., 2004).

The ability to generate persuasive and convincing arguments to support or to refute an explanation of a phenomenon is an important component of Science Education since a goal of scientific inquiry is the formulation of evidence-based justifications. Research points to the importance of designing specific learning environments to establish students' argumentation skills.

Research questions

- To what extent are high school students able to effectively engage in argumentation, without prior instruction?
- To what extent can we help students improve their ability to engage in argumentation through a specially designed learning environment?

DESIGN LEARNING ENVIRONMENT

Platform of STOCHASMOS

STOCHASMOS is a web-based learning platform for supporting students' scientific reasoning through authentic investigations with an embedded authoring tool. The authoring environment can be used for creating learning environments, to customize reflective templates for the Workspace, to engage in embedded assessment (synchronous, asynchronous feedback) and to collaborate with other teachers. The learning environments built on this platform consists of two main parts: the Inquiry Environment and the Reflective Workspace environment and focus on reflection during inquiry, student collaboration, interpretation of primary data and finally peer feedback. Overall the main goal is to scaffold students' learning helping them to organize their investigations and to make their thinking visible.

Scaffolding

The term *scaffold* is used to refer to the support provided to students for performing certain tasks. This, for example, could take the form of a hint that could focus students' reasoning on certain aspects. Another common type of scaffold involves the provision of a structure for certain tasks (e.g. templates to be completed by students in certain ways). The idea of scaffolding has emerged within the socio-constructivism theory of learning (Vygotsky, 1978) and rests on the idea that, when properly supported, students can usefully transcend what they can do by themselves with respect to tasks such as analyzing the parameters of a problem, gathering information, identifying and evaluating possible choices. STOCHASMOS provides curriculum designers with multiple options in terms of possible scaffolding tools they could be embedded in learning environments developed on this platform. Some of these options include the possibility to develop a glossary and a collection of hints for students, the use of templates, intended to help students organize the data they encounter in the learning environment but also to problematize them on how to interpret them.

Supporting reflective inquiry

The main goal of inquiry-based learning environments on the platform of STOCHASMOS is the reflection. Reflective inquiry encompasses both effective inquiry strategies and reflective activities. Students should be actively engaged in inquiry, asking questions, gathering data, analyzing data, drawing conclusions and communicating results. STOCHASMOS can support reflective inquiry in collaborative learning environments in science and the central role of reflection is to help students engage in critique activities and knowledge integration (Davis, 2003). The learners, who reflect during the inquiry, can incorporate ideas of others, and compose their contributions carefully. Students who spontaneously reflect or explain their ideas learn more and they monitor their own progress in understanding science.

Overview of the learning environment

The Inquiry Environment developed in this study consists of five main tabs (see figure 1). The first tab outlines students' mission ("There is evidence that the climate of the earth undergoes a shift. In the next few weeks we will organize a conference that will deal with the issue of climate change. Your mission is to get prepared for the conference") and introduces the socio-scientific issue that students are asked to address in their groups. In the second tab ("Weather Phenomena of concern") students are expected to review data so as to identify phenomena of global concern in relation to climate change. The third tab ("Parts of the system") includes information for the system's parts, the earth and its atmosphere, the sun and their interactions. Students are expected to appreciate certain ideas relevant to interactions of the various parts of the system. Additionally, they are provided on fundamental background information about the greenhouse effect (the different ways of energy transfer through heat, emphasis on electromagnetic radiation). Students are expected to identify radiation as a main way of transferring energy, appreciate the idea that all bodies emit radiation and to complete the template "Thermal Interactions" emphasizing in dynamic equilibrium. In the fourth tab ("Regulation of Temperature on Earth"), students need to concentrate on the increase of temperature and study information in relation to factors influencing the global temperature. Students, also, elaborate the mechanism of greenhouse effect. Finally, in the fifth tab ("Earth and Climate"), students need to take a position on whether global warming is a natural or man-made phenomenon, in order to construct arguments.



Figure 1. Climate change web-based learning environment

METHODOLOGY

Participants

Participants were 23 students aged 15 to 17 years old. The teaching intervention lasted twelve 110-minute sessions.

Data Sources

The main data source involved two written open-ended tasks, prior to and after the teaching intervention (intervention topic: climate change (CC), transfer topic: cystic fibrosis (CF)). Two

additional data sources that served a complementary role include the teachers' reflective diary (notes) and the templates completed by the students while interacting with the learning environment.

Argumentation Process

Initially, each student had to complete two written tasks (CC, CF) before the implementation (Figures 2&3). These engaged them in constructing arguments, counter-arguments and rebuttals using evidence-based justifications. Then, each student was assigned one of two roles, proponent of either the position that climate change is man-made or emerges as an outcome of natural processes. Prior to and after the teaching intervention, the various pairs engaged in dialogic argumentation on these two topics. Students' discussions lasted up to 20 minutes in each case and were facilitated by the chat tool embedded in STOCHASMOS. Then, students reviewed the data in the inquiry environment and they completed a template. At the end of this step each group was paired to another group and were asked to engage in argumentation (chat 1). The groups of students repeated the dialogic argumentation activity (chat 2) and engaged in a reflective activity using the template "Let's think I". Each group shared the completed template with another group so as to provide and receive feedback. After that, the groups of students' repeated the dialogic argumentation exercise for a third time (chat 3), completed a different template ("Let's think II") and discussed that with another group.

Preparation for the showdown

All students were divided in two large groups, of equal members, depending on the position they were asked to defend. Half of the students in each of these large groups were asked to serve as specialists about the arguments in support of their own position. The remaining half of the students was asked to serve as experts about the arguments in support of the other position.

Showdown

The members of two groups engaged in argumentation, in a structured manner. After the teaching intervention, students had to complete, for a second time, the written tasks which were exactly the same.

Cystic Fibrosis (CF) is an autosomal recessive genetic trait. It is one of the most prevalent genetic diseases. In England and the United States one out of 2000 newborns is affected and one out of 20 people is a carrier.

Cystic fibrosis causes a deficient functioning of the external secretion glands that is pronounced in the production of salty sweat, in digestion disorders, and in the production of large quantities of mucus in respiratory tracts. The mucus causes recurrent lung infections. Each additional infection adds to the long-term damage to the lungs. The disease is therefore lethal: patients rarely survive past the age of 40.

The gene responsible for CF has been located. Scientists from laboratories in several countries are now working on methods for genetic therapy.

Prenatal tests are not always accurate since the proportions of false conclusions vary from test to test. Prenatal tests, also, may cause inflammation, spontaneous abortion, fetal death in 1-3%.

Finally, there may be infections on the mother or on the fetus, such as detachment of the placenta.

Rebecca and Joseph both have brothers whom are sick with Cystic Fibrosis. Rebecca and Joseph got married and Rebecca is now pregnant.

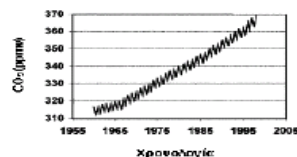
- What would you advise the couple? To do or not the prenatal diagnosis?
- Summarize your basic argument to support your position. Offer reasons for your position.
- Your friend disagrees with you. Define his/her position. Offer reasons for that position (to convince you that he/she is right)
- What will you answer your friend? Explain.

Figure 2. Written Task of CF

You are going to organize a conference in your school to inform your schoolmates about some phenomena that concern us nowadays, such as the ice melting. You are going to engage in a series of activities which will help you to get prepared for the conference.

Expert 1: Supports that global warming is a man-made phenomenon

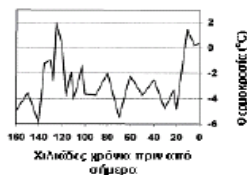
Human activities increase the amount of CO₂ and other greenhouse gases (methane). These gases 'trap' the radiation from the Earth's surface and this has as result the global warming. Some of these gases are useful for human life. However, human activities such as burning coal, oil or natural gas, increase the concentration of these gases, as shown in the graph below.



Graph 1. Changes in CO₂ concentration

Expert 2: Supports that global warming is a natural phenomenon

Climate has always changes. The periods with low temperatures were followed by periods of high temperatures and vice versa (graph 2). During the last decade, the temperature increase only 0,6 °C. These changes have occurred in the past and associated with the dynamic nature of Earth's climate. Data from the satellites do not show that human activity has a significant impact on the temperature. Greenhouse gases such as CO₂ water vapor and methane are main gases of the atmosphere.



Graph 2. Changes in earth's surface temperature

- Is global warming a man-made or natural phenomenon?
- Summarize your basic argument to support your position. Offer reasons for your position.
- Your friend disagrees with you. Define his/her position. Offer reasons for that position (to convince you that he/she is right)
- What will you answer your friend? Explain.

Figure 3. Written Task of CC

Data Analysis

Analytic Scheme for Written Tasks I & II

Students' responses to the written tasks were processed so as to evaluate the extent to which they were in a position to formulate evidence-based arguments, counterarguments (C-A) and rebuttals (R). Counterarguments are arguments that contradict one's original opinion. Rebuttals are arguments that refute the counterarguments. The criteria for the evaluation of the student arguments were: 1) number of evidence-based justifications included in the written responses (table 1) and 2) connection between counterargument and rebuttal (table 2). The analysis drew on a coding scheme developed by Zohar and Nemet (2002), which was adapted so as to fit our data.

Table 1. Criterion 1 and examples of student answers

Number of justifications	Students' answers (CC)
0 = no answer	
1 = only claim	People are the only responsible
2 = personal thoughts	The earth begins to decay due to the population
3 = justification with personal thoughts & evidence	Due to the climate change, sea water is heated more and so it produces more water vapor
4 = 1 justification with evidence	From old times the Earths' temperature has become increasingly high. It is not our fault that the warming has now reached high levels.
5 = 2 justification with evidence	It is a man-made phenomenon as people enhances the greenhouse effect, but greenhouse gases are produced by nature. Moreover, the temperature of the Earth over the last decade increased by 0.6 °C.
6 = 3 or more justification with evidence	Global warming is a natural phenomenon because there is evidence that the Earth underwent similar changes in the past, in that periods in which temperature was increased were followed by periods of higher temperature and vice versa. There is no evidence suggesting that human actions are responsible for this.

Table 2. Criterion 2 and examples of student answers

Connections between C-A & R	Students' answers (CF)
0 = no answer	
1 = Use of C-Alternative ¹¹	C-A: Prenatal tests are not always accurate since the proportions of false conclusions vary from test to test. R: It is better to take a doctor's opinion and then decide what they may do.
2 = Use of C-Critique ¹²	C-A: There may be infections on the mother or the fetus, such as detachment of the placenta. R: I would say that this possibility is only 1-3% and they must take the risk.

RESULTS

Written Task I: CC

Tables 3 and 4 show the results of the categorization of the students' responses using the coding scheme. As shown in table 3, the number of the evidence-based justifications underwent a substantial, statistically significant increase during the final assessment. Table 4 shows the differences between pre and post written tasks, where students made better connections between Counter-arguments and rebuttals after the teaching intervention.

¹¹ Disagreement together with proposal of an alternate argument

¹² Disagreement accompanied by a critique of the opponent's argument

Table 3. Results from criterion 1 - CC

Category	Argument*		Counter-argument**		Rebuttal***	
	Pre (%) N=28	Post (%) N=23	Pre (%) N=28	Post (%) N=23	Pre (%) N=28	Post (%) N=23
0	0	0	3,6	0	3,6	0
1	14,3	4,3	10,7	8,7	17,9	17,4
2	32,2	4,3	25	0	67,8	4,3
3	7,1	4,3	7,1	0	0	0
4	35,7	26,1	53,6	52,2	10,7	52,2
5	10,7	43,5	0	21,6	0	26,1
6	0	17,5	0	13	0	0
Total	100	100	100	100	100	100

* $z = -3,596$, $p < 0.05$, $r = -.58$, ** $z = -3,246$, $p < 0.05$, $r = -.65$, *** $z = -3,665$, $p < 0.05$, $r = -.72$

Table 4. Results from criterion 2- CC

Category	Intervention*	
	Pre (%) N=27	Post (%) N=23
0	11,1%	4,3%
1	40,7%	13%
2	48,1%	82,6%
Total	100	100

* $z = -3.000$, $p < 0.05$, $r = -.626$

Written Task II: CF

Similar findings also emerged from the transfer topic, as shown tables 5 and 6. Prior to the teaching intervention only a small proportion of students gave more evidence-based justifications. On the contrary, after the implementation students use more justifications when they construct their arguments, counter-arguments and rebuttals. As shown in table 6, the connections of counter-arguments and rebuttal underwent a statistically significant increase during the final assessment.

Table 5. Results from criterion 1 – CF

Category	Argument*		Counter-argument**		Rebuttal***	
	Pre (%) N=28	Post (%) N=23	Pre (%) N=28	Post (%) N=23	Pre (%) N=28	Post (%) N=23
0	0	0	0	0	0	0
1	3,6	0	17,9	4,3	14,3	0
2	17,9	8,7	28,6	13	46,4	8,7
3	17,9	4,3	7,1	0	7,1	0
4	46,3	30,4	46,4	47,8	28,6	52,2
5	14,3	52,3	0	34,9	3,6	39,1
6	0	4,3	0	0	0	0
Total	100	100	100	100	100	100

* $z = -2.768$, $p < 0.05$, $r = -.75$ ** $z = -3.113$, $p < 0.05$, $r = -.67$ *** $z = -3.443$, $p < 0.05$, $r = -.76$

Table 6. Results from criterion 2 - CF

Category	Intervention*	
	Pre (%) N=27	Post (%) N=23
0	14,8%	0%
1	33,3%	8,7%
2	51,9%	91,3%
Total	100	100

* $z = -2.486$, $p < 0.05$, $r = -0.518$

DISCUSSION AND CONCLUSIONS

This study has investigated the high school students' difficulties on argumentation and examined the extent to which their interaction with the learning environment has helped them develop argumentation skills. One claim that has been made in the literature is that argumentation skills do not emerge spontaneously, in that students who are not explicitly engaged in argumentation are not likely to develop these skills (Kuhn & Udell, 2007). Data from the initial assessment provide further empirical support to this claim and the corresponding position that the development of argumentation skills has to be treated as a desired outcome of instruction and pursued in an explicit manner. In addition to this, the findings presented in the study provide evidence for specific difficulties encountered by students in argumentation, including their tendency to use irrelevant or unconnected data (Zeidler, 1997; Sandoval & Millwood, 2005). This information could be useful in attempts to develop instructional materials for pursuing this learning objective.

The available evidence also provides support to an additional claim made in the literature, namely that argumentation skills are amenable to teaching elaboration in the sense that when provided with an effective instructional environment students can significantly improve their ability to construct better arguments (Osborne et al., 2004). Indeed, the results from the final assessment show that after the enactment of the learning environment students were better positioned to engage in argumentation by constructing more coherent arguments, counterarguments and rebuttals on both the intervention and the transfer topic. This is an indication of the meaning of promoting argumentation skills through well structured learning environments and the importance of argumentation skills using socio-scientific issues. Students should be involved in argumentation processes in groups, with the construction of online learning environments that promote scaffolding and specifically the argumentation skills (Sandoval & Reiser, 2004).

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**COMPTUER TOOLS FOR SCIENCE TEACHING AND
LEARNING: GAMES, MUTLIMEDIA, SIMULATIONS, MBL
AND VIRTUAL LABS**

CONTEXTUALIZED VIRTUAL LAB-BASED ACTIVITIES FOR CHEMISTRY EDUCATION IN SECONDARY SCHOOL

Carme Artigas, Jordi Cuadros, Fina Guitart

ABSTRACT

Despite the existence and availability of simulations and virtual laboratories for chemistry education, their presence in high school classes is in a minority. In this paper, we present the available problems in The ChemCollective virtual laboratory (<http://www.chemcollective.org>) and we discuss its integration in the Catalan school curriculum in both in terms of contents and competencies.

We also present three new contextualized activities that make use of this virtual laboratory. The activities have been designed to contribute to learning the topics of the chemical reaction (“Identificació de substàncies il·legals” and “Determinació i eliminació de la duresa de l’aigua”) and organic chemistry (“Prova d’insaturacions en productes alimentaris”) as they are taught at this school level.

The activity “Identificació de substàncies il·legals” asks students to identify different substances confiscated in a warehouse. To solve this problem, the user is asked to study the reactivity of a set of compounds and afterwards to use this knowledge to classify some potentially illegal drugs. The activity should help the students to make sense of what the chemical reaction is and what is its value for the qualitative analysis of different products.

The second activity “Determinació i eliminació de la duresa de l’aigua” models the process of the experimental determination of water hardness. It also explores the use of carbonate salts to soften it. This activity goes into the quantitative aspects of the chemical reaction.

Finally, the activity “Prova d’insaturacions en productes alimentaris” allows connecting organic chemistry, biology and chemical reaction concepts, through the study of the nature of the fatty acids present in three alimentary products: butter, sunflower oil and olive oil.

KEYWORDS

Virtual laboratory, chemistry, secondary education, context-based learning

INTRODUCTION

In the last years, teachers, schools and universities, have seen the decrease of science vocations and of the number of students in natural sciences and health in the first year of Batxillerat (Batxillerat is the name used in Catalonia to refer to the last two years of secondary education, i.e. 11th-12th grades).

This decrease can be partially attributed to the inherent difficulties of teaching and learning science. Although a relevant number of existing resources and technological opportunities can help in this effort, these are seldom used in the chemistry classes in secondary school.

One of these opportunities is the use of simulations and virtual labs, for example those that can be found at the ChemCollective website. The ChemCollective is “a collection of virtual labs, scenario-based learning activities, and concepts tests which can be incorporated into a variety of teaching approaches as pre-labs, alternatives to textbook homework, and in-class activities for individuals or teams”. “The ChemCollective began with the IrYdium Project’s Virtual Lab in 2000, which provides a flexible simulation so that instructors may use it for a great variety of student activities. The project evolved to create scenario-based learning activities designed to provide interactive and engaging materials that link chemistry concepts to the real world”. (Yaron *et al*, 2011)

The virtual laboratory collection of problems includes three different types of problems. First, some problems, the calculation and check problems, expect the students to use virtual lab to verify their results after solving a textbook-like problem. The second type, the online experiments, is similar to the laboratory practices, but in the virtual lab, students can have more flexibility and design their solving procedures. The last type of problems is the layered activities, where students perform a set of activities involving the same chemical system in increasing complexity order. (Yaron, Cuadros, Karabinos, 2005).

Each of these problems contains a brief statement describing it. While this description could be skipped to create a different activity, most of the problems are contextualized offering an opportunity for a more significant learning. An example of the description of a problem can be seen in the Figure 1.

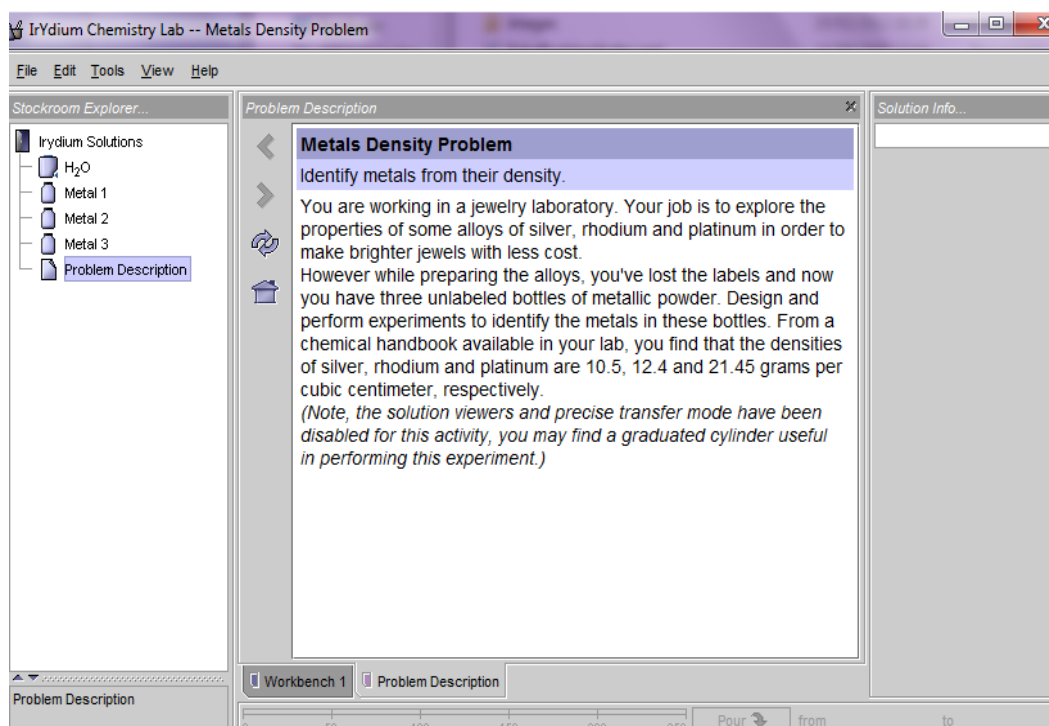


Figure 1. Example of the description of a problem in the virtual laboratory.

The integration of these problems into the Catalan curriculum will be discussed in this presentation.

DEVELOPMENT

Some of the existing problems can be useful in 4th of ESO (10th grade), for example the problems “Metals density problem” and “Liquid density problem”, where the students have to determine the density to characterize some products. Another example is the problem “¿Reaccionan?” where the students can work on the concept of chemical reactivity.

However, a great number of problems are suited to be integrated in the Batxillerat’s chemistry curriculum. The opportunities for this integration will be discussed first in terms of contents and afterwards in terms of the competencies of this education level.

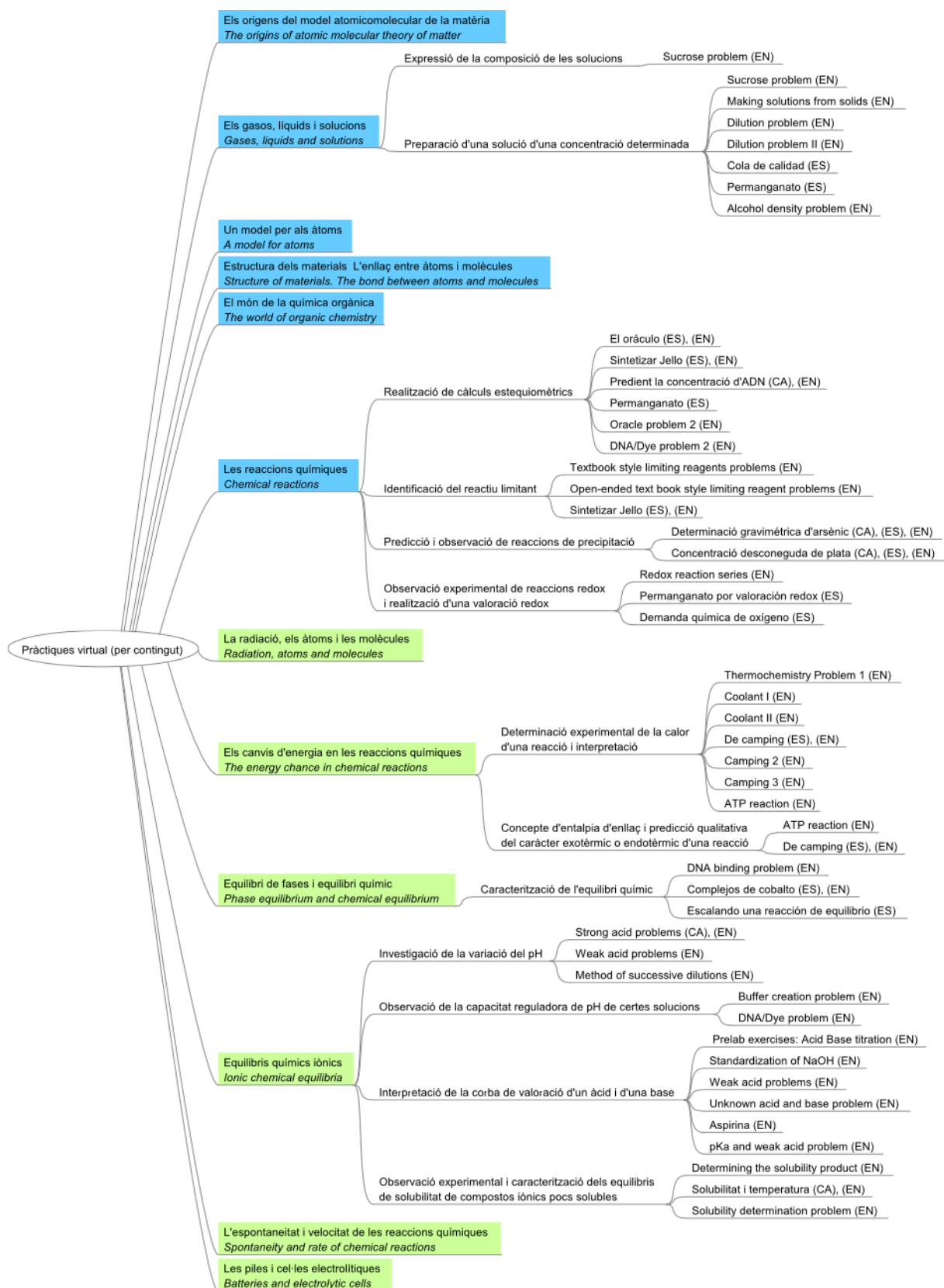


Figure 2. Virtual problems organized by contents (language of the problem is shown in brackets, CA: Catalan, EN: English, ES: Spanish).

Virtual lab problems organized by contents

In Figure 2 problems are presented according to the contents of the Batxillerat's Chemistry curriculum.

The first six branches of the map in figure 2 (shown on a blue background) are the topics corresponding to the first year of Batxillerat.

For the first, third, fourth and fifth topics there are not any suitable problems in the virtual lab. This is due to the theoretical character of these parts of the curriculum.

For the second topic, there are seven suitable problems available in the virtual lab. Most of them ask for the preparation of a solution with a certain concentration. As a slightly different problem, the "Sucrose" problem asks also to express the concentration in different units.

Four aspects of the "Chemical reactions" topic can be taught using virtual lab problems. For stoichiometry, we have selected six problems. Every one of these problems is contextualized and most of them allow students to design their own experiment. For the identification of the limiting reagents aspect, there are several textbook-like problems available. Only one, the "Open-ended text book style limiting reagent problem" is more open and allows for a more inquiry-based approach. To work with precipitation reactions, there are two virtual problems, both of them ask for the unknown concentration of a sample. For the last aspect, the oxidation-reduction reactions there are three different problems. In "Redox reaction series" students have to establish which metal is the strongest reducing agent. The other two problems ask the students to perform a titration either to calculate the permanganate concentration or to estimate the COD (Chemical Oxygen Demand) of a wastewater.

The last six branches of the map in figure 2 (shown on a green background) are the topics corresponding to the second year of Batxillerat.

For the first, the fifth and sixth topics, we haven't associated any suitable virtual lab problem.

In the second topic, which refers to reaction energy, problems dealing with the heat capacity and the enthalpy of reaction concepts can be used. There is also a problem, the "ATP reaction" one, which builds on the concept of bond energy.

For the next topic, chemical equilibrium, there are three problems and all of them are thought for characterized the chemical equilibrium. The problem called "Complejos de cobalto" is made with the objective of gaining an understanding of the LeChatlier's principle and observe how different factors influence to the displacement of the reaction. "DNA binding problem" asks for the calculation of the equilibrium constant and "Escalando una reacción de equilibrio" asks the student to fully describe an equilibrium reaction to scale it up in an industrial procedure.

The next topic refers to the chemical ionic equilibriums. In this section, there are lot of contents refers to acid and bases substances. The virtual problems are classified in four groups. The first one is related to the pH. There are three virtual problems where the students have either to prepare different solutions and then measure the pH or to make a solution with a certain pH. The problem called "Method of successive dilutions" aims to help the students to grasp an understanding of the logarithmic scale when preparing a pH scale. A second group of problems is referred to buffer solutions. There are two virtual problems and in the two cases students have to prepare a buffer. The third group corresponds to titrations curves. Some problems classified here have more guidance and lack of contextualization. Oppositely, there are some contextualized and more open problems that allow students to investigate and design the experiment by themselves. A last group of problems is related to the solubility of different substances.

Acquiring competencies with the help of the virtual laboratory

The Batxillerat's chemistry curriculum considers the contribution of this subject to the five general competencies of the education level. The fifth general competency is then detailed into three specific competencies. Table 1 lists them.

Table 1. General and specific competencies of Batxillerat Chemistry according to the current Batxillerat's organization (Catalunya, 2008).

Competències (Catalan)	Competencies
<i>Generals</i>	<i>General</i>
1. Competència comunicativa	1. Communicative competency
2. Competència en recerca	2. Research competency
3. Competència en gestió i tractament de la informació i competència digital	3. Competency of management and treatment of the information and digital competency
4. Competència personal i interpersonal	4. Personal and interpersonal competency
5. Competència en el coneixement i interacció amb el món	5. World knowledge and interaction competency
<i>Específiques</i>	<i>Specific</i>
1. Competència en la indagació i experimentació en el camp de la química	1. Investigation and experimentation in chemistry competency
2. Competència en la comprensió de la naturalesa de la ciència i de la química en particular	2. Understanding of the nature of science and particularly the nature of Chemistry competency
3. Competència en la comprensió i la capacitat d'actuar sobre el món fisicoquímic	3. Understanding and ability to act in the physic-chemistry world competency

The relevance of the virtual lab for competency building will depend on the activity proposed by the teacher. This said, some guidance and orientations are given below.

Some activities that can contribute to the development of the communicative competency can be done with the virtual lab. This competency will be worked on if written reports are asked of the students. It can also be developed if a problem in a foreign language is chosen and CLIL (Content and Language Integrated Learning) approach is used (European Commission, 2012).

In the case of open problems, where students set out hypothesis and define the experimental methodology, the research competency can be built. Examples of this type of problems are: "Metals density problem", "Cola de calidad", "Oracle Problem" and "De camping".

The only part which is developed in the management and treatment of the information and digital competency is the use of digital resources. Depending on the didactic activity proposed, it can be developed the part of treatment of data. An example is the "pKa and weak acid problem" where students can build the titration curve with the data obtained in the virtual lab. Another example is "Solubility Determination Problem", wherein students can build a graphic with the data obtained.

With the virtual lab problems, the personal and interpersonal competency is not developed, but it can be built with a determinate activity that stimulates for example the co-assessment.

The last general competency includes what is specific of the subject and is divided into three specific competencies.

The competency of investigation and experimentation in chemistry is present in open problems where students have to plan hypotheses and devise experimental methods. It can also be worked on problems

where a POE (Predict, Observe and Explain) (New Zealand Council for Educational Research, 2011) can be developed. A good example of a problem where a POE can be useful is the “Solubility Determination Problem”.

The second specific competency is the understanding of the nature of science and particularly the nature of Chemistry. The use of the scientific method as well as using the virtual lab to explore the models used to represent the reality can help building this competency. Moreover, using different contexts, the problems can be connected with the quotidian life and the socially relevant topics helping connect science and society.

The last competency is the understanding and ability to act in the physic-chemistry world. This competency refers to the disciplinary contents. As such, this connects with the content-wise classification discussed above.

New activities created

Besides from the existing problems already presented, three new activities related with the Catalan curriculum have been developed. These are created to be integrated in the first year of Batxillerat.

The first activity is called “Identificació de substàncies il·legals”. It asks students to identify the chemical nature of some substances that police have confiscated in an illegal warehouse.

In the virtual lab, the student will find four reference samples of cocaine, LSD, amphetamine and heroin, seven unknown samples and five identification reagents. The activity is contextualized in the scientific police department. First, students have to identify and document what are the colors that they obtain when reacting the illegal drugs with the reagents. Then they have to describe the process that they will follow to discover if some of the samples contain an illegal drug and apply it to identify the unknowns. The last part of the activity asks the students to justify their conclusions. The activity should help the students to make sense of what the chemical reaction is and what is its value for the qualitative analysis of different products.

The second activity, called “Determinació i eliminació de la duresa de l’aigua” models the experimental determination of the water hardness and allows studying the use of carbonate to soften it. This problem guides the students towards a quantitative comprehension of the chemical reaction through the use of a context mentioned in the Catalan curriculum.

The activity is divided in three parts. In the first part, students have the opportunity to familiarize themselves with the laboratory instruments, the change of the colors and the titration process. Still in this first part, the activity asks students to determine the concentration of calcium in the water sample and to calculate the hardness of this sample. The second part is the precipitation of calcium with carbonate to decrease the hardness. In this part, students first have to do different calculus and then to note the mass of calcium carbonate precipitated. The last part consists in repeat the titration with EDTA to determine the concentration of calcium after precipitate it with carbonate.

The third activity is called “Prova d’insaturació en productes alimentaris”. It allows relate organic chemistry, biology and chemical reaction concepts through studying the fatty acids present in three common products: butter, olive oil and sunflower oil. Each of these products has a different degree of unsaturation. Butter is the one with the smallest degree of unsaturation, olive oil has a larger degree of unsaturation than butter, but smaller than sunflower oil, which is the most unsaturated.

In the activity, there is a controversial muffin sample which has an unknown degree of unsaturation. The students have to determine if the degree of unsaturation corresponds to one of the three substances mentioned. To determine this, they will use of a solution of bromine in carbon tetrachloride. The students will use this colored solution and perform a titration with the different samples. Then they have to identify which product has the most unsaturated fatty acid.

CONCLUSIONS

In this contribution, the different opportunities offered by the ChemCollective virtual laboratory for contributing to the teaching and learning of chemistry in Catalan secondary school are presented.

The existing problems cover a large range of the chemistry curriculum contents and can allow developing the different competencies of the chemistry classes in the Catalan secondary education i.e. in Batxillerat.

Five out of the twelve major topics in Batxillerat's chemistry can be approached through using some of the available problems in the virtual lab. However, the topics of chemical reactions and ionic chemical equilibrium are these that have more associated problems.

Some suggestions are also offered on how to use the virtual to help building the Batxillerat's competencies.

Besides the existing problems, three new activities have been created:

The activity "Identificació de substàncies il·legals" asks students to identify different substances confiscated in a warehouse. To solve this problem, the user is asked to study the reactivity of a set of compounds and afterwards to use this knowledge to classify some potentially illegal drugs. The activity should help the students to make sense of what the chemical reaction is and what is its value for the qualitative analysis of different products.

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MATHEMATIC EDUCATION FOR THE DEAF: INVESTIGATING THE USE OF JCLIC FOR THE 1st GRADE IN ELEMENTARY SCHOOL

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ABSTRACT

The present paper addresses part of a study developed with the Graduate Program in Sciences and Mathematics Education at Universidade Luterana do Brasil. The main goal is to investigate the use of the Jclíc tool in the development of activities that may favor the acquisition of numeric-mathematic skills by deaf students in the first grade of Elementary School who attend an institute specialized in education for the deaf in a Brazilian city, through a bilingual proposal. The focus of this study emerged from experiences the researcher underwent when she was a mathematics and computer science teacher in that institution, in which she perceived the paucity of methodological and digital bilingual materials to support her work as an educator for the deaf. Initially, a study of different theoretical references was conducted regarding mathematic education for the deaf, acquisition of numeric-mathematic skills, Jclíc and methodologies for the use of digital material in the educational process. These theoretical sources contributed to prepare and apply the activities developed through the Jclíc. After classroom observations and interviews with the teacher of the class, activities were prepared and tested with the students. The collected and analyzed data demonstrated that Jclíc consisted of a tool that helped in the preparation and application of activities that contributed to acquire numeric-mathematic skills by deaf students in the first grade of Elementary School, as it allowed videos to be used, favoring the communication and understanding of tasks through the Brazilian language of signs, and provided options for developing ludic activities, which encouraged students to carry out their tasks.

KEYWORDS

Mathematic education for the deaf, numeric-mathematic skills, Jclíc

INVESTIGATION DESIGN

In this paper, we intend to analyze the possibilities of using Jclíc for creating and performing activities related to the acquisition of numeric-mathematic skills by deaf students in an Elementary School specialized in the education for the deaf in a city in the southern region of Brazil, aiming a bilingual approach. The subjects of this study were four deaf students and two teachers who worked with this group, one of them being the researcher and a computer science teacher and the other, the form teacher. The students consisted of three girls, two aged 8 years old, one aged 6, and an 8-year-old boy. All were children of parents with normal hearing and two girls wore a hearing aid. The term numeric-mathematic skills will be used to refer to counting skills, numeric sequence, counting procedures and different representation of numbers.

During the development of these skills in the first grade in elementary school, students are encouraged to count, enlisting numbers and quantities and using them in operations. For deaf students in this stage of schooling, it is not always an easy learning process, as, in addition to the mathematic language, it is

in this stage that the learning of their mother language, Libras (Brazilian Sign Language)¹³, begins in a consistent fashion, as well as their second language, Portuguese, since deaf children start to attend school around age seven, if not later, and most of the times, that is when their first contact with Libras takes place. Quadros (1997) considers that the earlier a deaf student is exposed to his/her mother language, the better his/her chances are for favorable social and cognitive development.

Therefore, it is important that a teacher in this stage of elementary school be supported by methodological materials to help in acquiring numeric-mathematic skills, taking into account these characteristics. The experiences that the researcher underwent as a mathematics and computer science teacher in the institution since 2008 led her to notice the paucity of digital materials that could give support to this bilingual approach¹⁴, and that is when this study began.

The choice of using Jclíc stemmed from the fact that it is a free software program through which resources can be created for didactic and interactive applications virtually in all curriculum areas, multimedia resources of different formats can be integrated into activities, and one can program activity sequences organized in projects and also publish the materials created with Jclíc on the web. After exploring this software, the guiding question of this paper emerged: what Jclíc resources could help in the development of activities intended to favor the acquisition of numeric-mathematic skills by deaf students in the first grade in elementary school using a bilingual proposal? We developed this analysis based on this issue.

To meet this goal, a partnership was started with the form teacher for the first grade in elementary school by means of an interdisciplinary proposal.

The investigation was conducted based on a qualitative approach. Data collection was carried out through classroom observations, films of the activities developed during Mathematics and Computer Science classes, questionnaires and interviews administered to the form teacher, meetings with the researcher and form teacher aiming at thinking about and analyzing the development of classes in order to organize activities to be conducted with Jclíc.

Data collected in this kind of research are descriptive and got from the direct contact of the researcher with the investigated situation. The concern is to report the participant's perspective about how the child interprets and interacts with the activities proposed by the Jclíc.

When this study started out, we sought to simultaneously combine, through action and reflection, the activities of the researcher and Computer Science teacher with those of the form teacher, so that together they could work in an interdisciplinary fashion in order to improve pedagogic practice and bring about improvements to the mathematic education of the deaf.

TECHNOLOGIES IN EDUCATION AND JCLIC

Technologies have increasingly become a helpful tool for the learning process, since “today's children are already born immersed in this technological world and their concerns and thinking patterns are part of this universe” (Weiss e Cruz, 1999, p.13).

¹³ Libras is the Brazilian sign language, it was given official status by Law No. 10.436 of April 24, 2002, and regulated by decree No. 5.626, of December 22, 2002.

¹⁴ Bilingual education in Brazil understands that the first language of the deaf should be the sign language and the second one, the Portuguese language in its written modality, the oral version being a personal choice of the subject.

Using suitably a computer in a school setting may lead to greater commitment of students to their learning process. With this in mind, many studies have been conducted with the purpose of using this resource for pedagogic activities.

For preparing didactic material, it is important that the resource enable students to interact and allow them to examine and make decisions. Learning objects (LO), according to Willey (2000), are digital resources that support this process, as they resize the conditions for access to information, broadening learning possibilities by using simulations, symbolic manipulations and multiple ways of representation.

Togni (2010) underscores a few important precautions for preparing learning objects, such as the necessary skills of the teacher for this job, interaction with a multidisciplinary team, and availability of software programs suited for what one intends to carry out.

Therefore, for building a learning object, the teacher needs to have skills so as to perform such a task, skills derived from “comprehensive knowledge, academic knowledge, specialty knowledge and knowledge from experience” (Perrenoud, 2002).

In addition to knowledge, it is important that the teacher can take part in a multidisciplinary team, in which he/she can share ideas, reflect and build, with the necessary care, the desired learning objects.

In this context, Jclíc is a tool that has contributed to the learning process, especially for the group of students that are the subjects of the present study. This software allows the teacher, or even the student, to create interactive activities in different curricular areas, enabling sound, image and video to be combined. It comprises a set of applications that are used for creating, performing and evaluating didactic activities and provides seven types of basic activities: associations and memory games, exploration, cell identifier and information screen, puzzle, written-answer activities, text exercises, word-find games and crossword puzzles.

JCLIC: PREPARING PROJECTS

The activities proposed in class by the form teacher started with the manipulation of physical materials such as dice, domino, golden material, lollypops, etc. through a project integrated with other curricular areas. This moment, the students were invited to learn the name of the object in Portuguese, its Libras sign, and its characteristics were briefly discussed. After this initial exploration, games were proposed with the material, aiming at the manipulation of the object by the student and development of a few mathematic skills, such as counting, identifying the predecessor and successor of a natural number, equal or different, ideas of combining, adding, removing, remaining, among others. At these moments, through questioning, the students were led to think about the actions and relationships they had performed/established, seeking progress in the construction of their mathematic knowledge.

In this sense, Schliemann et al. (1992) stresses that it is not the specific use of a physical material, but the meaning of the situation, the child’s actions and the reflection on these actions that matter for building mathematic knowledge.

In the pursuit of this idea, following data collection (carried out by means of questionnaires, interviews, observations, and films), we sought to prepare activity sequences that would complement the ones carried out in Mathematics classes, so as to contribute to the acquisition of numeric-mathematic skills and this reflective process. The activities were thought out during the meetings between the teacher and the researcher and produced with Jclíc by the researcher.

Once the Jclíc project was created containing the set of prepared activities, the project was administered to first-graders in Computer Science classes. The classes were filmed and, subsequently, watched and discussed again by the teachers.

Besides the films, the analysis of the statistical reports provided by the software also contributed to prepare a new class plan.

Sequência	Atividade	Correcta	Ações	Pontuação	Tempo
start	Atividade_1	Sim	1	100%	9"
	Atividade_2	Sim	1	100%	7"
	Atividade_3	Sim	4	75%	42"
	Atividade_4	Sim	1	100%	12"
	Atividade_5	Sim	1	100%	7"
	Atividade_6	Sim	3	100%	37"
	Atividade_7	Não	0	0%	10"
	Atividade_8	Sim	1	100%	9"
	Atividade_9	Sim	1	100%	7"
	Atividade_10	Sim	2	100%	21"
	Atividade_11	Sim	1	100%	8"
	Atividade_12	Sim	1	100%	6"
Total:	12	11 (91%)	17	89%	3'0"

Figure 1. Report of the activities develop on the Jclíc_Dados

In Computer Science classes, students were allowed, during tasks, to discuss resolution strategies and other questions that could emerge jointly with the teacher and/or classmates.

This dynamics has contributed to the development of Mathematics classes, as, in addition to the continuous reflection on teaching, the students have shown signs of engagement and learning in the acquisition of numeric-mathematic skills.

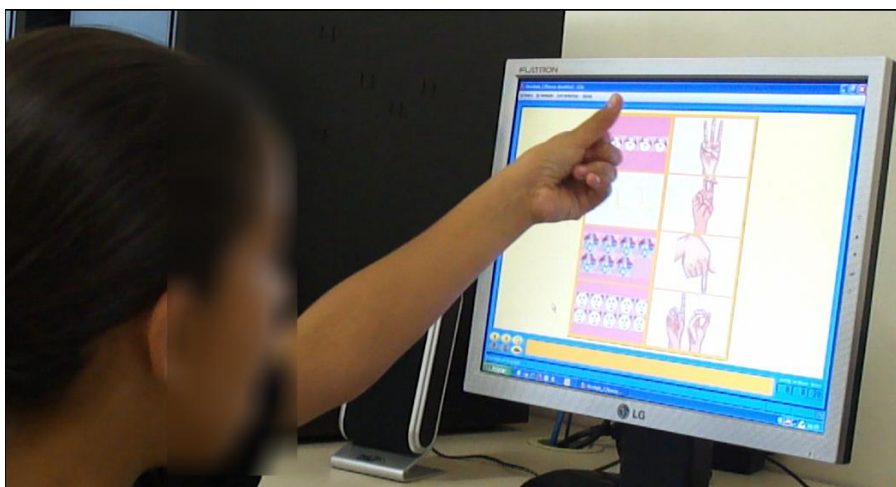


Figure 2. A student carrying out an activity on Jclíc

JCLIC: CONTRIBUTIONS TO A BILINGUAL PROPOSAL

We intend to highlight and follow some of the resources provided by Jclíc that contributed to the development of activities, aiming at a bilingual approach.

- Videos:

Each Jclíc project that was created followed a few patterns. The initial screen for the project is an example, as on it a video is presented explaining the tasks and concepts involved in the project. The video is in Libras and written in Portuguese, for deaf students to be able to rely on explanations in their first language. According to Kamii (2004) “autonomy intended for education is, in a sense, a new idea

that will revolutionize education”, stressing the declaration of Piaget that the aim of education should be to develop the child’s autonomy, which is inextricably social, moral and intellectual, and that arithmetic, just like any other subject, should be taught in the context of this broad objective.

- Pictures:

For the deaf, the visual element is considered one of the main facilitators in the development of learning (SALES, 2008). Thus, favoring visual-spatial resources in methodological strategies is extremely important. In order to contribute to this context, many pictures were used for preparing projects, in which two groups stood out. The first one comprised drawings from number 1 to 10 that were developed in the course of technical drawing provided by the institution to deaf students in the final grades of elementary school and high school. The drawings were made from the signalization of these numbers by the hands of the students themselves, they were released to the institution, which, by its turn, authorized the pictures for Jclíc projects. The second group of important pictures was made by first-grade students who produced them in different classes according to the projects developed by the class, then, they were scanned and used for Jclíc projects. These pictures significantly contributed to first-graders, who, by performing mathematic tasks, had the chance not only to work with mathematic symbols and the name of the numbers in Portuguese, but also to represent the numbers in Libras. In addition, they were extremely happy to see their own drawings in activities of the project.

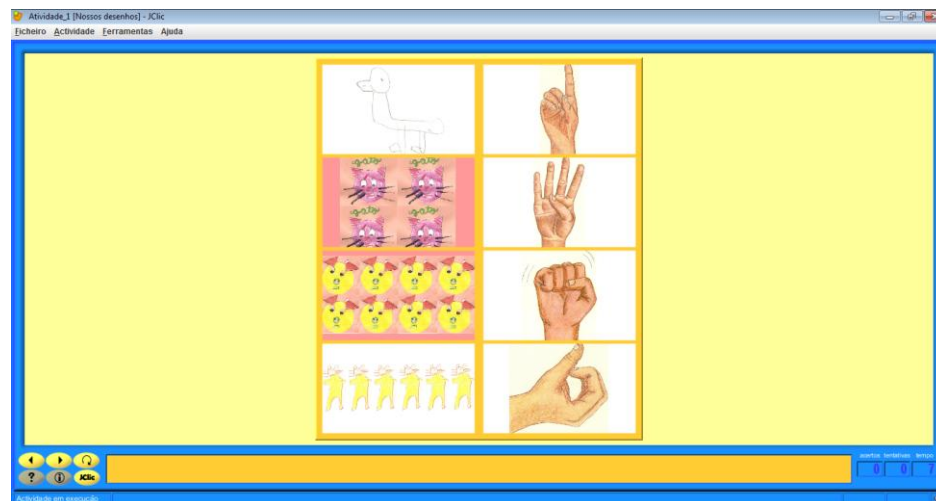


Figure 3. Activity in Jclíc with pictures by the students and numbers in Libras (sign language)

- Gifs:

The possibility of placing gifs in the activity messages also strengthened and encouraged both the ludic aspect and the creativity of these students in resolving activities. The researcher in partnership with a deaf teacher from the institution created some gifs in Libras, using photos and the animator software. Again, the bilingual focus could be addressed in the project.

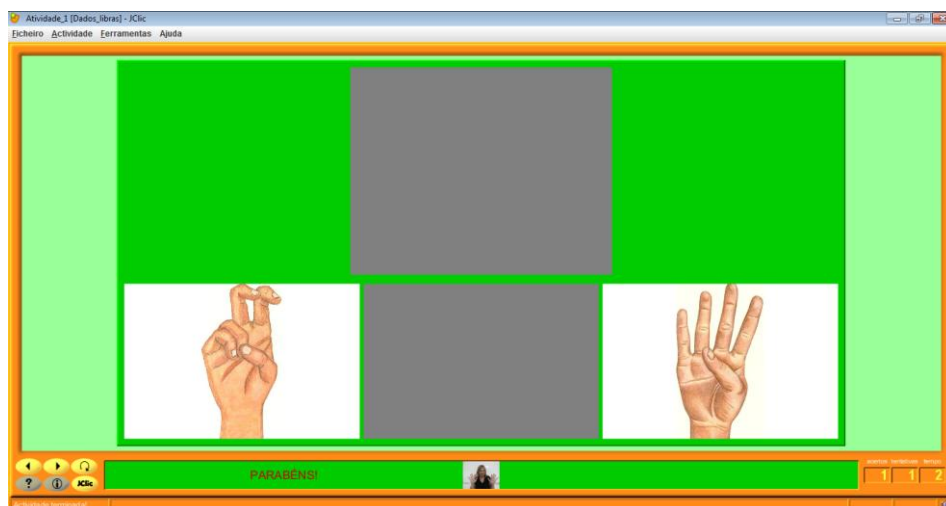


Figure 4. Gif for the sign “congratulations”

JCLIC AND GAMES

According to Vygotsky (1987), the first game creates an area of proximal development, allowing the actions of a child to excel the development that has already been attained (actual development), propelling him/her to conquer new possibilities of understanding and action on the world. Playing may constitute a learning space.

In this sense, one can perceive that Jclíc provides possibilities of performing ludic activities, such as the memory game, puzzles, and associations. These resources stimulate first-graders to pleasantly and willingly carry out all proposed tasks.

Below are a few activities developed on Jclíc involving these different possibilities:

- Simple Association: two sets of information are presented having the same number of elements. Each element in the first set corresponds to an element in the second set.

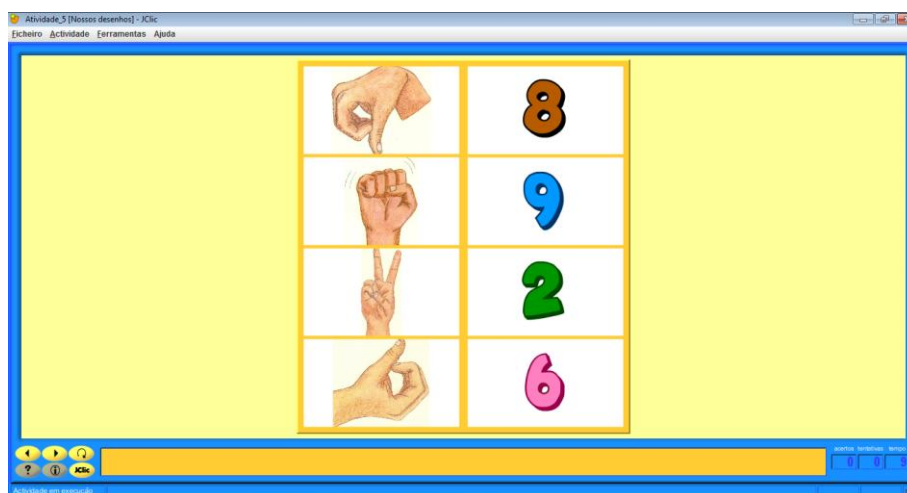


Figure 5. Simple association activity

- Complex Association: two sets of information are presented, but these can have a different number of elements and among them there may be different types of relationship: one to one, many to one, elements without any relationship with another element.



Figure 6. Complex association activity

- Memory Game: in this type of activity one needs to find pairs of elements amid a set of pieces that are initially hidden. The pairs may be formed by two equal pieces or by two related elements.

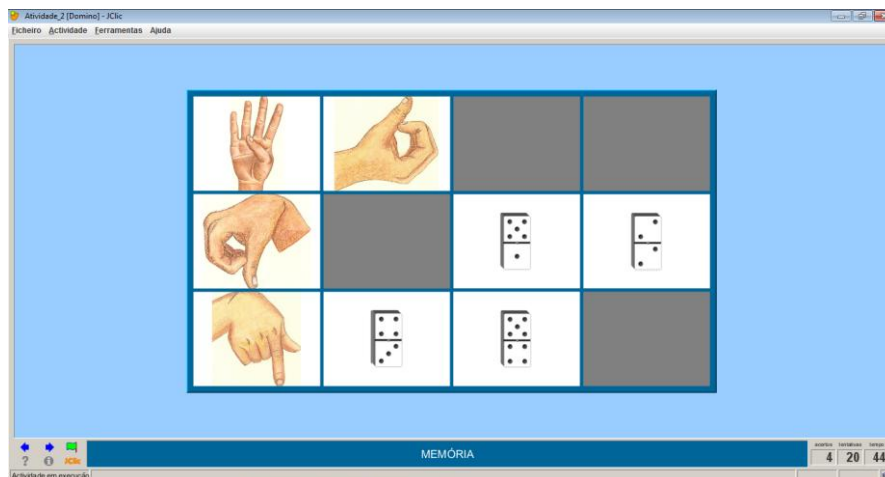


Figure 7. Memory activity

- Puzzle: plans the construction of information that is initially untidy.

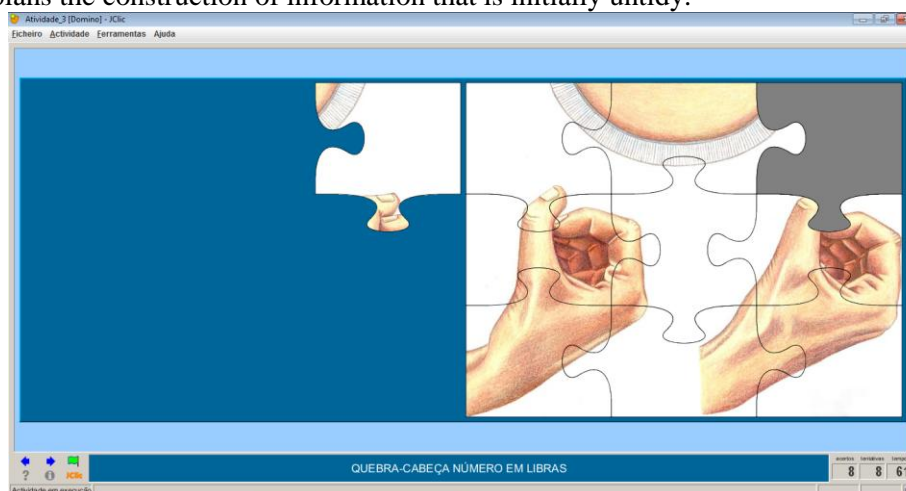


Figure 8. Puzzle activity

FINAL CONSIDERATIONS

Respecting the deaf sign language, in the case of Brazil, the Libras language, is the first step to the actual integration of the deaf into society. Primarily, schools must be prepared to tend to deaf students, who are entitled to having a bilingual education.

Hence, the role of an educator is of paramount importance in the pursuit of a significant education for deaf students by using methodologies and resources suited for their needs, using Libras as their first language and learning Portuguese as their second language.

Thus, being able to rely on an educational resource that favors this approach is important. Through this study, the software Jclíc was found to provide resources that help in the development of activities intended to favor the acquisition of numeric-mathematic skills by deaf students in the first grade of elementary school, based on a bilingual proposal.

The possibility of inserting videos, pictures and animations in the Libras language contributed to the understanding and autonomy of deaf students when these carried out tasks, in addition to concomitantly being helpful for Portuguese language by using texts.

The software meets one of the main characteristics of first-graders, their playful nature, as it offers the possibility of creating games such as the memory game, puzzles, word find games, associations, etc.

The fact that the software allows statistic reports to be issued enables teachers to verify, while activities are being developed, the learning and non-learning status of each student, contributing to necessary interventions and a new class plan.

Nowadays, education takes place through a plethora of possible paths that can be followed. Jclíc has become one of these paths, with a lot of possibilities herein explored, but with so many others to still pursue. Bilingual education for the deaf needs this pursuit to be able to make use of the new technologies that have contributed and may contribute even further to this setting

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SECOND LIFE AS A PLATFORM FOR PHYSICS SIMULATIONS AND MICROWORLDS: AN EVALUATION

Renato P. dos Santos

ABSTRACT

Often mistakenly seen as a game, the online 3D immersive virtual world Second Life (SL) is itself a huge and sophisticated simulator of an entire Earthlike world. Differently from other metaverses where physical laws are not seriously taken into account, objects created in SL are automatically controlled by a powerful physics engine software. Despite that, it has been used mostly as a mere place for exploration and inquiry, with emphasis on group interaction. This article reports a study conducted to evaluate the SL environment as a platform for physical simulations and microworlds. It begins by discussing a few relevant features of SL and a few differences found between it and traditional simulators e.g. *Modellus*. Finally, the SL environment as a platform for physical simulations and microworlds is evaluated. Some concrete examples of simulations in SL, including two of our own authorship, will be presented briefly in order to clarify and enrich both discussion and analysis. However, implementation of simulations in SL is not without drawbacks like the lack of experience many teachers have with programming and the differences found between SL Physics and Newtonian Physics. Despite of that, findings suggest it may be possible for teachers to overcome these obstacles.

KEYWORDS

Second Life, Physics teaching, virtual worlds, physics microworlds, computer simulations.

INTRODUCTION

There are hundreds of *game worlds*, e.g. *World of Warcraft*, specifically created for entertainment, and over 50 different Multi User Virtual Environments (MUVE) currently available (Taylor, 2007), created to simulate real life in some sense. Among them, SL, followed by *OpenSim* and *Active Worlds*, stands out as the platform that, even if without the biggest user population (Taylor, 2007), it is the one that offers more services and tools for developing applications with quality (R. Reis, Fonseca, & Escudeiro, 2011), in terms of realism, scalability, interaction, user-friendliness, and safety. In fact, differently from other virtual worlds where physical laws are not seriously taken into account, objects created in SL are automatically controlled by the powerful Havok™ physics engine software. As we are particularly interested in Physics simulations, these points have led us to choose it for our research purposes.

We evaluate here the SL environment as a platform for physical simulations and microworlds.

METHODOLOGY

Initially, specific features of the SL environment, relevant to its use as platform for physics microworlds (Papert, 1980) and simulations, will be discussed in detail, as a support for subsequent analysis.

Afterwards, the SL environment as a platform for physics microworlds and simulations will be evaluated, using the criteria established by Reis & Andrade Neto (2002). We will focus on features relevant to the teaching and learning than on others more relevant in terms of computing.

A few concrete examples of simulations in SL, including two of our own authorship, will be presented briefly in order to clarify and enrich both discussion and analysis.

RELEVANT FEATURES OF THE SL ENVIRONMENT

On May 2012, the world of SL was made up of thousands of uniquely named *Regions* - virtual parcels of land representing an area of 256 m x 256 m - linked together to make the *Maingrid*, *Private*, *Homestead* and *Openspace* areas that spread over 1,962.93 km² (Shepherd, 2012) of virtual land, not much smaller than the country of Luxembourg. Each Region is rendered by a single process running on Linden Lab servers ("Simulator," 2010) that simulates a full rigid-body physical dynamics, including gravity, elasticity, and conservation of momentum ("Physics engine," 2008), and an accurate, polygon-level collision detection of all the objects in the column-space above its land.

Each server is edge-connected to four other machines as a grid. This grid computes a simplified solution of the Navier-Stokes equations to simulate the motion of winds and clouds that time-evolve across the entire world (Ondrejka, 2004a; Rosedale & Ondrejka, 2003). It also runs user's scripts and streaming routines to send back all the data needed to view the world to anyone's connected client (Ondrejka, 2004a). As a result, the SL 'Sun' usually rises and sets each 4 Earth hours always directly opposite a full Moon ("llGetSunDirection," 2009), objects fall under the effect of gravity, trees and grass blow in the wind and clouds form and drift (Ondrejka, 2004a). Therefore, SL is a big simulation of an entire Earthlike world.

Once logged through the client software, SL users can enjoy the 3D scenery, fly, drive cars, interact with other avatars, play games, or create objects. In fact, well over 99% of the objects in SL are user created (Ondrejka, 2004b), what has been characterized as a shift of culture, from a media consumer culture to a participatory culture (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006).

In a rapid tour through many virtual spaces dedicated to Science, however, one will almost only find real-world replica, mere institutional presences, with traditional classrooms, virtual boards exhibiting 2D PowerPoint™ presentations, and video seminars. We agree with Kapp (2007) that this is certainly not the best use of Second Life or any other metaverse. The real advantage is using it to do innovative things that could not otherwise be done in a classroom that reach into the pupil's imaginations (de Freitas & Griffiths, 2009).

SL offers interactivity features to add to the objects through its *Linden Scripting Language* (LSL) ("LSL Portal," n.d.). Its structure is based on *Java* and *C* languages and it provides nearly four hundred functions, among which several of interest to Physics studies in SL used e.g. to access the position or the velocity of the object in the region or to apply a force to it.

However, some important points should be taken into account when one wants to build a simulator or a microworld in SL. See also (dos Santos, 2009) for a deeper discussion on these points.

Time can be affected by different kinds of lag and, therefore, SL will definitely not give response time down to milliseconds consistently for quantitative simulations. There are no fluids in SL (dos Santos, 2009): outside the SL 'oceans', 'water' is a mere texture applicable to an object. Besides, friction, air and water resistance, and buoyancy were not fully implemented in SL. Remarkably enough, light cannot be contained by the walls of a room and, as a consequence, light simply "is there" in SL, as an state of illumination, without any physical mechanism involved in its production or propagation, as in the most primitive conceptions of light (Lindberg, 1981). Finally, SL does not even try to simulate any physics beyond Mechanics, and, therefore, a designer may have to use creativity to simulate other interactions like electromagnetic or nuclear ones.

We have already demonstrated that SL does not simulate a real-world Physics virtualization or the Galilean/Newtonian "idealized" Physics (dos Santos, 2009). It was also noticed that certain physical

quantities such as mass, acceleration, and energy have very different meanings in SL as compared to real-world Physics.

It was further noticed that SL is lacking of some basic functions to provide initial conditions to objects, e.g. their initial velocity and position, as simulators usually have (dos Santos, 2009). Furthermore, physical objects are, in principle, affected by SL ‘wind’ and ‘gravity’ and, therefore, they will not keep that velocity constant and will deviate from its rectilinear trajectory. This difficulty can be seen in the following three concrete examples.

Oddprofessor Snoodle, a Physics teacher, was recently creating a replica of an *air track* for her *Museum and Science Center* (Figure 3). She found herself unable to have the glider to move along a track at a given constant velocity even if using buoyancy to cut down on friction (Linden, 2010).



Figure 3. Oddprofessor Snoodle's air track replica at the *Museum and Science Center*
Source: photo taken by the author

As another example, Greis & Reategui (2010) have built a simulator themed as a pair of amusement park non-wheeled bumper cars running on rail tracks and performing head-on collisions (Figure 4). In a private communication to this author, Greis manifested the same kind of difficulties in controlling the velocity in SL as *Oddprofessor Snoodle* faced.



Figure 4. Bumper cars head-on collision simulator
Source: (Greis & Reategui, 2010)

To investigate the feasibility of building physics microworlds in SL, we have built a ‘cannon’¹⁵ that can simulate both Newtonian Mechanics and its predecessor, Buridan’s Impetus Theory as per user’s choice. We have described in detail elsewhere (dos Santos, 2010a) our difficulties to counterbalance gravity and to achieve a rectilinear trajectory simulation for the cannonballs and our workaround for these difficulties.

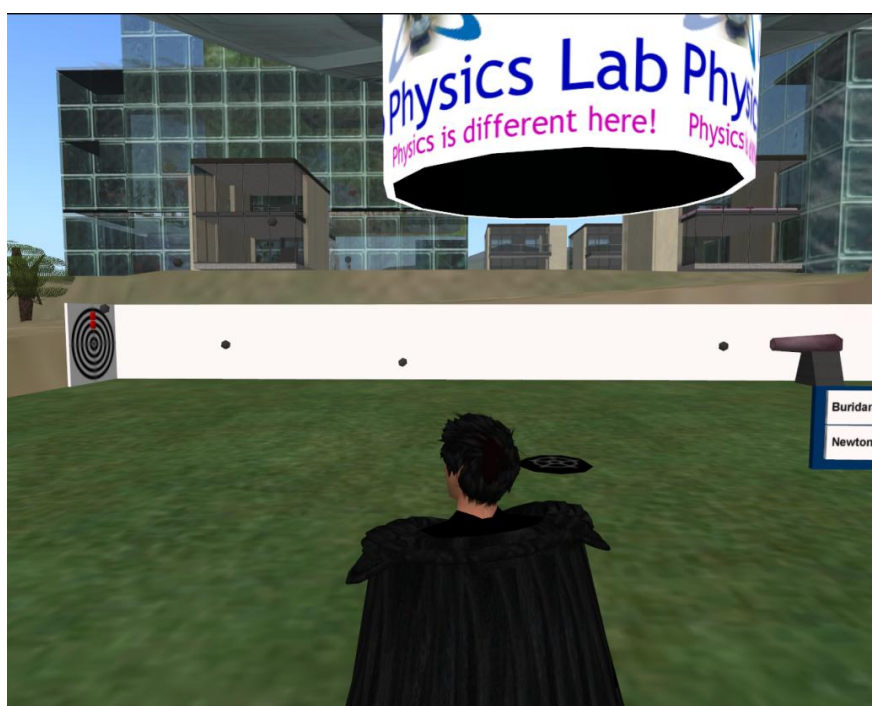


Figure 5 - Projectiles falling down due to script delay to counterbalance gravity
Source: photo taken by the author

¹⁵ This cannon is freely accessible in our Second Life Physics Lab via the link http://www.fisica-interessante.com/virtual-second-life-physics-laboratory.html#Buridanian_Cannon

Now, we proceed to evaluate the SL environment as a platform for physical microworlds and simulations.

EVALUATION OF SL AS A PLATFORM FOR PHYSICAL SIMULATIONS

Following Reis & Andrade Neto (2002), we will give more emphasis to features relevant to the teaching and learning process than to criteria more relevant in terms of computing like stability, aesthetics, compatibility, portability, and the like. We had, however, to generalize their criteria, as their work was focused its analysis on simulations of mechanical collisions.

1 & 2. Representation of physical quantities in real time

Physical quantities are not automatically represented by the SL client. Nevertheless, LSL provides functions to access directly some of them, e.g. *llGetPos* and *llGetVel* that return the position and velocity of the object in the region, respectively. Therefore, these quantities can be represented directly, in real time, during the entire duration of the phenomenon, as highlighted in Figure 3 and in Figure 6. There are no functions in LSL to access the value of some other relevant quantities, such as kinetic energy, momentum, and so forth that can be easily calculated by the script from those basic quantities, however.



Figure 6 – Information panel in our gamesim *Lander Simulator*¹⁶.
Source: photo taken by the author

¹⁶ This *gamesim* is freely accessible in our Second Life Physics Lab via the link http://www.fisica-interessante.com/virtual-second-life-physics-laboratory.html#Lander_Simulator

3. Explicit relationship between conservation of physical quantities and type of collision

As we have seen above, the script either has access to the relevant quantities or can calculate them. Therefore, it is not a problem for the programmer to make the script to display some kind of warning, depending on the quantity is conserved or not. This could lead the student to pay attention to the way the experiment happened and make the desired association.

4. Representation of physical quantities both in scalar and vector form

LSL functions return the value of physical quantities in the correct scalar or vector form. We have already demonstrated elsewhere (dos Santos, 2012a) how the script can make use of the SL resources to represent them in correct form.

5. Is it a simulation of an actual experiment?

Reis & Andrade Neto (2002) argue that difficulties in student understanding, arising from differences between experiencing a phenomenon through an actual experiment or through a computer simulation, could be minimized if it represented an actual, easily accessible, phenomenon in student's everyday situations or laboratory. If we compare the collision simulators of Figure 3 and Figure 4, we have to agree that the former is more "real" in the sense that it duplicates a well-known laboratory equipment. However, the interactivity, the sense of 'presence', the participant observation from inside the experiment, of the second simulation, surely provides a richer, more intense, and meaningful experience to the student (Greis & Reategui, 2010). Likewise, the exploration of interactive life-size molecules (Lang & Bradley, 2009) and of fractals (Lee, 2007) do not represent 'real' experiments and much less accessible ones, but are innovative and stimulating experiences that definitely cannot be made in a classroom or in a laboratory. Therefore, we allow ourselves to disagree with Reis & Andrade Neto (2002) on this criterion, when referring to simulations in immersive 3D virtual worlds like SL.

6. Manipulation of initial parameters, e.g. velocities, masses, and positions

This feature is very important because it assists students in understanding their relationship with the physical concepts and phenomena. It is feasible in SL, as the script can use the LSL *llRezObject* function to set the initial position and velocity of a physical object. To define the object's mass, it can use the *llSetScale* function, since in SL it depends on the size and not the 'material' of the object, as we have already discussed elsewhere (dos Santos, 2009).

7. Variety in visualization of physical quantities

LSL and SL resources to build and manipulate textures and objects allow the script author to represent them in various forms, including bars, graphics, animations, icons.

8. Ease of use of the program, stability, and portability

The computational effort exerted by SL grid of computers leads to undesirable but understandable system instability and occasional falls. On the other hand, as almost all the processing occurs on servers, the client software is small and easily portable to a variety of operating systems. Unfortunately, however, the simulation itself cannot be exported as Java applets and be run remotely in a web browser as allowed by other platforms, e.g. *AnyLogic* (Rodrigues, 2008).

In conclusion, the rich immersive 3D massively multi-user experience SL provides is pleasant, engages the user to explore the territory, and, therefore, offers a number of advantages over a 'traditional' 2D simulator. Despite of that, we cannot say that SL is an easy-to-use platform. Most users agree that a high learning curve exists for new users (Sanchez, 2009), which means that any proposal of using of SL for teaching has to set aside several hours, just to have the students become familiar with basic tasks, e.g. walking, pass through doorways, go up stairs, manipulate objects, and so forth.

CONCLUSION

Sanchez (2009) concluded that "designers can create a user experience that will build on the strengths of the virtual world while overcoming the obstacles." We agree with Sanchez and consider that SL

shows itself as a viable and flexible platform for microworlds and simulations even if it requires some creativity to overcome the difficulties of implementation seen on the above examples. We consider that Modellus (Teodoro et al., 1996) main innovation was to provide users with a very accessible interface that eliminated the need to program graphic interfaces in personal computer working in DOS. Our vision is that SL is equally innovative as a 3D platform that could be made much more accessible to novice users with a textual interface such as TATI - The Amiable Textual Interface for Second Life (dos Santos, 2012b) which is under final development. It allows users to build simple simulations and microworlds in an easy way without being forced to enter into the depths of LSL programming, reducing the above-mentioned learning curve and making such an interesting tool as SL available to a number of teachers.

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HOW TO IMPLEMENT A BETTER USE OF MBL IN THE SCIENCE CLASSROOM?

Fina Guitart, Montserrat Tortosa

ABSTRACT

A teacher training course on the use of new technologies in secondary science laboratories was designed and implemented with science teachers. The sequence was designed as a result of an international Socrates project on the Effective use of ICT in Science Education, and on the basis of reflective practice as a methodology to improve own teaching practice. Participants were experienced in service teachers, but novice in the use of microcomputer based laboratories and real time experiments. The objective of the work is twofold. On one side it aims to establish, from the point of view of teachers, what are the most relevant aspects of a Microcomputer Based Laboratory (MBL) activity that lead to an effective use of it. Moreover this work aims to contribute to preview if teacher training strategies promoted an improvement of the use of MBL in the classroom.

In this work we present the aims and structure of a teacher training course designed to promote an effective use of ICT in science education and opinions of teachers that participated in this course. We focus on an activity contextualized in pollution from heavy metals in a pond. In this activity teachers guided their students using a conductivity sensor to perform an experiment and the corresponding calculations to remove a metal using precipitation. Teachers were interviewed and videotaped. Their videos were used and self-analysed in the teaching training course.

KEYWORDS

MBL, teacher training course, lab activities

INTRODUCTION

Some background in the effectiveness of MBL

Microcomputer Based Technology (MBL) has demonstrated the ability to improve students understanding of science concepts and cognitive skills such as observation and prediction. The ability of the computers to display the data graphically is cited as one of the reasons why MBL is so effective (Friedler, Y et al. 1990). This technology has been strongly recommended by many science educators who adopt a constructivist approach to education (Tortosa et al, 2008). The use of MBL in chemistry lessons has increased en last years among secondary teachers en Catalonia, but the use of sensors is not generalized and teachers usually don't feel confident of the use of this equipment (Pintó, R.; Sáez, M, 2006). Some analysis and reflections point toward the use of MBL to develop general skills and scientific competencies in students (Lope, S. et al., 2009).

However, the effectiveness of ICT is linked to pedagogical models and strategies surrounding ICT activities, as well as the teacher's skills and confidence to use equipment. Teacher training is a key aspect to get an effective use of this equipment. During the development of the project "Effective use of ICT in Science Education" there was a change in the teacher training model of the Department of Education and a teacher training approach focused on reflection of own practice was implemented.

A teacher training methodology: Reflection on own practice

Reflection on own practice is a teacher training methodology based on the experience of teachers in their own practice, in which teachers share and contrast their teaching. This methodology takes into account personal and professional experience, its focus being to update and improve teacher

performance. The use of reflective practice methodology in teacher training promotes the formation of learning's communities (Tigchelaar et al, 2005). Teachers learn from each other "peer to peer learning" and the teacher trainer is as the other participants, but at the same time he has the role of expert and delivers the theoretical information (articles, books, presentations, etc.) (Korthagen, F.,2001).

To implement this methodology it is necessary to create the "learning community". That means that it's necessary to work in a systematic way in order to develop the atmosphere for mutual confidence between the members of this learning group, because these community teachers will have to share experiences, to observe each other, to self-observe. The communications between the members of the group, and between them and the teacher trainer, are of primary importance. This is partly done through the use of an online network (Moodle) specially created and designed for these group work teams.

The video analysis: a good way to collect evidence in classroom

Video analysis is one of the best ways to collect evidence of what happens in the classroom and to analyse many different aspects involved in the class management. This includes the performance of the teacher in the classroom. This technique is considered very useful when using reflection on own practice teacher training methodology. It allows teachers to analyse themselves and have peer to peer feedback about their performance in the classroom and to look for evidence of the teaching and learning process.

DEVELOPMENT

Looking for good MBL practice

What do we understand for a better use of MBL? What are the most relevant aspects of MBL activity to achieve an effective use?

A study of the characteristics of a good MBL practice was carried out. Teachers' networks were created and guidelines of ICT activities were analysed using a list of elements to be assessed and teachers had to answer questions after performing the activity. Questions were about the guidelines for the activity and about classroom dynamics and teachers' management, and about pupils' assessment (grid for pupils). The reported analysis and conclusions are from the work carried out by 17 Chemistry and Physics teachers from 10 secondary schools. Each teacher tried out one or more activity. During this practice based period, teachers exchanged ideas and opinions and gave each other feedback about their experience.

The findings, based on teacher and student opinions, shown that: -worksheet for students are more useful if they are adapted for the time proposed, - activities are more effective when the laboratory materials for the experiments are easily set up and assembled, - the easier the activity, the better the students can understand how the sensor and equipment works, - it's better to begin with simpler experiments and graphs because students are not used to reading and interpreting charts.

The features of a guideline of good activity were discussed. The conclusion was that a good guideline should take into account a context of the activity, a problem to solve and some questions to help students to set the hypothesis, to analyse which variables take part, how to measure them, how to set up the system according to the parameters needed when working with MBL activities, etc. It's recommended to put the instructions about selecting the appropriate sensor and setting up of the data logging system, etc. at the end of the student worksheet, or in an annex document. Guideline has to promote comparison between hypothesis or predictions and obtained results, to promote qualitative analysis of the data obtained before the quantitative analysis, interpreting the results and drawing a conclusion related to the initial problem. It has to propose the generalization and application to different situations and also to ask students to produce a report on the activity and to communicate results and conclusions.

In the analysis of MBL, an important aspect was noticed. How to plan the activity (adapting the activity to the specific didactic objectives and the level and previous knowledge of students) and how to manage

the students during the activity was very important to improve learning. So, we realised that one of the most important aspects to take into account when performing ICT activities with students is classroom management. When we say classroom management, we mean and understand: time management, the lay out of the classroom or lab, and the distribution of equipment, the teachers' behaviour in the different phases of the lesson and also the students' participation in individual or group work.

Video analysis of classroom performances became a key tool to look for more effective classroom management. 15 films of teachers performing activities MBL were analysed by all the teachers of team, through the questionnaire which included questions about: the layout of classroom or lab, how the aims of the activity are presented, the context of the activity, how the activity has been planned, students' interactions and teachers' intervention, analysis of the results and conclusions, etc.

The conclusions of the analysis of classroom management using ICT activities can be summarized as follows:

- The organization of the environment is an important aspect. A lay out that promotes a good development of the activity is that student are sat in groups around the computer, placed in a way that everybody can see the computer monitor and the teacher.
- The presentation of the aims of the activity has to be with the participation of students. Isn't a good practice to read or to tell to the students a long list of aims and it's useful that teachers ask about context and make questions and comments to relate the activity with other ones and show the relation between them and previous experiences using MBL.
- It's important don't forget to spend the necessary time for students to make their predictions and hypotheses and for discussion amongst students in their group and to contrast those predictions and hypotheses with the results of the experiment to find an explanation, and argue their conclusions. It is important that students share their results and ideas.
- It is appropriate that the teachers help the students to work in an autonomous way. They have to promote a dialogue between student and teacher (Socratic dialogue) that conduct the students to overcome their difficulties, solve problems and construct learning. Teachers could ask students what are they doing and why or they doing this way. Sometimes it can be necessary for some explanation to the whole classroom. The role of the teacher has to be interactive, asking questions to make students think of the answer, more than a teacher giving a lot of instructions, telling results before performing experiment, etc.

The teacher training course: characteristics of the course and feedback from teachers

How teacher training strategies promote an improvement of the use of MBL in classroom?

The pilot course designed during the Comenius project "Effective use of ICT in science education" (Demkaninn et al. 2008; Guitart, J. et al., 2009) uses reflection on own practice as a teacher training methodology and includes the results of the analysis of good ICT practices. It's a course for science teachers (Biology, Chemistry and Physics) at secondary school. The aim of the course is to help the participants in the improvement of the planning and management of ICT activities. There is only a small part of the course for technical aspects. The course consists of 4 sessions (10 h contact time) and 10 hours non-contact time. Session 1, 2 and 3 can be run consecutively but there must be a break of 6 weeks between sessions 3 and 4.

The course takes the teachers own experience in using MBL with their pupils and looks to arrive at a consensus of what features make good management of MBL activities. The participants will see and analyse films of teachers in action, they will plan MBL activities in groups or individually, they will do activities with their students and will film their own classroom session.

Video analysis is a key point of the teacher training course. Teachers in the course uses the questionnaire previously designed to analyse management aspects of effective use of MBL, and they analyse videos of other teachers and they own videos.

Methods used during sessions are a variety of analysis and comparative methods (individual reflections, discussions, presentations, group work, feedback, etc.).

The non-contact work consists of:

- To plan an activity that can be done with their students. It may be the same activity participants have already planned working in groups during the course or they have already seen in the videos.
- Film all or part of the chosen activity taking into account aspects of good management of ICT activities and model videos.
- Keep in touch with the teacher trainer and the participants of the group by using Moodle and to keep using it after the course.

Feedback from teachers is collected from questionnaires of video film analysis and from worksheets used in the teacher training course. The teachers saw video films in where other teachers performed MBL experiments in classroom. The teacher training course engaged sixteen teachers.

In this communication we focuses in the analysis of one of the video films of an experiment (Tortosa, 2008) in which students collect data using a conductivity sensor connected to MBL equipment. Students could calculate, from their results, the amount of iron in a polluted water in order to remove the metal of it. The laboratory worksheets were designed as a learning cycle. The analysis of video films was focused on classroom management, but also included questions about the laboratory worksheet.

CONCLUSIONS

Communication brings the results of analysis questionnaires of classroom video films used in this course and feedback from participants and also from the comments and opinions of teachers who were engaged in teacher training course. We have drawn the conclusions from questionnaires and from feedback.

Questionnaires contain questions about the organization of the environment, how does the teacher present the activity, the planning of the activity before carrying it out, the interactions between the students and between the students and the teacher, the organization of the activity in one or more lessons, the analysis of the results and the conclusions, to cap and to summarize the activity, and the feedback from the students.

Analysis questionnaires of classroom video films

Conclusions about an effective use of ICT based on the results of analysis questionnaires of classroom video films were drawn:

- Participants identify and highlight the many factors and aspects related to the effective use of MBL. Among them, there are: a good distribution of equipments, enough time so students can make hypothesis and predictions, the discussion of their predictions between them, the dialogue between students and teacher, the contrast between predictions and the graph and how conclusions are drawn.
- A relevant feature is related to the design of student worksheets and the context in which the activity is presented to students.
- The importance of classroom management.
- To see video films of activities and the videotaping of their own activities as an important tool to learn about how to perform these activities and how to improve their practices.

Feedback from the trainers and from participants

After performing the pilot teacher training course, feedback from the trainers and from participants allow drawing some conclusions based on, the comments from teachers involved in the course, and feedback worksheets from participants in the teacher training course:

- There were no problems with the activities of the course and the general development. The trainers felt satisfied with the course but the time planned for some activities was too short, and it is because of that, that some activities were not completely finished. Sometimes these sessions overrun a few minutes. There is the possibility to enlarge the time schedule for each session. Participants had to do a lot of homework. For this kind of work some extra hours could be added.
- Participants were satisfied with the course and would like to keep on working together. The comments of teachers after the course were positive and they highlighted the importance of MBL in the graph plotter and importance of didactic and pedagogical aspects involved in the use of MBL. Effective use of MBL activities is largely determined by aspects as classroom methodology and a teacher training that promotes reflection about teacher's own practice.

COMBLAB: an international project to support teachers to enhance the significant use of dataloggers in science classrooms

With the objective of accompanying teachers to enhance the significant use of dataloggers in science classrooms, a new international project (The acquisition of science competencies through ICT real time experiments- COMBLAB), co-financed by the Long Learning Agency of the European Union and several Universities has started in January 2012. The partners of the project are Universitat Autònoma de Barcelona, Universitat de Barcelona, Charles University in Prague, University of Vienna, University of Helsinki and Bel Matej University of Slovakia. The project will take into account previous experiences, as the one presented in this work, to prepare a teacher training course.

The objectives of the COMBLAB project are to:

1) *Obtain research based teaching materials* to enhance on students the acquisition of science competencies trough ICT real time experiments. 2) *Obtain research based teacher training materials* to enhance the mentioned competencies. As ICT real time experiments are a new technology, few teacher training materials are available. 3) *Share within the consortium and to disseminate the outcomes in a public website* and in the future in *national and international conferences and journals*. 4) *Create a community* of teachers/researchers from different countries of the consortium to exchange experiences and good practices in the field, and be *in contact with existing communities*. 5) *Create synergies with national and local education authorities* of each of the countries of the consortium to promote that the use of the outcomes of the project is taken into account both in initial and continuous teacher training.

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COMPARISON OF TRADITIONAL AND COMPUTER-BASED PRACTICAL ACTIVITIES IN PHYSICS AT THE UNIVERSITY; THE PERSPECTIVES OF MODELLING AND TASK ANALYSIS

Christian Buty, Claire Wajeman

ABSTRACT

This communication deals with the use of ICT in practical activities about ferromagnetism, in the second year of University (vocational route). During these activities, students work by pairs, guided by written instructions, with the occasional help of a teacher; at the end of the practical session (four-hours long), they must deliver a written report. This study has its origin in the replacement of an old version of the instructions, involving traditional equipment, by a new version, involving a computer-based animation and data acquisition. The computer-base animation introduces a new modelling level (at a mesoscopic scale), which is not in the old version.

We want to know how the combination of ICT (animation and data acquisition) with tasks may or may not help students to better understand the hysteresis phenomena and to perform practical tasks.

We analyse the video records of students' activity and compare it to written instructions according to two dimensions: first, the modelling levels of the utterances in students' verbalizations and in the text; second, the activities performed by students and the tasks demanded to students. The kind of analysis is a categorisation, performed through the use of the VideoGrapher software.

The achievement of the innovation learning objectives relies upon dialectics between the didactical innovation elements (model and students' tasks) and the ICT-based resources: each kind of resources (traditional equipment or computer-based animation and data acquisition) strengthens different kinds of knowledge and the pedagogical environment has a major influence to support students' activity and progressive understanding of models.

KEYWORDS

Ferromagnetism; animation; data acquisition; modelling; tasks.

INTRODUCTION

Although ferromagnetism-related phenomena have a great practical and technological importance, it is noticeable that very few studies have been devoted in science education to their teaching or learning, while a substantial literature exists about magnetism in general (for example Borges & Gilbert, 1998; Saaglam & Millar, 2006; for some elements on hysteresis phenomena and the use of ICT for teaching magnetism, see Mukhopadhyay, 2006).

However, teaching experience shows that ferromagnetism-related phenomena are difficult to understand for students at the first grades of University, for several reasons:

- The vectorial and three-dimensional nature of physics entities that are involved;
- The emergence of a new entity, the excitation field H , particularly abstract, which is omitted in every application of the magnetism in everyday life;
- The unusual character of the hysteresis phenomena;

- The fact that everything happens inside a material, and therefore everything escapes our direct perception; all the physical quantities can only be measured indirectly.

Consequently, this work is based on the idea that, for going beyond these hurdles, it is useful to give students a simplified explanatory model of hysteresis phenomena and a visual representation of it.

THE CONTEXT OF THE STUDY

This work was carried on in the context of a vocational University chemistry curriculum, during a physics practical course. Students work by pairs, under the supervision of a teacher who is in charge of six pairs working on different activities. The activity lasts four hours. While performing their experiments and measurements, students must write a report, which is to be finished at the end of the 4-hours session. As the teacher deals with six groups, s/he intervenes in a given group only a few minutes in the session, generally at students' request, and when there is a problem.

A practical activity about hysteresis phenomena has existed in this course from many years, using traditional devices such as a galvanometer. Given the obvious difficulties students had to understand what the knowledge objective of the activity was, a new version of the practical activity was elaborated, by the authors of this communication and another colleague, and put in operation from 2008. Due to the limited length of this paper, no indication will be given for justifying the design of this new version of the activity. The important point for our purpose here is that this new version involved the use of two ICT tools: a simulation of a simplified model for hysteresis phenomena, and a data acquisition system.

THEORETICAL PERSPECTIVES: MODELLING AND TASK ANALYSIS

A constant tradition in science education research (for example Gilbert & Boulter, 1998; Buty & al., 2004) has emphasized the importance of modelling processes, as well in designing teaching activities as in analysing the classrooms events and discourse. By nature, this modelling perspective consists in distinguishing (at least) two different levels in knowledge or in verbalisations: the world of objects and events, the world of theories and models, to use Tiberghien's terminology (1994). In some cases however, it can be useful to specify the scale of the models. For example Besson & Viennot (2004) introduce three scales of modelling in pressure phenomena in fluids: a microscopic model, at the scale of atoms or molecules; a mesoscopic one, at an intermediary scale; a macroscopic one, at a scale of perceptible events for human beings that is, at the scale of macroscopic quantities.

Tasks is a notion inherited from common language, which refers nevertheless to various research traditions; in particular it is of frequent use in computer science (Dix & al, 2003), and it has been widely employed in mathematics education (Chevallard, 1992) or in science education, specifically in labwork studies (Wajeman & al., 2005). The interest of using this notion is twofold: for designing an activity, by giving a hierarchical organisation and criteria of relevance (such as learning objectives, students' state of knowledge, teaching constraints); for analysing the relationship between prescribed tasks (in the instructions) and effective tasks (during the practical session). It is important to insist on the idea that a task involves an effective action (not only reading) from students.

Coupling the perspective of tasks organisation and the perspective of modelling processes allows addressing some questions like the kind of tasks (and of resources used in these tasks) that favours the use of such and such modelling level, or the establishment of links between modelling levels.

DESCRIPTION OF THE TWO VERSIONS OF THE PRACTICAL ACTIVITY

The old version

The former version of the practical activity was organised around an experiment, consisting in drawing the hysteresis cycle for a ferromagnetic torus, with two coils on it. A set of switches allowed giving several different values to the current in the primary coil, thus changing the magnetic excitation H

inside the ferromagnetic material, and consequently the magnetic field B . During the changes, a small quantity of electricity was moved in the secondary coil, which provoked the rotation of a galvanometer. Students had to measure the current and the deviation of the galvanometer, and (by using some formulas) to convert the current in values of the magnetic excitation, and the deviation in values of the magnetic field. This allowed drawing the hysteresis cycle (figure 1). The ferromagnetic torus is shown on figure 2.

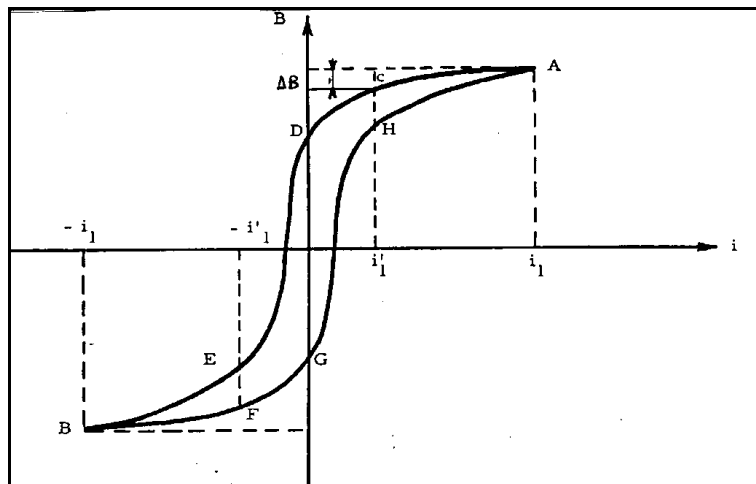


Figure 1. The hysteresis cycle.



Figure 2. The experimental device for the old version of the activity.

The main difficulty for students consists in understanding that a given deviation of the galvanometer corresponds to the variation between two values of B (ΔB on figure 1). During this practical activity, they constantly work with macroscopic entities and with objects or events.

The new version

The revised version of the practical activity still uses a ferromagnetic core with two coils. It has an organisation in two steps, basically. The first step is the use of a computer-based simulation; the screen of the computer is represented in figure 3.

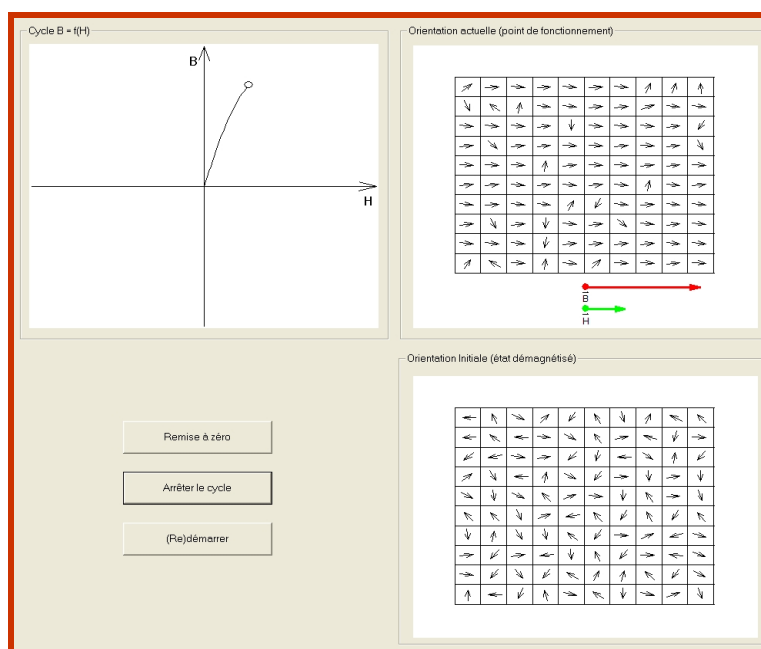


Figure 3. View of the simulation; in the top, left, a state of the hysteresis cycle for a given value of H and B ; on the top, right, the corresponding representation of the orientation of magnetic domains; down, right, a recall of the initial orientation (in complete disorder) of the magnetic domains; down left, the buttons for commanding the simulation.

This simulation establishes a correspondence between the macroscopic hysteresis cycle and a representation of magnetic domains (in the elementary form of arrows), which can be attributed to a mesoscopic level of modelling. Students have to describe the whole cycle, observing the orientation of the elementary magnets for the various positions of the point on the cycle.

The second step is a data acquisition through a bidirectional-computerised interface (figure 4). The interface commands the variation of the current in the primary coil; it also measures and digitalises the voltage between the extremities of the secondary coil, so that the computer can calculate the variation of B between two states of the current. The calculation and display under the aspect of an oscilloscope is realised through Labview© (figure 5). Students can visualise the voltage, its integration and the hysteresis cycle; they acquire the values from one point to the other, by clicking on a button on the screen.



Figure 4. Interface in the computer-based activity.

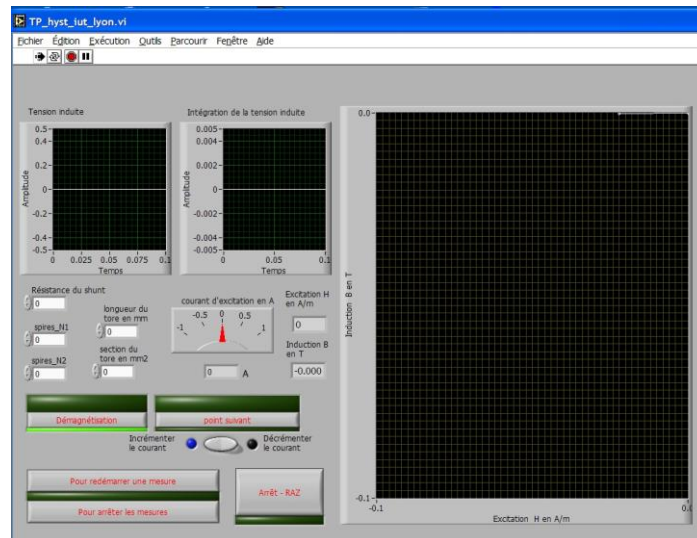


Figure 5. View of the screen when acquiring the data in the new version.

If we compare the old and the new versions of the practical activity, they have in common the decision to draw the hysteresis cycle point by point, emphasizing the scientific mechanism going from a discrete variation of intensity to a discrete variation of the magnetic field. The main difference, from a pedagogical point of view, is that in the second version students must make a reflection on the meaning of the hysteresis cycle before doing the experiment. To this regard, the use of two computer-based tools, articulated in a single activity, has something common with the proposal made by Pinto and colleagues (2010), although our pedagogical background is much more traditional than inquiry-based learning.

ANALYSIS OF THE INSTRUCTION TEXTS

Questions

If we consider only the instructions that are given to students to perform the practical activities, we can compare the two versions, the old and the new, from the point of view of the modelling levels that are used in the text. The underlying idea is that reading and working at a given level could prompt students to verbalise the same level, or at the contrary, to make a link with another modelling level. This could be thus considered as a preparatory study for forthcoming analyses about students' activities.

Methods

Given what has been said about the two versions of the activity, four modelling levels will be used in these didactical settings:

- The world of objects and events.
- A micro-model, involving the atoms and their magnetic moments.
- A meso-model, involving magnetic domains in the ferromagnetic material.
- A macro-model, involving physical quantities such as the fields or the permeability, or relations between these quantities.

It is highly probable that the micro- and meso-level will be used in the new version only.

We have chosen to count the lines of the texts, in order to study the use of each modelling level in these instructions. Each line is attributed a level; sometimes, in a line we can find reference to several levels: we decided to count this line for each of these levels, for this could be a sign of a link between the levels, and not simply juxtaposition.

The various steps of the activities have been classified into several types in order to compare the two versions (table 1).

The results are given later in table 2.

Table 1. Categorisation of tasks.

Categories of steps	Codes	Complementary information
Theoretical parts	T	
Technical information	W	Information about connecting the components for example
Experimental activity (without measurements)	E	
Experimental data acquisition	A	
Data processing	P	
Interpretation (of results or observed phenomena)	I	
Simulation	S	Interpretation of phenomena from the use of the simulation

ANALYSIS OF THE STUDENTS' BEHAVIOUR DURING THE PRACTICAL SESSION

Questions

Considering what has been said about the text analysis, a first series of questions concerns the correspondence between the use of modelling levels in the texts and in the students' verbalisations, in order to estimate the implications of the way the texts are written on the modelling processes developed by students.

Our other focus is the relationship between the kind of tasks performed by students and their use of modelling levels.

Methods for collecting the data

The collected data mainly consist in video-recording the performance of a pair while realising the practical activity, using one camera and two microphones.

Methods for treating the data

The video-recordings were analysed through the software Videograph© (<http://www.ipn.uni-kiel.de/aktuell/videograph/enhtmStart.htm>). The principle of this software is to affect pre-defined variables to intervals of the videotape. We decided to take a fixed duration (15 seconds) for the intervals. It means that we somehow realise a sampling of the videotape, with a resolution of 15 seconds (see figure 6).

The coding was realised by both authors, independently in a first phase. We cannot explain here the sophisticated process allowing resolving the disagreements between the two coders; at the end of this process and for each variable, the agreement is better than 85 % of the intervals coded with this variable.

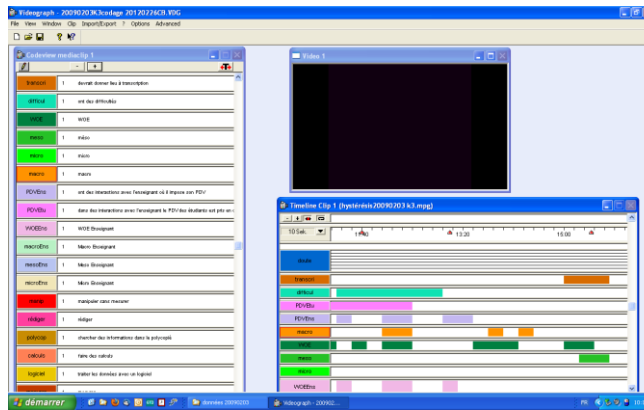


Figure 6. The computer screen when coding the videotapes; upright, the video runs in the black window; left, the window with all the coding categories; downright, the display of the time intervals (horizontally) and of the categories (vertically); an interval appears as coloured on a line if you have clicked on the corresponding category in the left window.

SOME RESULTS ABOUT STUDENTS' PERFORMANCE

We shall present here some findings for two practical sessions, the first one concerning the old version of the practical activity and the second one concerning the new version, therefore involving two different pairs of students, supervised by two different teachers.

Global use of modelling levels

We present these results in table 2, giving the analysis for the texts in the second and fourth columns, and comparing it to the analysis of students' activity in the third and fifth columns.

Table 2. Repartition of lines and time (time intervals) in the two versions between the various modelling levels. The percentages in the second section of the table (modelling levels) are calculated from the total number of lines or intervals. The percentages in the third section (students' tasks) are calculated from the total number of lines or intervals during which students are demanded (text) or realise (videos) an observable task. It is normal that the total of percentages overpasses 100%, as some lines/intervals are counted in two levels.

	Old version		New version	
	Text	Video	Text	Video
Number of lines/intervals	96	640	184	968
WOE	51 %	50 %	30 %	12 %
Macroscopic model	54 %	26 %	66 %	20 %
Mesoscopic model			9 %	2 %
Microscopic model			4 %	0 %
Students tasks (number of lines/intervals)	25	576	55	667
Students tasks in WOE	76%	66 %	20 %	14 %
Students tasks in macro model	28%	31 %	80%	24 %
Students tasks in meso model			11%	2,5 %

A remark must be made to interpret a rather surprising observation. In the second practical activity, the low percentages of verbalisations in the various modelling levels can be explained by the fact that students write a lot for their report: 65 % of the total time.

Global allocation of time by students to the various kinds of tasks

Figure 7 shows the percentage of time that students allocate to the different types of tasks (as defined previously), which they have to perform, comparing to this regard the old version of the practical activity and the new one. It is clear that the panel of tasks is much richer in the new version, at a first level; and secondly it can be observed that an important proportion of this time is devoted to the use of the simulation, where the mesoscopic model is introduced and linked to the macroscopic model.

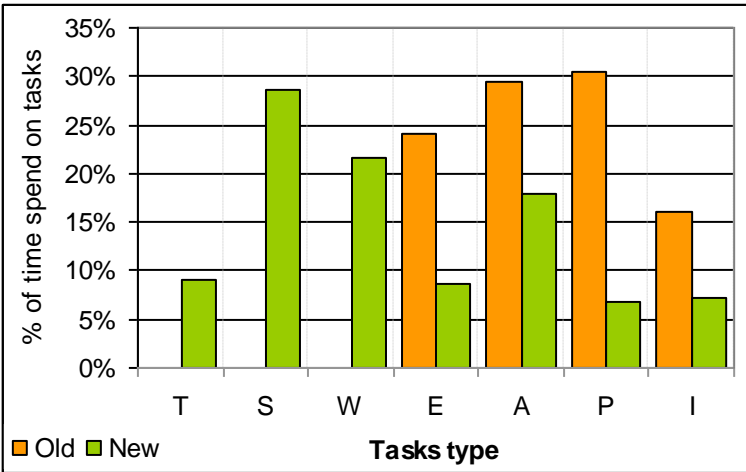


Figure 7. Allocation of time by students depending on the kind of task.

The order of the kinds of task on the graph figure 7 is not arbitrary: it follows more or less the chronology of tasks in the two practical activities as can be seen on figure 8.

Modelling levels and tasks

Figure 8 below shows the use of modelling levels by students during the various tasks of the practical activities.

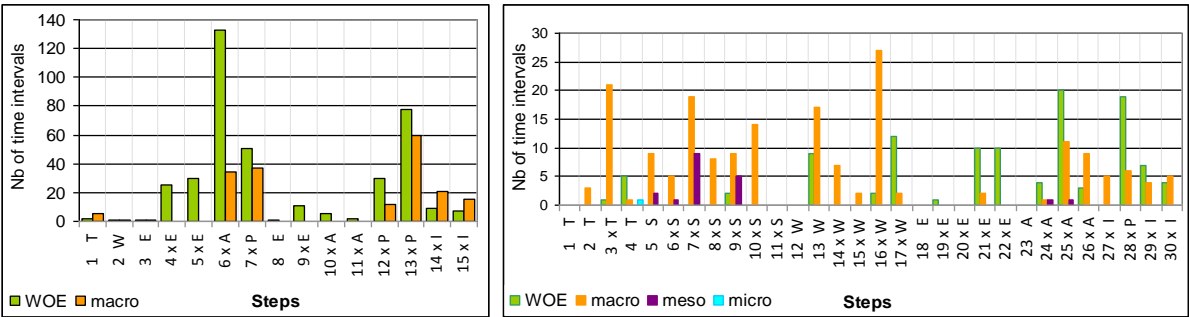


Figure 8. Repartition of the modelling levels in the old practical activity (left) and in the new one (right); the different elementary steps of the activity are sequentially indicated by numbers (1 to 15 for the old activity, from 1 to 30 for the old one); the steps that need a task to be performed by students are marked by an 'x' and the kind of task by its code (see table 1).

DISCUSSION AND CONCLUSION

A first remark is that the proportion of time devoted to the world of objects and events is obviously lower in the new version than in the old one; it is normal, because the computer takes in charge a lot of manipulations students had to realise by themselves in the old version, and thus it is not worth giving instructions on it. In the new version, the use of the mesolevel of modelling is rather limited, to 9 % of the lines, and the winner in the transformation is rather the macrolevel of modelling. Hence we can suggest that the explanatory power of a feature (here the mesomodel) is not necessarily a matter of quantitative abundance.

The group working with the old version encounters many difficulties during data acquisition and processing. Therefore they spend 84% of tasks time on these tasks and it requires frequent interventions of the teacher. Finally they spend little time dealing with the hysteresis phenomenon to be studied (interpretation tasks). Furthermore the frequent relations between the WOE and macro levels that are observed meanwhile, do not concern the phenomenon, but data acquisition and processing strategies. With the computer-based data acquisition system, the group working with the new version spends much less time on these tasks (33% of tasks time). It seems that also they spend less time on results interpretation, but this can be interpreted as follows: they spend a lot of time working with the simulation (see figure 7), which allows them to identify quickly and successfully the various aspects of hysteresis. The new version allows the students to relate the modelling levels in various circumstances, meso and macro, or WOE and macro levels mainly, but sometimes the 3 levels while working with the simulation. These students encountered once a practical problem about the circuit demagnetization; however they could explain it almost alone, by mobilizing the 3 levels. Furthermore this new version allows these students to work autonomously.

Finally the new version of the practical activity, based on two different pedagogical possibilities for computer in science education, clearly seems to improve the understanding of hysteresis phenomena by students.

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MULTIMEDIA LEARNING IN PHYSICS

Raimund Girwidz

ABSTRACT

In this paper multimedia will be regarded as a tool (among others) to promote learning. However, there are many factors that can become relevant. Thus, it makes sense to focus in a first step on the most important aspects that characterize the strength of multimedia. According to Weidenmann (2002) those special features are multicoding, interactivity, and multimodality. They open up new ways for teaching and learning.

However, strictly seen, multicoding, multimodality and interactivity describe superficial characteristics of the user interface. Further theoretical considerations can help to improve teaching and learning. They focus on particular instructional intentions. Among them are: a) Offering additional knowledge representations by visualizing essential aspects, b) Supporting the construction of mental models and connecting abstract concepts with examples from reality, c) Using special features to assist the development of "cognitive flexibility", d) Using illustrations to structure knowledge. Also findings from empirical studies will be presented, showing factors and conditions that are important to achieve these objectives. Furthermore, different examples will make clear that it is important to guarantee a sufficient depth of processing, as well as to avoid a cognitive overload by offering to many details in a short time.

In addition, some findings from the MPTL (Multimedia in Physics Teaching and Learning) reviews will be presented. For 10 years this international group has evaluated internet resources.

KEYWORDS

Multimedia learning, multicoding, multimodality, interactivity, web-based learning, e-learning, mental models, cognitive flexibility

This paper also summarizes descriptions from several of my former papers and presentations.

INTRODUCTION AND OVERVIEW

Modern media provide new ways to present information and offer new communication opportunities. At first the following features will be regarded: multicoding of information (*i.e.*, offering different presentations and coding systems), multimodality (*i.e.*, the possibility to address several senses), and interactivity with a learner/user. These characteristic features of multimedia will be explained by concrete examples.

Then aspects of well-designed applications, seen from the eyes of experts, will be regarded in the second part of this talk.

However, when focusing on learning processes, it should be clear that these features characterize a rather superficial structure, and further aspects of learning have to be considered. For example, multicoding might be helpful in assisting learning by combining the potential of different code systems. However, offering multiple representations may increase the density of information and cause a cognitive overload. Therefore guidelines derived from psychology of learning will be regarded to take into account further aspects that go beyond a superficial perceptual structure. The explanation of theoretical considerations by concrete examples will be the intention of the third part of this presentation.

MULTICODING, MULTIMODALITY, AND INTERACTIVITY

According to Weidenmann (2002), multicoding, multimodality, and interactivity describe special features of information and communication structures, offering new ways for teaching and learning.

Multicoding

Weidenmann (2002) highlighted the importance of different coding systems when using multimedia to promote learning. Any processing of information is based on code-specific expressions, especially in the early stages of a learning process. Additionally, physiological studies provided evidence that specific cerebral cortex areas are responsible for processing textual or visual information (Springer & Deutsch, 1998). Visualizations are useful if they present facts and concepts in task specific ways. However, if they are not understood in the right way, they can also cause difficulties (Schnotz & Bannert, 2003). Therefore, an appropriate form of presentation plays an important role in learning.

Learning and problem solving in physics make extensive use of different kinds of representations. Graphs, illustrations, diagrams and various symbol systems are used (see fig. 1 for some examples).

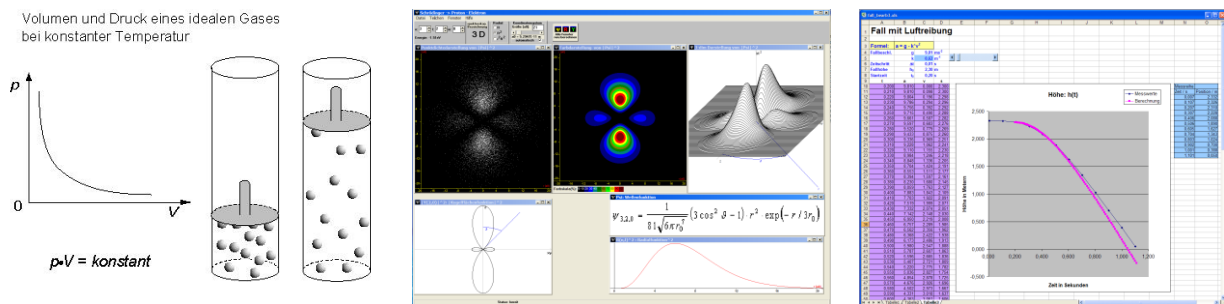


Fig. 1: Examples for multicoding of information.

Multimodality (Sounds and Pictures)

A multimedia application which offers acoustic and visual information activates different senses. Mayer and Moreno (1998) described a "split-attention-effect" and found better learning results when verbal and visual explanations were combined. The authors underlined the importance of two separate channels for processing visual and auditory information in working memory. The combination of verbal and written components, therefore, may lead to a better processing in a working memory with a limited capacity (Moreno & Mayer, 1999).

Interactivity

Interactivity is expected to motivate and activate learners by permitting them to play an active role. Learning theories more and more put emphasis on active learning and self-pacing in learning situations. Furthermore, especially simulations can offer also an inherent feedback by the reactions of the system that is regarded.

QUALITY ASSESSMENT BY EXPERTS ACCORDING TO A DEFINED LIST OF CRITERIA

MPTL is the abbreviation of "Multimedia in Physics Teaching and Learning" and stands for a conference group that deals with the challenges posed by the use of new multimedia learning tools. Since 2002 an international MPTL working group has evaluated multimedia sites. Every year the focus is laid on another branch of Physics. Every six years a second round gets its turn. Summaries of the annual reports are available at the website: www.mptl.eu.

The review

Every year a link-list of websites is collected by Bruce Mason (University of Oklahoma) and his students. Also existing lists from MERLOT, the ComPADRE digital library, Didattica, Multimedia Physik, Web searches are included in the collection. Only non-commercial websites are reviewed and the material is free. E.g. in 2010 about 180 web sites were found for Mechanics, each of them with an average of 8 to 10 objects of learning. The evaluations focus on different fields and aspects (see table 1). Each item is assessed on a Likert-scale with 5 grades and finally a summarizing assessment is given.

The first part focuses on the aspects "user-friendliness", "attractiveness", and "clear description of purpose and work assignment". The second part looks at the content. The third part is about methodical aspects. The reviewers were mainly members of the international advisory board of MPTL (see www.mptl.eu). The list makes clear that there is a multitude of aspects to consider. However, it is also obvious that so many aspects cannot be analyzed in detail. It depends on the experience of experts to find out recommendable examples.

Another evaluation, the MERLOT (Multimedia Educational Resource for Learning and Online Teaching) peer review used similar criteria, although they were not summarized under the same headlines. The categories are named: "Quality", "Potential Learning Impact", and "Ease of Use". There were only little differences between both groups of reviewers about the highly recommended sites in 2010. Those sites which were highly ranked are described by the annual reports (see www.mptl.eu).

General remarks

Here are listed some general remarks from the review:

- Most of the material is about standard topics (e. g. kinematics, dynamics, harmonic oscillators).
- A few sites offer a complete program, based on lectures. Most of them are still primarily text based ("html-text books").
- Some sites include simulations, interactive tutorials, video clips and virtual labs. They use new ideas for teaching. However, they often are related only to isolated topics, and are not embedded into a comprehensive learning environment.
- There are some sites dealing with special topics like baseball. These sites use Physics to explain the theoretical background of the topics. However a systematic learning of Physics is not the main interest.
- There is no general standard for the design of websites. – We have to live with individual styles and user interfaces.
- Only a few sites offer suggestions on how to implement the material in teaching and learning processes.
- Concerning trends, a new shooting star is video. However, video collections do not yet belong to the highest ranked sites. Seldom they are not embedded into an adequate learning environment.
- To deal with the variety and to administrate the widely distributed material, special search engines are needed, offering also individual administration tools, to collect, combine and supplement the material for teaching. (One option is: <http://www.compadre.org/psrc/>.)

Table 1: Items of the rating sheet (with abbreviations)

Motivation	User-friendliness	Is it easy to start using the MM?
		Are the design comprehensible and the image quality satisfactory?
		Is the function of control elements evident?
		Are the software requirements clear and of adequate proportion?
	Attractiveness:	Is the layout appealing?
		Is there a motivating introduction?
		Are there interactive components?
		Is the topic interesting (reference to everyday life, applications, explaining a phenomenon)?
		Is the MM up-to-date / innovative?
	Clear description of purpose and work assignment	Is the intention of the MM evident?
		Does the user know what is expected from him?
		Is there a problem to solve or a context to understand?
Content	Relevance	Is the topic important?
		Does it make sense to use the MM (e.g. problems in understanding, dynamic process)?
	Scope	Is there a profoundness of content?
		Is there a broadness of content (special case, general overview)?
	Correctness	Is the content of the MM correct?
		Are simplifications indicated?
Method	Flexibility	Is the MM appropriate for a broad target group (incl. self-learning)?
		Is it possible to use the MM in different teaching and learning sit.?
		Does the MM allow for the same topic to be approached in different ways?
	Matching to target group	Is a reasonable didactical reduction implemented?
		Are technical terms explained?
		Are the objectives appropriate?
	Realization	Is the general approach suitable to present the subject and realize aims of the given MM?
		Is the type of MM chosen reasonable (video, simul., animation)?
	Documentation	Is the operation obvious or explained?
		Is the material self-evident or explained by additional text?
		Is there a reference to material for further studies?
		Any suggestions for implementation into teaching process?

THEORETICAL GUIDELINES AND CONCEPTS

The features described above - multicoding, multimodality and interactivity - characterize more or less superficial structures of a learning environment. To make them effective for learning, they should be part of more specific concepts about teaching. Now, illustrated by examples, we will look at theoretical consideration about multimedia learning and refer to some findings from psychology of learning. The next chapters will show ideas how to realize the following intentions: (1) become familiar with different kinds of knowledge representation, (2) help to develop adequate mental models, (3) foster a flexible use of various kinds of knowledge representations, (4) assist in constructing a well-organized knowledge structure, (5) use rich contexts and arrange situated learning and anchored instruction, in order to avoid "inert knowledge", (6) guarantee a depth of processing, and last but not least (7) use the special benefits of multimedia without producing cognitive overload. Some findings from empirical studies will also be reported.

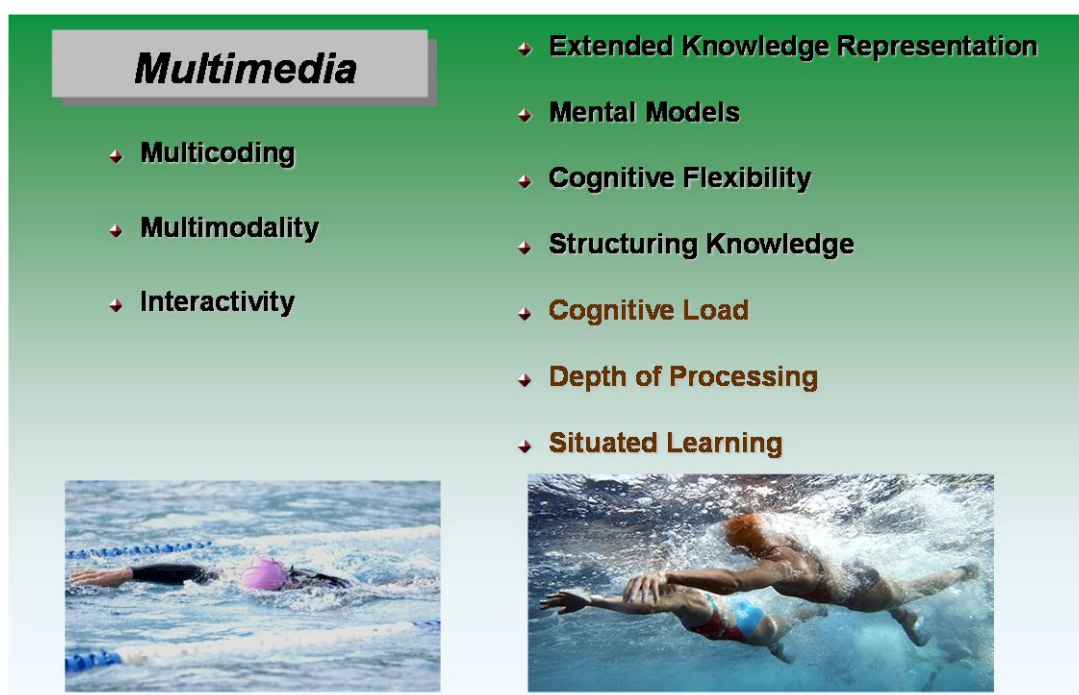


Figure 2: An illustration referring to the following explanations: Up to now we have been looking at more or less superficial features – shown on the left side; on the right side the aspects are listed that will be considered now. Changing the point of view will provide different insights. This is illustrated by the additional pictures.

Extending Knowledge Representation

Offering different visuals can bridge the gap between theory and concrete application. An interesting idea is to extend our perception and to illustrate what cannot be seen under normal conditions.

At http://www.physikonline.net/filme/mpg_m3_scheinkr/foucault13.mpg a pendulum is filmed with a rotating camera – providing a view from a rotating frame of reference. One can experience the effects of the Coriolis acceleration, respectively of the fictitious forces.

Another application is to "take a seat on a basketball" and fly with the ball on a trajectory into the basket (see figure 3).

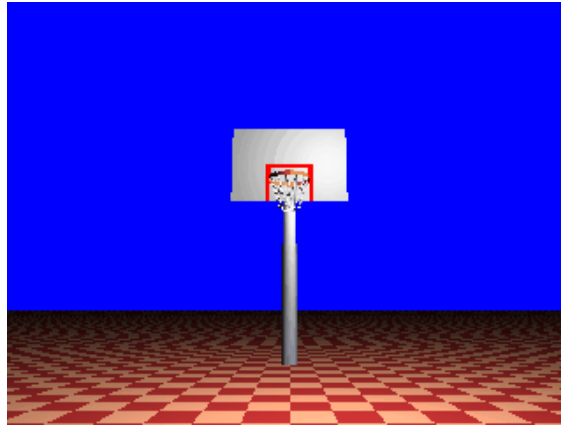


Figure 3: Animation to show what could be seen flying along the trajectory of a basketball
<http://fearofphysics.com/Proj/betheball.html> (12.6.2012).

Connect to real phenomena

Realistic scenarios can directly be related to more abstract representations of Physics. An example can be seen on the website referred in figure 4. The motion of a harmonic oscillator is described by using different methods. The relationship between the different kinds of representation is always illustrated.

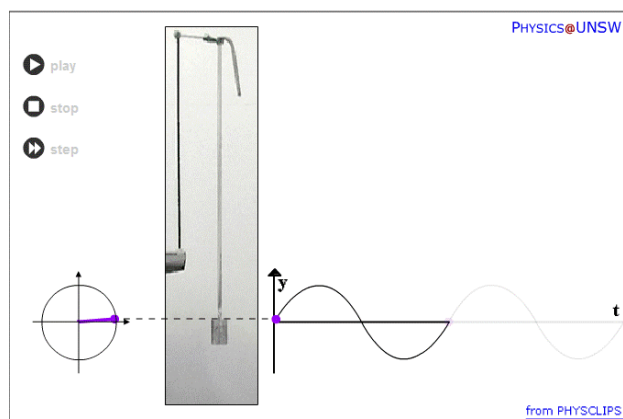


Figure 4: Combination of realistic and abstract representations of a harmonic oscillation.
<http://www.animations.physics.unsw.edu.au/jw/SHM.htm#yva> (12.6.2012)

From observation to conceptual understanding

Video clips can assist proceeding from simple observations to conceptual understanding if additional visual and aural information help to understand phenomena. The referred site from Rutgers (see figure 5) offers videos to train observing and describing phenomena. Additional guidelines for teachers are described that help to realize the concept of cognitive apprenticeship.



Figure 5: A picture out of a video showing effects of perpendicular pokes on a rolling ball
<http://paer.rutgers.edu/pt3/movies/bowlingball.mov> (20.8.2010)

Some empirical findings about multimodality

Multimedia makes it possible to offer visual presentations directly in combinations with written or spoken text. This meets the demands of spatial and temporal contiguity (Mayer, 2002). As a part of a phd-project it was analyzed, how additional information (presented as aural information or as a text to read) can influence the processing of pictorial information (modality effect). Also the use of animations and still pictures for the illustration of dynamic physical processes was compared. The content was characterized by three features: There were complex interdependencies; the processes could not be seen with naked eyes; dynamic process components were essential for understanding the phenomena. A multimedia learning environment in four different versions was analyzed, using

- i. animations and aural information
- ii. animations and written information
- iii. still pictures and aural information
- iv. still pictures and written information.

(See Lippstreu, 2011, Lippstreu & Girwidz, 2010a, b for more detailed descriptions).

Two different methods were applied: Lectures with a final questionnaire for 251 pupils and an eye-tracker study with 86 students. The remarkable results of this study concerned three issues.

a) Is it better to use spoken or written text?

In summary, it has to be distinguished between knowledge that is based on pictorial information and text based knowledge. In combination with illustrations it was significantly better to offer spoken text than written text, especially with animations. Whereas, for text based knowledge (information about facts and numbers) written text was better (see figure 6).

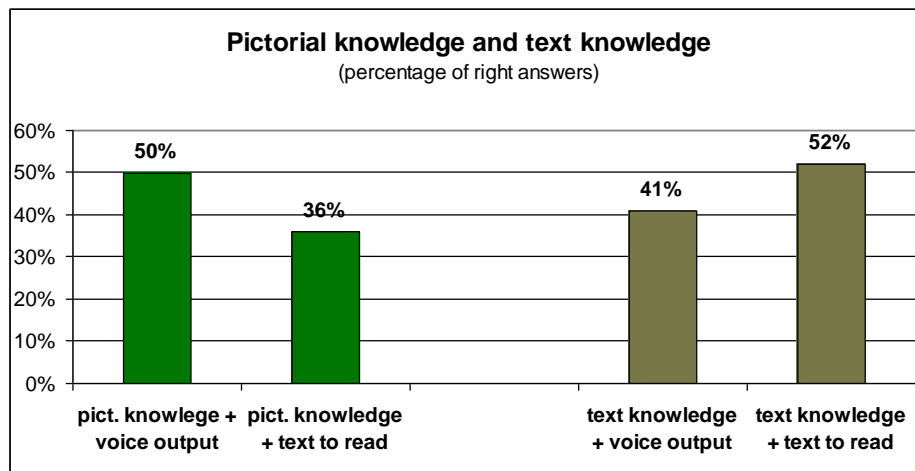


Figure 6: Spoken text vs. written text for pictorial and text based information.

b) Are animations better than still pictures?

For time dependent, process oriented knowledge the animations led to better outcomes than series of still pictures (see figure 8).

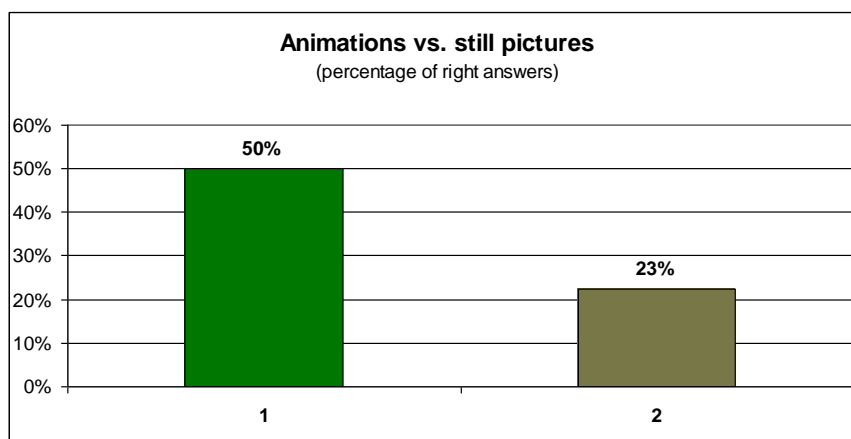


Figure 8: Animations (1) vs. still pictures (2).

c) Lines of vision, focal points and time for picture processing.

The eye tracker system showed clearly which part of the monitor was focused.

Also quantitative data are available. The time spent on looking at specified areas can be determined. With spoken text much more time was available for picture processing, whereas in the versions with written text it took most of the time to read the text (see figure 9).

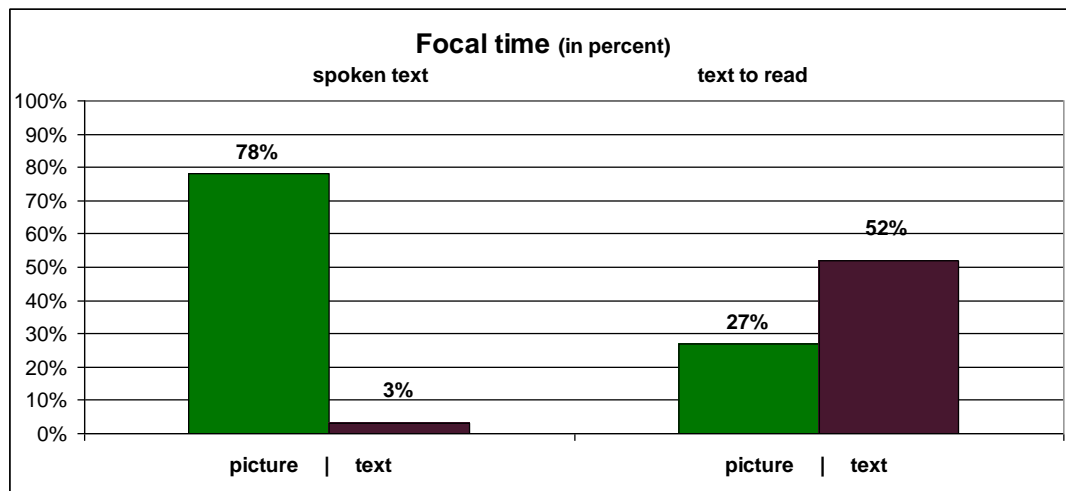


Figure 9: Focal time for pictures and text
(remark: about 20% of the time is lost because of blinking and unspecific eye movements).

Multicoding and mental models

Multicoding uses the strength of specific descriptions or visualizations, can bridge the gap between theory and application, and help to develop adequate mental models (see figure 10 and Girwidz et al. 2006a, b, Girwidz & Rubitzko, 2008).

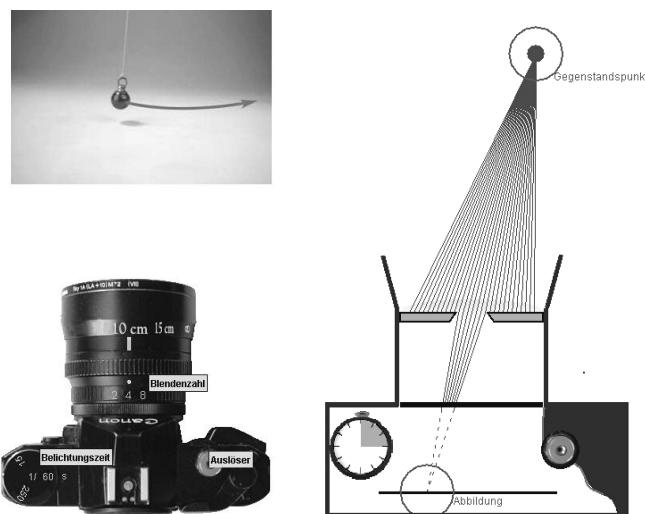


Figure 10: Snap shots from the program "virtual camera", opposing a realistic view and a model.

Mental models are analogous, pictorial representations, enabling the brain to simulate complex systems and to imagine how they might work under different settings. They provide a reference frame for understanding new issues and offer a base for subsequent planning (Dutke, 1994). For problem solving, the use of an adequate representation is important (already underlined by Larkin, 1983).

The "virtual camera" offer possibilities to change from one representation to another, especially from a lifelike view to a physical model of a camera. The role of different components like lenses, aperture, and rays of light can be examined by changing instrument settings and analyzing corresponding results

in both kinds of representation. (For more details about the virtual camera see Girwidz & Rubitzko, 2008.)

Figure 11 combines a photograph (realistic view) with a graphical illustration. In an animation the photography is gradually substituted by the more abstract illustration that also shows the underlying process for the development of clouds within a temperature inversion setting. In the right picture arrows show the flow of air (figure 11). This shall assist developing a corresponding adequate mental model.

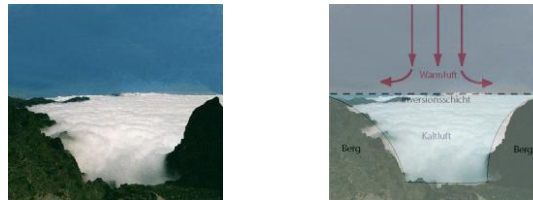


Figure 11: Different kinds of visualization explain the development of clouds in a valley.

Fostering Cognitive Flexibility

A central aspect of cognitive flexibility is the ability to switch from one representation to another, and to use an appropriate knowledge representation for problem solving. "Cognitive flexibility" includes the ability to restructure available knowledge according to the demands of a given situation (Spiro & Jehng, 1990). Thus, a knowledge ensemble can be tailored to the needs of a problem-solving situation, or to support learning and linking of new concepts (Spiro, Feltovich, Jacobson, & Coulson, 1992). Cognitive flexibility helps to apply knowledge under various conditions in an effective way.

In physics this also comprises the capability to use different symbol systems. One idea, I appreciate very much, comes from Härtel already from the 1990th. The electric current circuits in figure 12 are equivalent, however their topology differs. By running the animation according to figure 12 it is shown that the circuits are equivalent. I used another example in my lecture, showing the equivalence of two transistor circuits. There is a slider integrated in this application to change the speed of the animation and even let it run backwards. This was implemented because of two reasons that we found out to be important in an empirical study:

- If you miss or don't perceive a detail in simple animations the information is gone. Animations provide short-living information, and under bad circumstances you have to repeat the whole animation.
- In simple animations the user is "condemned" to be a passive viewer. You can't control the situation (what is an important psychological aspect).

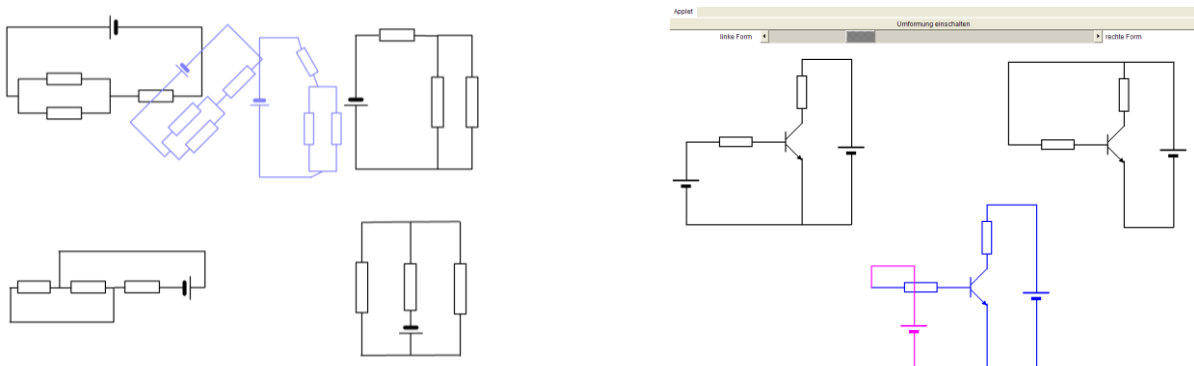


Figure 12: Pictures from applications to show the equivalence of electric circuits.

Another strategy we studied is the supplantation principle (Salomon, 1979, 1994), which means that cognitive skills, a learner cannot perform, are illustrated by means of media.

Some empirical findings about the application of the supplantation principle

Figure 13 shows a simple example from science education. According to Bergmann's rule the size of penguin species grows with lower temperatures in their habitat. The smallest penguins live near the equator, the biggest near the South Pole. Essential is the relation between volume and surface. An analogous problem is to find the best form for a cylindrical tin with a maximum of volume but a small surface. A hint is given in the diagram on the right. If you do not see this at once you have the same problem as our 9th graders had. One step is to show the meaning of this diagram by linking it with realistic pictures (see fig. 14). The application illustrates the meaning of a point of the graph. (See also Vogel et. al, 2007 for more details.)



Fig. 13: Context volume and surface.

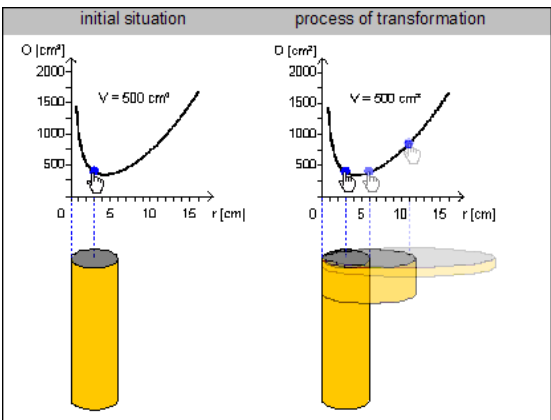


Fig. 14: Connecting a graph and its "message".

Figures 15 and 16 show two more examples, where this principle is used.

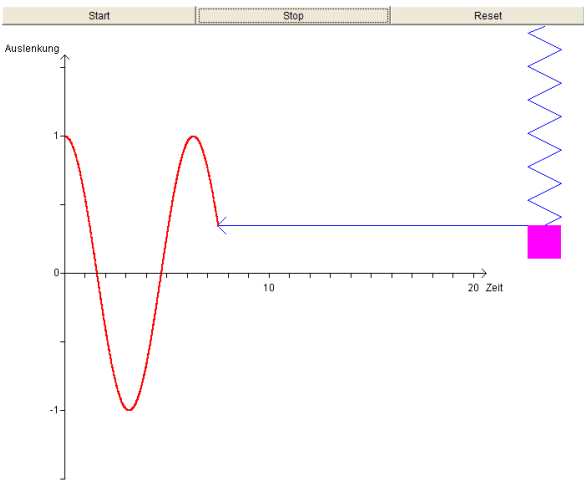


Fig. 15: Motion graph and the corresponding experiment.

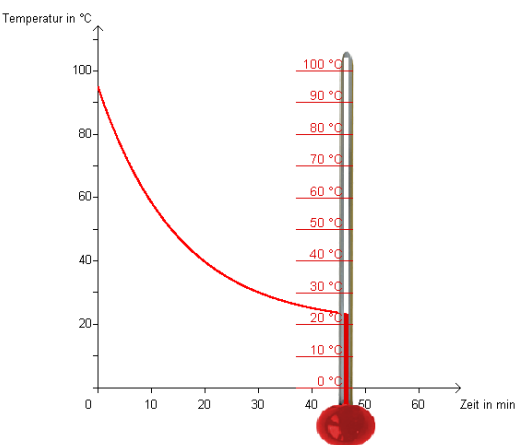


Fig. 16: Illustrating, what is shown in a graph.

Figure 15 illustrates the behavior of an oscillator, both in a representation similar to reality, and by the use of a corresponding $y(t)$ -diagram. The arrow connects the concrete and the abstract representation.

Structuring Physics - with concept maps towards a knowledge network

A structured knowledge base is important for problem solving. De Jong & Njoo (1992) emphasized that structuring of knowledge and linking it to prior knowledge are two important components of a learning process. Well-structured and properly organized knowledge improves the accessibility and is also important for problem-solving (Reif, 1981). Charts, mind maps and diagrams can illustrate relations, can help to analyze a knowledge domain, and improve recognition of information (Beisser, Jonassen, & Grabowski 1994). From that point of view also multimedia applications that offer "clickable" concept maps are of special interest. Fig. 17 shows examples from "Hyperphysics" making it easier to organize knowledge in a pictorial representation and to see connections.

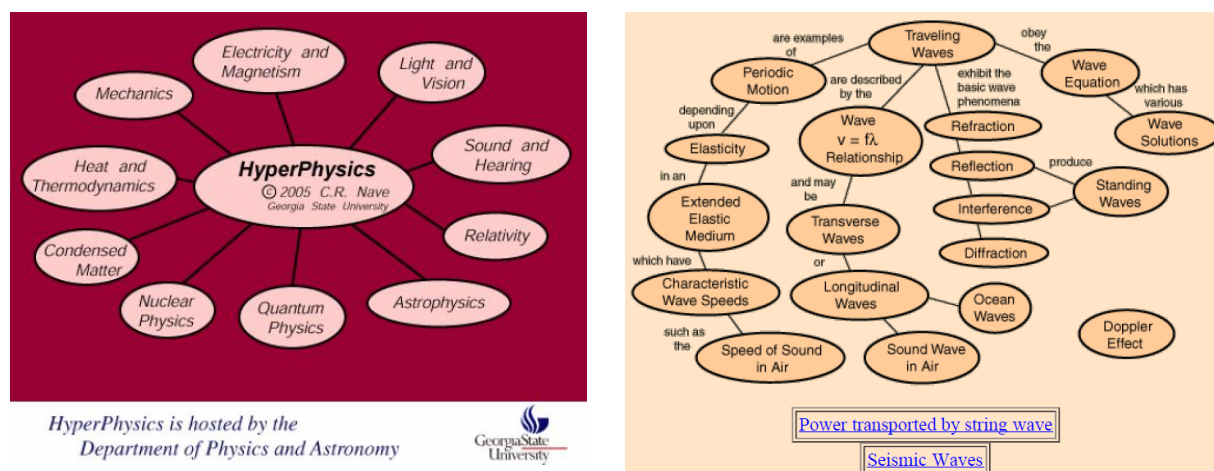


Fig. 17: Maps to illustrate knowledge domains
<http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html> (12.6.2012)

Considering Cognitive Load

"Cognitive load theory" (Sweller, 1994) focusses on the limitations of working memory as an important factor for learning (Chandler & Sweller, 1991). A use of different sensory modalities normally reduces cognitive load (Tindall-Ford, Chandler, & Sweller, 1997) unless the presentation itself causes a load, e.g., for net-working auditory and visual information (Jeung, Chandler, & Sweller, 1997).

Figure 18 illustrates a bird's strategy to minimize the energy loss in their (un-insulated) legs. According to theoretical considerations, additional aural/spoken explanations are provided. Details that are not necessary for understanding are faded out. In order to avoid a split-attention-effect temperature values are displayed directly beside the veins and colors indicate cold and warm areas (see also Girwidz et al. 2006).



Figure 18: Reduction of cognitive load by narration, color coding, and fading-out

Control the flow of information to adapt cognitive load

Three approaches to control and adjust the flow of information are:

(i) Allow users to control the progress of work. (ii) Arrange information according to the principle of temporal and local contiguity, meaning that information should be presented when and where it is needed. (iii) The "single concept principle", that points to one single matter of fact, term or concept. Different aspects can then be treated in sequence step by step. Examples dealing with fundamental principles concerning waves are shown in Figure 19. On the left hand a set of physical terms is shown. Clicking on a term starts playing a short video clip to illustrate the underlying principle (see also Girwidz et al. 2006).

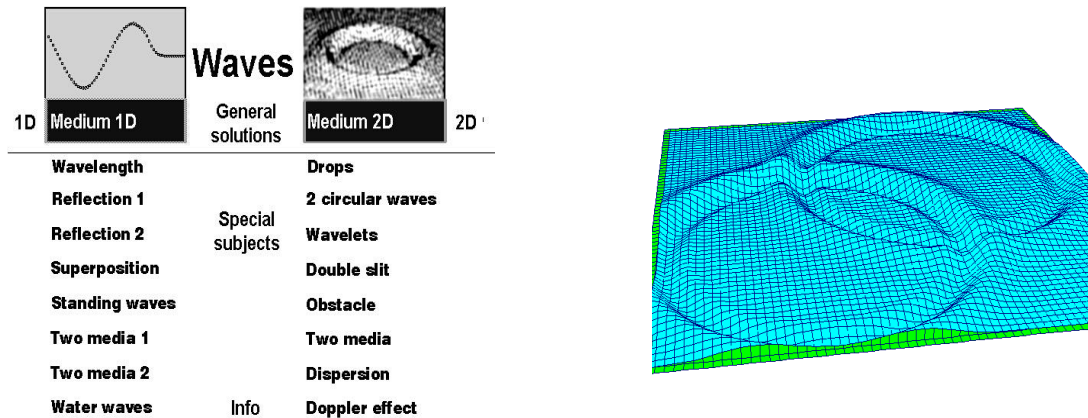


Figure 19: A list of applications dealing with wave phenomena (A) and an example for an accentuated phenomenon: inter-penetrating circular waves / principle of undisturbed superposition (B)

Situated Learning and depth of processing

Not least the following aspects are worth considering: Anchoring to lifelike scenarios; simulating and modelling of problems. This is shown in the last example:

As explained in many text books water waves are neither transversal nor longitudinal waves. The particles move in circles, having a phase shift between neighboring particles. This can be wrapped into an illustrated context from everyday life. Waves make water to go up and down. But, where does the material for an elevation come from – where is the water gone, if there is a trough / a valley? This is only possible if there is also a transport of material in horizontal direction (see figure 20).

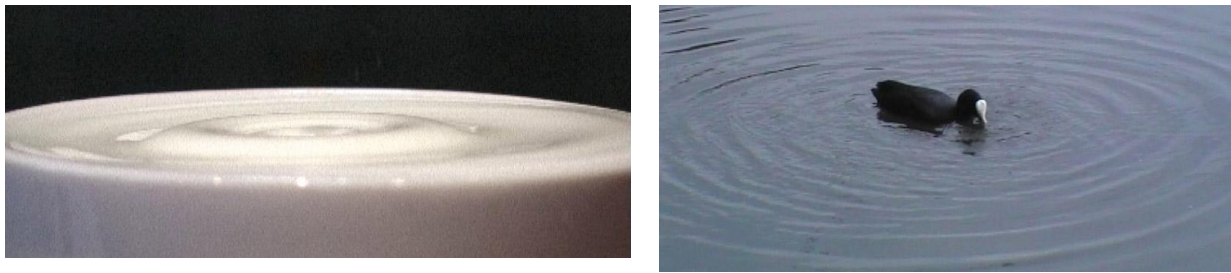


Fig. 20: Water waves in a context

Observations in a natural surrounding or in an experimental setting (even in a bath-tube) can be linked with simulations based on the theoretical background. However in a bath-tube you have to consider so called standing waves and at a certain position the dug will only move vertically and at another position only horizontally (see figure 21).

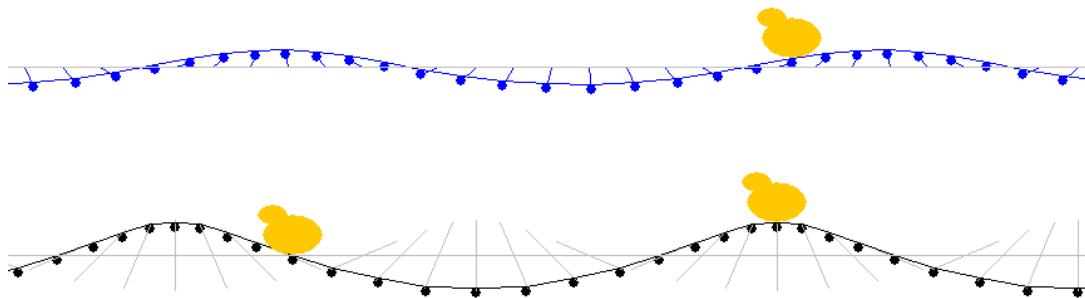


Figure 21: Movement of dugs caused by water waves

Anchoring and modelling can help to promote a deeper processing and to avoid inert knowledge.

CONCLUSION

In the internet we can find good and inspiring material for multimedia learning. Nevertheless we need research and have to train, how to use it in the best way. For that intent examples of best practice have a double value: They are tools that can directly be used, and they can put theoretical considerations in concrete terms. This helps in developing research based guidelines for using multimedia applications.

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A ROADMAP TO EMPLOY NEW TECHNOLOGIES TO TEACH SCIENCE TO CHRONICALLY ILL CHILDREN

Denise Whitelock, Roser Pintó, Rufina Gutierrez

ABSTRACT

This research set out to construct a Roadmap to flesh out the role that technology can play in the teaching of science to chronically ill children. The first step in the construction of the Roadmap was to send a survey to a group of experts, comprising of academics, teachers, medical staff and education and administrative staff, all working with these children. This survey was an adaptation of the Delphi Method (Gordon, 2003) which made use of a panel of experts and aimed to build a consensus over a range of issues. 103 participants returned the survey, a good response rate.

The Roadmap which was agreed upon by the experts consisted of a four year plan with four major parallel activities. These activities were: 1. The ICT infrastructure; 2. The Training needs of professionals working with sick children; 3. The Development of digital science educational materials; 4. The Construction of virtual repositories and a web portal for use by the professional caring for and teaching sick children. It stressed the need for multidisciplinary teams to work together in order to achieve this vision.

The participants also emphasised the need for a strong and valid evaluation programme throughout this four year period and that research findings from both ICT and pedagogy should inform and influence the current plan. Importance was placed on the role of effective learning which should help each child reach their full potential and that the main driver should be one of pedagogy and not the introduction of new technology for its own sake.

KEYWORDS

Roadmap; chronic illness; science teaching; technology; mobile phone

INTRODUCTION

Children who are not able to participate in mainstream education, for whatever reason, are not usually able to gain the same quality of education as their more fortunate peers. This project set out to analyse the current educational developmental needs of chronically ill children and then see how to apply technology effectively to give these children an alternative educational experience appropriate to their circumstances. The research therefore aimed to build a Roadmap for TeaCH (Technology-Enhanced Activities for Children in Hospital), accessible and useful to educators whose role is to support these learners.

The methodology adopted for the construction of the Roadmap was influenced by the work of Glenn & Gordon (2003) and employed a Delphi Study to answer the following research questions:

- Who are the key stakeholders that need to be consulted
- What are the key issues with respect to pedagogy, medical care and technological advances that need to be addressed by the stakeholders?
- What support is required for the development of technology enhanced activities for learning science in hospital?

- What timescale can be attached to a Roadmap or vision of the future landscape that will help hospitals and authorities in the compulsory education sector to make decisions about their future plans?

BACKGROUND

Roadmap Study

This project, based at the CRECIM at the Autònoma University, set out to review current policies and initiatives relating to teaching chronically ill children who spend long periods of time in hospital and cannot attend school regularly, as documented by a number of professional associations such as HOPE and the NAHHT, European funding bodies and a range of seminal projects such as the eHospital group of projects. Strategic priorities, projects and research activities were identified to assist with the recommendations for future coherent development in this field. This was achieved through not only suggesting ways to implement such policy documents but also by adding value to the teaching and learning sector, through the advice of known experts gained during the development of the roadmap. This outcome was progressed through a *modus operandi* which selected a number of facets from a range of roadmap methodologies collected by Glenn and Gordon (2003).

Building a Roadmap

In general the aim of a technology roadmap is to provide a consensus view or vision of the future landscape available to decision makers. The roadmapping process should provide a way to identify, evaluate, and select strategic alternatives that can be used to achieve a desired science and technology objective (Kostoff and Schaller 2001). In the case of this roadmap, the science and technology objective can be summarised as ‘effective implementation of technology enhanced science teaching of chronically ill children in hospital or who are convalescing at home and are of compulsory school age’. This roadmap seeks to present a vision of the future landscape that will help organizations and individuals in the compulsory school age sectors to make decisions about their future plans with respect to ICT.

There are a number of approaches that can be taken to develop a roadmap. However Gordon, 2003; Kostoff & Schaller, 2001 indicate that what is required when building a map to highlight future directions in any given field is a prospective roadmap i.e. a map to help find out where we are going, as opposed to a retrospective roadmap which is intended to illustrate how we got to our present position. Kostoff and Schaller identify the two extreme types of prospective roadmaps. These being:

- Requirements-pull roadmaps (which start with desired end products and fill in the remainder of the roadmap to identify the R&D necessary to arrive at these products) and
- Technology-push roadmaps (which start with existing research projects, and fill in the remainder of the roadmap to identify the diversity of capabilities to which this research could lead).

For this project, a method was required that took into account both the requirements-pull and the technology-push driving the field at this time together with the fact that the development of this roadmap must consider political, pedagogical and health drivers in order to understand how the technology can be appropriated and used to support this target group of chronically ill children.

Factors influencing the choice of methods included:

- Duration and budget of the project
- Availability of expertise outside the project team
- Reports and policies identified to be relevant to this particular Roadmap

The methods used are described in the following section of the paper. Additionally, this project recognized that in general, science and technology roadmapping is difficult, particularly where fundamental research is involved as Gordon points out:

“On complexity, most topics of interest are ultimately found to be fractal, that is, the more detailed the analysis, the more detail is left to discover. When the subject is fundamental research, the identification of nodes is particularly difficult since the nodes will inevitably include discoveries not yet made. As a roadmap is constructed, there comes a time when the analysts must say, enough. The balance between depth and superficiality is crucial but often hard to achieve.” (Gordon, 2003, p 9).

Methodology

The project fell divided into three main stages, as illustrated in Figure 1 below.

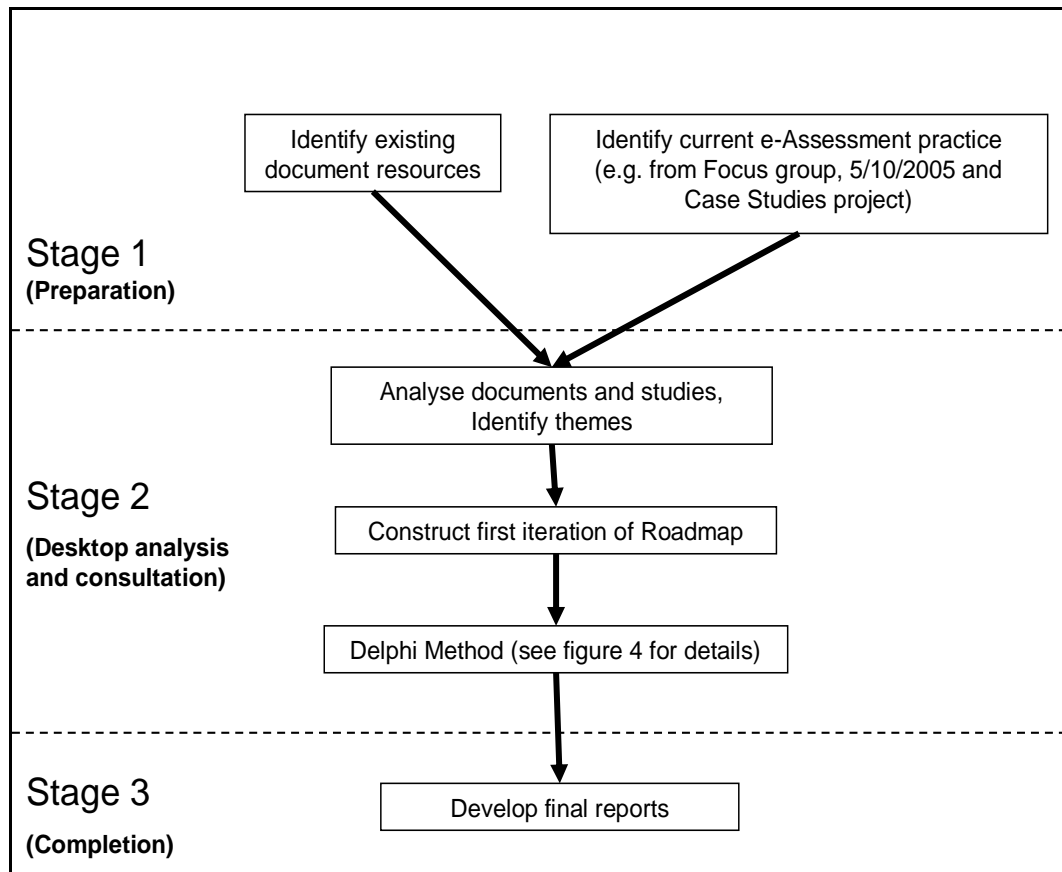


Figure 7. Graphical representation of the stages in the project

Stage 1: Preparation phase

Stage 1, the preparation phase set out to achieve two goals.

1. Identifying key documents
A number of European and international organizations considered to be important players with respect to the education of chronically ill children were identified. Policy and other documents which described the plans and policies of these organizations were obtained, together with published academic papers, about the role of pedagogical standards, technology and health issues that affect the target group. These included papers by Balanskat et al (2006), Carsten (2004), Lombaert et al (2006), Martinez & Ercikan (2009), Taras & Potts-Datema (2005).
2. Identifying current practice
Sources of information about the current state of the art in practice, and the future plans of leaders in the field, were identified and included Shaw and McCabe (2008), Key Competences for Lifelong Learning: A European Framework.

Stage 2: Desktop analysis and consultation

An analysis of the key documents and the construction of a database of current practice identified in Stage 1 was carried out, to identify the strategic issues and challenges and benefits of using ICT to teach these children together with the institutional, operational and pedagogic enablers and barriers to the effective use of ICT. This analysis led to the development of a framework for constructing the roadmap and producing the survey which was part of the Delphi method employed for the consultation phase of the construction of the Roadmap.

Stage 2: The Survey

The main test instrument was a survey sent to a group of experts, comprising of academics, teachers, medical staff and education and administrative staff all working with these types of children. This survey was an adaptation of the Delphi Method (Gordon, 2003) which made use of a panel of experts and aimed to build a consensus over a range of issues. 103 returned the survey, a good response rate.

The survey was designed after a literature review was undertaken and key issues identified. Although termed 'Survey' it was more of an electronic consultation as the experts were asked to give their opinions and to write free text responses for some of the questions.

The survey probed experts' opinions on the following issues:

- a) The benefits of using ICT to teach sick children.
- b) The role of multi discipline teams to instantiate the vision of using ICT to teach science to sick children
- c) The availability of digital science education materials for sick children
- d) The training of hospital teachers to use ICT for science teaching
- e) Difficulties that need to be overcome to achieve the vision.

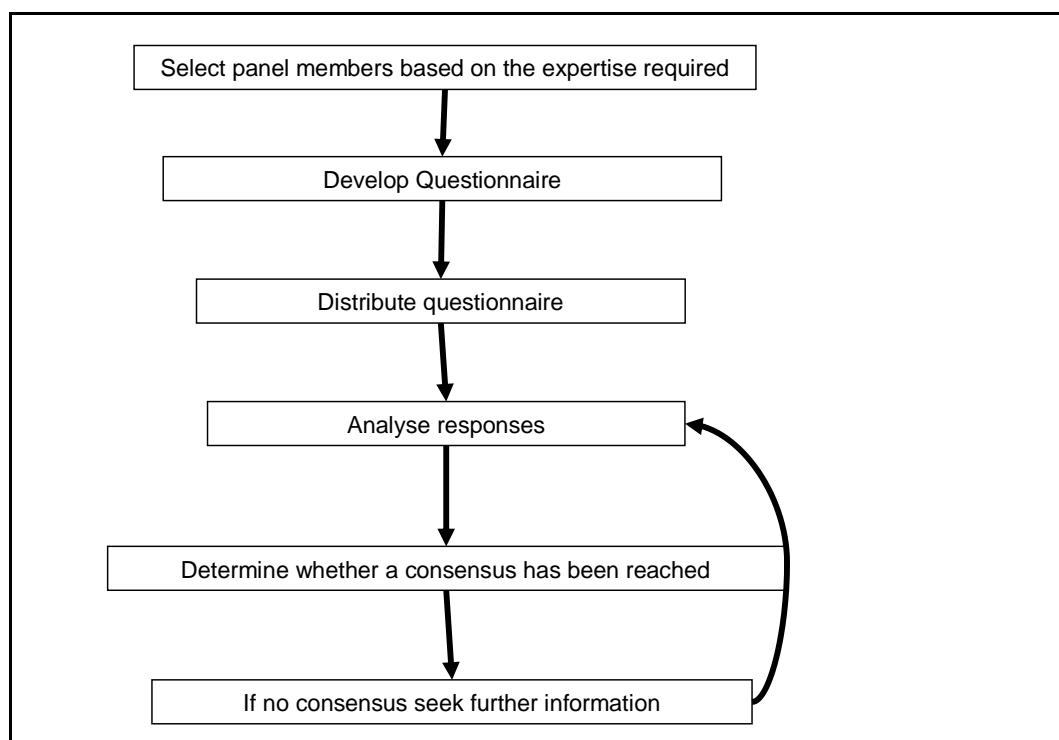


Figure 8. How the Delphi Method was used to reach a consensus from the experts about the Roadmap

The findings from the survey were analysed and an outline of a Roadmap constructed. The participants were then asked, via a second survey, whether they agreed with the parameters of the Roadmap and also

the timings for completion of these key components. This survey was designed to clarify areas where a consensus had not been reached from the findings of the first survey.

Analysis of the results from the two surveys enabled the production of a roadmap that illustrates the planning of future developments and strategic drivers and initiatives relating to the productive use of ICT to support the teaching and learning of chronically ill children.

Participants

103 participants completed the first survey, 50% were medical staff and 35% were teachers. Other hospital teaching and administrative staff returned their opinions to the research team as illustrated in Table 1 below.

Table 1. Participants who responded to the first questionnaire “Science education with ICT for sick children”

Category of Participants	Percentage of total responses
Medical Staff including doctors & nurses	50
Hospital School Teachers	21
Home Tuition Teachers	10
Teachers in both services	4
Education administration staff	9
Pedagogues and speech therapist	2
Researchers in hospital pedagogy	2
NGO staff in education programs	1
Patients organisation staff	1

RESULTS

First round of Delphi Method

The first round of the peer consultation process which took the form of an electronic survey revealed that the majority of participants agreed upon the following issues:

- (a) That chronically ill children would benefit from ICT use with their studies
- (b) This could be achieved within 5 years
- (c) The greatest advantage of using ICT would be in facilitating access to a range of interactive teaching materials and also supporting the chronically ill children to communicate and collaborate with their peer group at school
- (d) ICT tools can assist with the holistic development of sick children e.g. in the affective and cognitive domains
- (e) The one laptop for each student policy in the ‘Plan Escuela 2.0’ <http://ordenadoresenelaula.blogspot.com/2010/03/escuela-20-en-cada-comunidad-autonomica.html> will support the use of ICT for teaching sick children and integrate them into more mainstream education through an increased peer contact
- (f) Medical staff and teachers should collaborate in producing the new pedagogical materials for chronically ill children
- (g) Materials and expertise should be shared between hospitals
- (h) More training is required for teachers in the use of ICT for teaching science to this group of children

Second round of Delphi Method

All the participants were subsequently sent a second survey to complete. The key stakeholders were asked to agree a timeframe for the main components of a Roadmap devised from their responses to the first round survey. The main constituents included the following:

1. The ICT infrastructure
2. The Training needs of professionals working with sick children
3. The Development of digital science educational materials
4. The Construction of virtual repositories and a web portal for use by the professional caring for and teaching sick children

A surprising finding was that the experts agreed upon a four year plan and not a five year one as suggested by the first survey. They believed that if the four major activities noted above were carried out in parallel then a four year timespan would be sufficient to complete the introduction of ICT into hospital schools and for children with chronic illness working from home.

The Roadmap therefore consists of the four parallel activities as illustrated in Figures 3 to 6 below.

An evaluation phase was also agreed for each of these four activities and the final strands of the Roadmap are shown below.

TARGETS		Availability of laptops for children at hospitals and homes	Availability of an informatics service in hospitals and homes			Evaluation of the endowment of laptops, mobile devices and informatics service in hospitals and homes, and also the evaluation of the objectives		
	Availability of Internet access at hospitals and homes	Access to free software			Availability of mobile devices for supporting learning in hospital and homes			
		1 year		2 years		3 years		4 years
TIME								

Figure 3. The ICT infrastructure plan

With this strand of the Roadmap it is important that the community capitalises on the use of mobile technologies to support the children's learning together with monitoring the use of free apps that will be available for the newer android mobile phones

TARGETS	Offer the professionals a course on strategies to work collaboratively	Offer the professionals a course on Pedagogical use of ICT	Offer techniques and informatics and pedagogical criteria to analyse the advantages and limitations of digital materials for supporting sick children learning science. These educational materials will be evaluated and will be the ones available from the Internet repositories, hospital schools website, medical websites, etc. in each Autonomous Community	Offer the professionals a course on science education, with a biology content suitable for experts	Courses from 2 nd year repeated in the 3 rd year	Evaluation of the efficiency of the courses in modifying experts practice with sick children
		Offer the professionals a course on ICT tools and a course on dealing with affective-emotional aspects of illness and health		Offer the professionals a course on dealing with affective-emotional aspects of illness and health		
		1 year		2 years		3 years
TIME						

Figure 4. The professional plan

Although all the experts agreed with this plan, the medical staff believed the time plan should be shortened and that a course on mental health should also be included.

TARGETS	In each Autonomous community, establishment of multidisciplinary teams to produce digital educational materials for science education of sick children			Analysis of current science digital materials for sick children freely available in Internet repositories, hospital schools website, medical websites, etc. in each Autonomous Community	Production of digital science materials for sick children with input from key multidisciplinary teams from each Autonomous Community	Production of digital science materials for sick children useable in mobile devices	Refine the digital science materials for sick children	Evaluation of goals achievement
	Establishment of criteria for the task distribution in the team, for the selection of basic science-medical concepts to deal in the materials, to design the Web portal sections, etc., to be done by the professionals					Pilot the digital science materials for sick children		
		1 year		2 years		3 years		4 years
TIME								

Figure 5. The development of digital science materials plan

All the participants agreed with this plan but 2% believed the time span should be shortened.

TARGETS	Production of the digital educational materials for the training courses	Addition of the courses digital training materials in the Web portal	Informatics framework production of a central virtual repository for professionals in the field of sick childcare and establishment of a link with the Web portal	Addition of the best practices and digital science education materials for sick children in the virtual repository	Establishment of new Web portal sections: the evaluation module and the communication collaborative module (i.e.: by webcam, by on-line blackboards, etc.) to facilitate the productive tasks of the multidisciplinary teams in each Autonomous Community	Addition of new digital science materials produced by the multidisciplinary teams of each Autonomous Community	Up-date of Web portal sections and contents of the virtual repository	Evaluation of the Web portal and virtual repository utilization				
	Informatics framework production of a Web portal devoted to professionals in the field of sick childcare. Establishment of the Webmaster and the management and updates criteria for the software and contents of the Web portal	Piloting the initial sections of the Web portal: technical support, training courses, digital science materials repository							Piloting the access and modification of the Web portal content			
		1 year		2 years							3 years	
	TIME											

Figure 6. The virtual repositories and web portal plan

The Plan for the construction of virtual repositories and a web portal. All the participants agreed with this plan.

DISCUSSION

The key stakeholders who took part in the Delphi Study were identified as doctors, nurses, administrative hospital staff, hospital teachers and home tuition teachers, educational staff associated with the Ministry, patients' organisation staff and NGO staff in education programs and technical experts. The key issues which were probed in the first survey revealed that all the experts agreed that

chronically ill children could benefit from ICT use with their educational studies and that the timescale to achieve this end would be about five years.

The final consensus, received from the experts after the second survey, revealed that if the following four types of activities took place in parallel, the Roadmap could be instantiated within four years. These include the ICT infrastructure, the training needs of professionals working with sick children, the development of science educational materials and the construction of virtual repositories and a web portal for use by professionals caring for and teaching sick children.

The ICT plan comprised of sourcing products both hardware and software with installation plans within the first year. The instantiation would take place within three years, together with exploitation of mobile devices to support the teaching and communication between students and teachers.

A second strand included the training of professionals in ICT usage and courses for teachers that also included one on mental health issues with respect to chronically ill children. The third strand included the development of suitable digital science materials. A lot of these children use medical nomenclature without understanding it and are not always able to comply with their medication because of science misconceptions about the basic function of vital organs within the bodies, such as the kidney and heart.

The final requirement to complete the Roadmap was the virtual repositories of materials that could be searched, used and refined. This would also be a place to share best practice. The use of an adapted Delphi Study using the main test instrument as an electronic survey worked well.

In conclusion, all four strands of the Roadmap point towards a clear way of harnessing technology to support the science teaching of chronically ill children. It stresses the need for multidisciplinary teams to work together in order to achieve this vision. A notion which was supported by a majority of the participants in both surveys who were themselves experts from four major disciplines.

The participants also stressed the need for a strong and valid evaluation programme throughout this four year period and that research findings from both ICT and pedagogy should inform and influence the current plan. Emphasis was placed on the role of effective learning which should help each child reach their full potential and that the main driver should be one of pedagogy and not the introduction of new technology for its own sake.

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COMPUTERS GAMES AS TOOLS TO TEACH SCIENCE IN THE CLASSROOM: WHEN IS THIS A GOOD IDEA?

Mary Ulicsak

ABSTRACT

Computer games have been the subject of sustained attention amongst educators now for twenty years. The debate around usage has accelerated and widened in the 21st century. It is assumed by some that the models games employ lead to learning, as young people learn how to play without necessarily being explicitly taught, and while playing they do vast amounts of reading or interacting with others; while others see games as boring, tedious, time-consuming, and repetitive.

Both of these viewpoints can be true: the impact of a game is not solely dependent on the game itself, but is affected by the players, circumstances of use, and mediation of the teacher. In fact, some academics claim that we cannot state computer games are beneficial to learning as much research does not take into account circumstances of use.

So what does this mean for educators wishing to use computer games in their science classroom? In order to effectively evaluate the research to decide whether a specific game would achieve the desired learning goals an understanding of the terminology and assessment techniques used by the research - as well as the outcomes - is required. This paper introduces the terminology and how games could be used within a classroom.

KEYWORDS

Teaching with games, game definitions, science teaching, primary education, secondary education

INTRODUCTION

Computer games have been the subject of sustained attention amongst educators now for many years. Back in 1980 Thomas Malone asked: “How can the features that make computer games captivating be used to make learning – especially learning with computers – interesting?” (Malone 1980, p.iii). Yet computer games have not become integral within the education system and the debate around their usage has accelerated and widened in the 21st century.

Academics such as Paul James Gee, Nick Barham, and Kurt Squires argue that the models games employ lead to learning, as young people learn how to play without necessarily being explicitly taught, and while playing they do vast amounts of reading or interacting with others. With respect to science teaching in 2011 the National Research Council in the US stated computer simulations and games have the potential to “advance multiple science learning goals, including motivation to learn science, scientific discourse and argumentation, and identification with science and science learning” (National Research Council, 2011, p5).

Yet others, as Hanghøj points out find games: “boring, tedious, time-consuming, repetitive, temporary, one-off events” (Hanghøj 2010). And some have found that narrative games can be detrimental in teaching depending on the teaching goals (Adams et al 2012).

Both of these viewpoints can be true: the impact of a game as a teaching tool in a classroom is not solely dependent on the game itself, but is affected by the players, circumstances of use, and mediation of the teacher. In fact, some academics claim that we cannot state computer games are beneficial to learning as much research does not take into account circumstances of use (Hanghøj & Brund 2011, Sandford et al 2006).

So what does this mean for educators wishing to use computer games in their science classroom? In order to effectively evaluate the research to decide whether a specific game would achieve the desired learning goals an understanding of the terminology and game structure and mechanics are required.

This short paper is written for practitioners and those considering the use of games within the classroom. It is designed to provide the background; for example, the differences between serious games, casual games, simulations, commercial off the shelf games (COTS), edutainment and virtual worlds. It considers how games can be used to teach science, and be integrated within the classrooms.

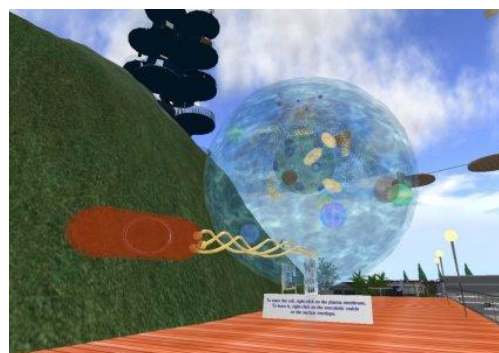
WHAT ARE COMPUTER GAMES?

Although this seems a straightforward question there are a myriad of answers depending on viewpoint. What are the differences between digital games, computers games, electronic gaming, and video games? Is using Angry Birds to demonstrate angles of velocity equivalent to visiting Genome Island in Second Life which allows players to step inside a rotating plasma membrane and the same as making a game to illustrate the impact of mixing chemicals in LittleBigPlanetChemistryLab

a)



b)



c)

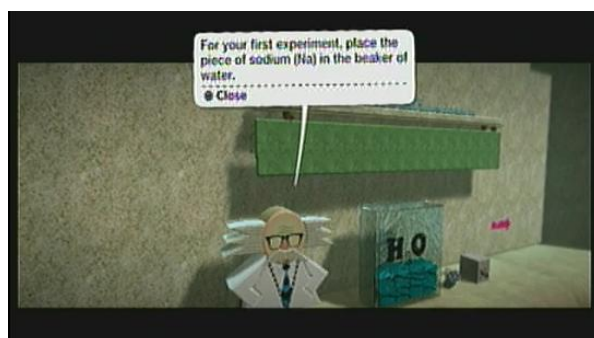


Figure 1: Screen shots to illustrate game formats: a) Angry Birds, b) Genome Island, Second Life, c) LittleBigPlanetChemistryLab

Before deciding if using games to teach science is a good idea first we need to be clear about what is being considered. In this paper computer games refers to those directly played on a PC. However, they could be included in *digital games* – which is the term used by DiGRA¹⁷ to denote games that have a technology basis and *electronic gaming*. Electronic gaming is the term used by Ofcom¹⁸ to cover held games consoles, games consoles connected to a television, computer games online, computer games on a PC or CD ROM games. *Video games* is the term used by industry bodies for television-linked consoles and portable video game systems.

For the purpose of this paper games are defined as having a story or purpose, certain game mechanics (for example how the game world behaves in terms of physics or weather), rules, the graphical environment (the sensory representation of the experience of playing), interactivity, and a sense of challenge or competition (Derryberry 2007). Games can allow repetition until the skill is mastered, and they offer immediate feedback to the player¹⁹. In this discussion computer games are divided into three categories:

- Games designed to teach specific content or skills
- Games designed for playing in leisure periods
- Games that were designed for leisure but are being used to teach specific content or skills

Each of these categories contains various game genres, the areas of interest to science teachers are the first and third.

Games designed to teach specific content or skills, which are usually found if a search for “science games” is performed, include the genres:

Edutainment – these are often based on a behaviourist model of learning, that is, when a correct answer is given the student is given a reward. The reward need not relate to the subject being studied, for example, being allowed to shoot at aliens for correctly answering sums as in Mathblaster! however it can be integrated, such as having to calculate a budget for an expedition.

Serious games – these tend to be designed for training, and specifically for training adults. They are usually set in a realistic context and simulate events employing tools and strategies which can be directly transferred into the real world. Examples of serious games in the military include teaching drivers to travel in convoy in Afghanistan, in police training they can be used to allow forensic scientists to practice in crime situations, or in medical teaching they allow nurses to practice triage skills on severe accident sites.

*Epistemic games*²⁰ – these allow players to be apprenticed in authentic tasks, for example, taking on the role of a medical ethicist the in Pandora Project, a forensic scientist in CSI Web adventures, or running the kitchens in a Marriott Hotel²¹. The player then uses that profession’s tool kit of knowledge, skills and values in order to produce the products that those professionals produce – in this case arguments around using organs for animals in humans, identifying a criminal, or running a kitchen successfully.

¹⁷ The Digital Games Research Association (DiGRA) in the UK focuses on all digital games, not only those in education, (www.digra.org/digrainfo)

¹⁸ Ofcom is the independent regulator and competition authority for the UK communications industries

¹⁹ For a more detailed description of games in formal education settings see the Computer games and learning handbook by Futurelab (http://www.futurelab.org.uk/sites/default/files/Computer_games_and_learning.pdf) and The GAMEiT Handbook (<http://computerspilzonen.dk/sites/computerspilzonen.dk/files/rapportfiler/gameithandbook%20v2.pdf>)

²⁰ See www.epistemicgames.org.

²¹ For details of all three games see: <http://epistemicgames.org/eg/category/games/negotiation/>, <http://forensics.rice.edu/> and <http://news.marriott.com/2011/06/my-marriott-hotel-opens-its-doors-on-facebook.html>.

Simulations – these are frequently equated to games, and like serious games use rigorously structured scenarios with a highly refined set of rules, challenges, and strategies. An example would be Racing Academy²², which uses an accurate model of how engines, tyres etc interact.

Virtual worlds – these 3D persistent social environments can contain game elements, casual games and simulations that enable learning, the most frequently cited example is Second Life with its various educational worlds.

Programming environments – such as Scratch and SandBox²³ which are designed for students to learn formal programming skills as well as allowing them to demonstrate subject knowledge by incorporating these into a game.

Most COTS (commercial off the shelf) games fall into the second category; games designed for leisure, and are played on a variety of platforms. These encompass genres such as action games, adventure games, racing games, sports games etc. Such games do result in learning, at the very least the player learns how to play the game! And proponents such as James Gee argue that mastering a game requires the development of problem-solving skills. However, unless these skills are made explicit then they are rarely used or transferred to other circumstances. For example, in the Teaching with Games project the assumption that students sharing a computer would automatically collaborate was found not to be true (Sandford et al 2006).

The final category is educational leisure games. The COTS game Roller Coaster Tycoon has been used to teach physics, while Spore has been used to teach classification of animals. This group is expanding as companies realise the potential. For example, teacher packs exist for the DS games Professor Layton and Nintendogs to be used as starting points for lessons. Below are three game genres within COTS that have been used specifically for education.

Sandboxes – in this context it is the term used for games that allow play outside the intended game challenge where skills can be practiced. For example, testing a creature designed can actually move as intended in Spore or ensuring design stability in RollerCoaster Tycoon.

Casual games - these are short, intuitive, accessible and easy to play games played on mobile phones, games consoles (handheld and television linked), as well as on a more traditional computer. They often involve puzzles and quizzes. For example, Angry Birds in Space accurately models gravity and not only is it the fastest downloaded game so far but NASA astronauts have given a physics lecture on why this subject is important²⁴.

Programming environments – such as LittleBigPlanet²⁵, have proposed teacher packs to enable teachers to create levels around science, technology, engineering and maths which are tailored for their specific students. More generally LittleBigPlanet levels have been awarded prizes for teaching science²⁶ and have collated levels found to be effective in teaching²⁷.

²² For details and to download search for Racing Academy on the page <http://www.lateralvisions.com/Services/Portfolio.aspx>

²³ Scratch is a programming language while Sandbox is designed for making games - for details and to download see: <http://scratch.mit.edu/>, and <http://www.sandboxgamemaker.com/>

²⁴ The video can be found at <http://www.nasa.gov/microgravity/>.

²⁵ The Head of Sony Entertainment suggested that teacher packs would be created for the second release of LittleBigPlanet (<http://www.gamesradar.com/ps3/littlebigplanet/news/sony-uk-pushes-for-schools-to-adopt-games/a-2011011115441339081/g-2007030735927344042>)

²⁶ See the Digital Media Learning (DML) competition for examples - <http://hastac.org/competitions/winners>

²⁷ Sony has gathered some examples of use at <http://www.connectededucation.com/products-services/sony-playstation/littlebigplanet-2-in-education/>

HOW COULD GAMES BE USED TO TEACH SCIENCE?

In addition to knowing what games are available it is also important to consider how games will be used within the classroom. The two major ways that games could be used to teach science are:

1. Games to teach or illustrate content

This is the most likely use of games; they can introduce a subject, illustrate a specific point, stimulate a class debate, provide a context for other learning (in Scottish primary schools Rock Band has been used as a context for students to practice languages in mock interviews, English for writing record reviews, maths for budgeting tours, geography for calculating the optimum route etc) or in some cases be used to test knowledge. They can allow students to experience situations not possible due to risk and cost in the average science classroom. Students can investigate animals under the sea in Endless Ocean, explore spatial physics in Portal 2, or see the rate diseases can be spread by sneezing in the casual game Sneeze²⁸.

2. Allow students to create games to demonstrate understanding of principles

This is more complex as involves students learning the skills to make games as well as the content. There are also issues around teaching game design if the goal is to make games more complex than a simple quiz.

In both these cases it is important to have a clear teaching goal in order to select the most appropriate tool. Firstly the teacher must be confident in the content if using it as a text. It is relatively easy to find online examples of games with minimal game mechanisms to teach or test specific content, for example, the BBC has a range of “games” around science²⁹. However, identifying games that have relevant content from the COTS games for leisure category can be difficult. In the case of games originally designed for leisure there is an issue around whether the material is appropriate - after all game designers are not necessarily content specialists. From the Teaching with Games study teachers had to work hard at creating game conditions that met reality in terms of modelling physical behaviours. So for gravity to “work” the number of cars in RollerCoaster Tycoon's sandbox had to be fixed - which was used by students to identify the relationship between friction, launch speed and height and eventually the formula for kinetic energy.

Secondly, teachers need to assess the game structure and mechanics with respect to their teaching goal. If the goal is for a student to deduce a food chain having a mechanism that focuses on time, for example, having to assess how likely a creature is to attack in under 10 seconds, then guessing rather than deduction might occur. However the same mechanism might be really useful if the goal is to test how well the student can identify animal structure that indicates it is a predator. Which means that teachers will need to have played and know the game in order to integrate it successfully or need to be able to express mechanics required to their students if a game is being developed.

Finally, there is identifying the appropriate place of the game where the relevant content appears. Many COTS games are meant to be played over an extended period, linear narratives can often take 30+ hours. Thus the teacher needs to be able to save at an appropriate point as otherwise the time taken to reach this point may negate the teaching benefit.

USING GAMES IN THE CLASSROOM

Once the game has been identified this does not mean that they can be used in the classroom or will have the desired effect. Much of the Teaching with Games project involved supporting teachers integrating the games into their school and lessons. This includes addressing issues around providing

²⁸ For a description of the games see: <http://endlessocean.com/>, <http://www.valvesoftware.com/games/portal2.html> and <http://www.miniclip.com/games/sneeze/en/>

²⁹ See <http://www.bbc.co.uk/schools/games/> where ages and subject can be selected

sufficient game licenses, being able to access kit of a high enough specification, ensuring they could book the relevant computers during lesson time and that they had sufficient kit for their students as well as having support from the school administration. These concerns are reiterated by a 2009 EU survey in which 28% of teachers stated they did not use games because of insufficient availability (Wastiau et al 2009).

Equally important is the attitude of students. Despite being termed digital natives, Net Generation (Net Gen) or Generation Z (Gen Z), which simply means they have always known the Internet and had access to computers, young people do not instinctively play computer games. And even if they are experienced gamers that does not preclude them making mistakes. In the Teaching with Games project teachers using COTS games in their classroom were surprised that students were performing what they considered to be advanced skills, for example, using cheats in the SIMS to get money, when they could not perform more basic skills such as furnishing a room.

There is also an assumption that games automatically motivate young people. Although there is research validating this, especially the impact on young males, again using games does not automatically equate to enthusiastic students. Kurt Squires found that 25% of history students withdrew from his study, which used Civilization to teach geography and history, as they found it too hard, complicated and uninteresting (Squires 2005).

As Thorkild Hanghøj summarised in his keynote to the ECGBL 2010 conference: “We need to describe the messy reality of actual gaming and teaching practices” (Hanghøj 2010). He argues that researchers have often looked at the learning outcomes and the actual inherent learning potential of particular game designs rather than the actual practices of *teaching* with games^(Hanghøj & Magnussen 2010). In order to use games effectively they have to be considered in context.

SUMMARY

The definition of games is broad and they are not equivalent. Games can be useful as they engage and motivate some students, they allow experiences that are not possible within the classroom as well as allowing the player to repeat as many times as required and provide them with appropriate feedback. However, games do not automatically lead to learning. The success of games as a teaching tool depends on the teacher. The skill of the teacher is in selecting an appropriate game and effectively mediating the learning experience. Students need support to identify the relevant learning, and to transfer this to other tasks.

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INTERACTIVE MULTIMEDIA TEXTBOOK – A WAY TO INCREASING LEARNERS' INTEREST IN CHEMISTRY CLASSES

Jiří Šibor, Irena Plucková, Eva Trnová, Josef Trna

ABSTRACT

Interest of students in natural sciences shows a declining tendency all over the world. Chemistry along with physics belongs to the least popular subjects. Research shows that one of the main causes of this state is the way chemistry is taught at schools. The students' style of learning is currently changing due to the influence of information and communication technologies. It is thus necessary to seek innovative approaches to teaching chemistry. Using an interactive board is one of such approaches. The present paper describes an interactive multimedia textbook of chemistry for lower secondary schools. This was created by authors. The textbook complements a classic printed textbook. In one place, it integrates photographs, videos, interdisciplinary links, interactive exercises, audio recordings of a text of the given textbook, interesting facts and Internet links related to the subject matter of chemistry. The textbook has been compiled so that it helps teachers to alter the traditional style of teaching which is uninteresting for learners. The modern design of the interactive textbook motivates learners to the study of chemistry and enables better understanding of its subject matter. This can be also a very effective instructional strategy for students who benefit from repetition, who need to see the material presented again, for students who are absent from school, for struggling learners, and for review for examinations. It draws on studies dealing with characteristics of the present generation of learners, sometimes referred to as the Net generation, and respects their learning style.

KEYWORDS

Interactive multimedia textbook, chemistry, lower secondary school students, learning style of present generation, motivation to the study of chemistry

INTRODUCTION

Many sociological studies (for example Bastl, 2010; Palečková 2007) show that interest of students in natural sciences shows a declining tendency all over the world. Chemistry along with physics belongs to the least popular subjects (Schreiner, Sjoberg, 2004). Research shows that one of the main causes of this state is the way chemistry is taught at schools. The students' style of learning is currently changing due to the influence of information and communication technologies. We were prepared Interactive multimedia textbooks – Chemistry for these reasons. Firstly, we wrote classic chemistry textbooks for lower secondary school students (Mach, Plucková, Šibor, 2010; Šibor, Plucková, Mach, 2011). Subsequently, we prepared workbooks for both classes (Mach, Plucková 2010; Plucková, Šibor 2011). On the basis was created Interactive multimedia textbook of chemistry for 8th form of elementary school (Mach, Plucková, Šibor, 2010). The Interactive multimedia textbook of chemistry for 9th class will be prepared soon. We hope for increased interest with our Interactive multimedia textbook of chemistry.

INTERACTIVE MULTIMEDIA TEXTBOOK (IMT)

The IMTs – interactive multimedia textbooks of chemistry for 8th and 9th forms of elementary school are based on printed textbooks and they have been expanded by a large number of different supplements. They can thus be used in classes not only for visual instruction, but also for varying and deepening the taught subject matter, specifically with the use of supplements which are already part of these electronic versions of the textbooks. IMTs include (apart from the graphic design of the printed textbook and possibly the workbook) also recorded texts, interesting facts, web links, photographs, videos, animations, various interactive exercises with a key (gap-filling, crosswords, different versions of Memory, revealing pictures, quizzes, flash tasks, etc.) and references to interdisciplinary links.

If the textbook is accompanied by a workbook, it is also part of the IMT and can be used for work on the interactive board.

Interactive multimedia textbooks of chemistry are universal. They can be used not only on any interactive board, but teaching from them is only possible while using a computer connected to a data projector or in a computer laboratory. They are prepared in a multi-license version, i.e. they can be installed on an unlimited number of computers at school using the same serial number, and teachers are also allowed to install them in their private computers at home.

You can add your own materials to the IMTs – photographs, videos, notes on teaching, web links. You can create your interactive exercises using preset templates. In addition, we are also repairing connection to various types of voice and answering devices, which will enable to test pupils' knowledge with an immediate response from each of them (the structure of test questions can thus be adapted to individual capabilities). All supplements that you add to the IMTs can (but don't have to) be shared and used also by your colleagues.

An IMT, i.e. a printed textbook converted into an interactive format (together with all supplements) is stable. Teachers who add their own supplements into the IMT store them in their own layer which can be edited at any time and the teachers can decide at any time whether they want to share the layer with the other colleagues. If they agree with others on sharing their layer, they can use all supplements inserted by all teachers in the course of a single lesson.

An IMT, besides the visual ground of the printed textbook, contains icons which hide just those supplements that you can use, instead of having to search them by yourself, often in a laborious and time-demanding manner:



audio – This icon is located beside the text (paragraph) which is recorded in the given audio. By clicking on this icon you start playing a particular audio recording.



video – Videos offer a possibility of varying the teaching by using a “visual aid“. The length of videos is accommodated to the possibilities of teaching. By clicking on the icon you open a page with an image of the video (animation). The video starts playing by clicking on its image.



photo – This icon is also located as close as possible to the particular topic. By clicking on it the given picture or photograph is displayed as an open object and is enlarged so that you can view it in detail. You can move it about on a page as you like and change its size just as with general pictures.



information, interesting facts – By clicking on this icon you will be transferred to the page containing further additional information (e.g. concerning discoveries and new findings) and sometimes pictures related to the covered topic.



interdisciplinary links – A printed textbook contains a list of interdisciplinary links. By a mere click, an IMT enables us to transfer to a page in a textbook for a different subject which contains a particular subject matter related to the topics which are currently being taught. By doing this, the IMT

supports effectively the effort whose aim is that pupils do not conceive the covered subject matter in isolation, but rather understand it within the context of the whole spectrum of acquired education.



internet – If a given computer is connected to the Internet, by clicking on this icon you will be transferred to a particular website related to the currently taught topic.

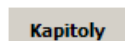
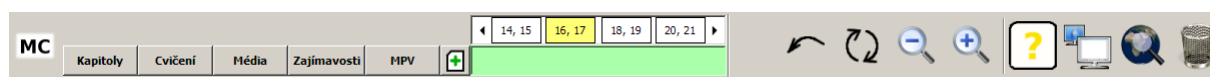


interactive exercise – Interactive exercises provide the opportunity of practising the taught subject matter or varying the lesson in a playful “interactive” way. Each interactive exercise is specific; how to proceed in solving it is learnt from instructions to the particular task. The key to solution to the given exercise is displayed when you touch the button “Solution”.

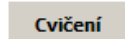


key (solution) – In contrast to the printed textbook where the key (solution) to individual questions is placed at the end, by clicking on this icon the solution is displayed directly beside the particular question.

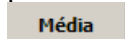
All links to supplementary materials are placed not only beside the particular topic which is being covered and which they relate to, but they are also placed in a clearly organized toolbar:



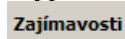
Chapters – By this button you can move in IMTs from chapter to chapter according to the current need.



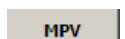
Exercise – By clicking on this button you can display all interactive exercises in the particular IMT.



Media – By clicking on this button you can open a list of supplements of a given IMT – audio recordings, videos, animations, pictures, photographs, web links – then you can choose from the supplements which of them you currently want to open.



Interesting facts – By clicking on this button is displayed a list of all interesting facts and additional information about the subject matter of the given IMT.

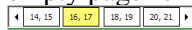


MPV – By this button you can transfer to pages of other textbooks so that pupils do not understand the subject matter in isolation, but rather in some other contexts.

Thanks to this toolbar you can not only choose any supplement of the particular interactive multimedia textbook, but you can also use other icons for working with an opened IMT.



next page – By clicking on this button a new “subpage” is opened to the opened page of an IMT where you can also post your own teaching materials, photographs, links, etc. You can also use it as an empty page for assignments of pupils.



selection of pages – By using these buttons you can choose any page or subpage of the textbook you want to display.



one step back – By clicking on this icon you will return one step back. In this way, you can gradually step back by even more actions.



refreshing the page – By clicking you can refresh an opened page into the “original” shape. All you have created on the given page will be deleted without saving.



minimizing, removing – By using this icon you can minimize a displayed text, picture or a whole page.



enlarging, approximation – By this icon you can enlarge a displayed text, picture or a whole page.



clue – If you do not know how to do something, it suffices to click on this icon.



network – By clicking on this icon you can connect to your school intranet.



Internet – After clicking on this icon a web page opens which serves for searching expressions (meaning of expressions, photographs....) in the environment of the Internet.



trash – By highlighting an object and a subsequent click on the icon you delete the given object. You can delete individual files by simply dragging them into the trash bin.

When working with IMT you are likely to use this toolbar:



tool for selection of an action

tool for blocking actions

tool for shifting enlarged (approximated) objects and pages

tool for highlighting a text, drawing into pictures

tool for deleting

tool for drawing a straight line

tool for drawing a square, a rectangle

tool for drawing a circle, an ellipse

tool for writing user's own text

tool for creating a note on the page

tool for colouring in of the whole highlighted object

tool for homogenization of colour

tool for selecting an inner colour of the added objects

tool for selecting a colour for writing and drawing in

tool for selection of the weight of a line

tool for basic selection of colours.

Chemistry 8 – General and Inorganic Chemistry

The textbook first introduces pupils to the concept of chemistry, then to chemical substances and blends, composition of substances, chemical reactions, elements and inorganic compounds. The textbook is supplied with several laboratory assignments, ideas for observation, experiments, project ideas, key competences and expected outcomes, cross-section topics, group assignments, key terms in English and German, revision tasks, interesting facts and tips for the use of the Internet. The textbook includes a periodic system of elements and a table with density, melting temperature and boiling temperature of some elements. Emphasis is also put on the connection between the subject matter and its practical applicability. A workbook has been prepared to accompany the textbook, too.

Chemistry 9 – General, Organic Chemistry and Biochemistry

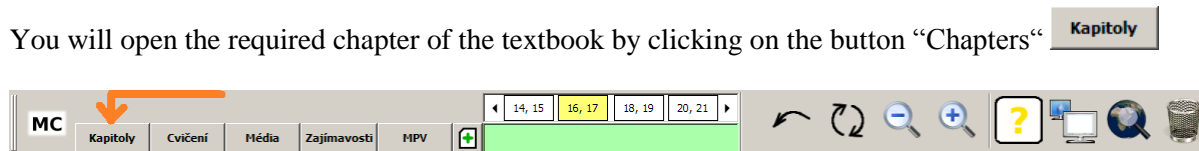
The textbook follows Chemistry 8 and also has the same structure. This textbook is focused to general chemistry, organic chemistry and biochemistry, especially. It is complemented by the environmental chemistry and applied chemistry.

IMT Chemistry 8 – general and inorganic chemistry

The interactive multimedia textbook and workbook contain 18 videos of chemical experiments (e.g. reaction of sodium and chlorine, decomposition of mercury iodide, formation of silver chloride, effects of sulphur dioxide on plants, properties of sodium hydroxide). The IMT further contains 43 interactive exercises (e.g. chemical equations, identify an element, we are learning about the composition of substances) and a number of additional photographs. Moreover, there is an interactive periodic system available on every page of the IMT.

After the installation of IMT according to the instructions an icon appears on the screen of your computer. If you double-click on this icon, the installed IMT opens along with all supplements which will be available at any time during the teaching.

You will open the required chapter of the textbook by clicking on the button “Chapters”



and you will select the given chapter in the menu. After it is opened, a double-page of a printed textbook will be displayed, together with the above-mentioned icons.

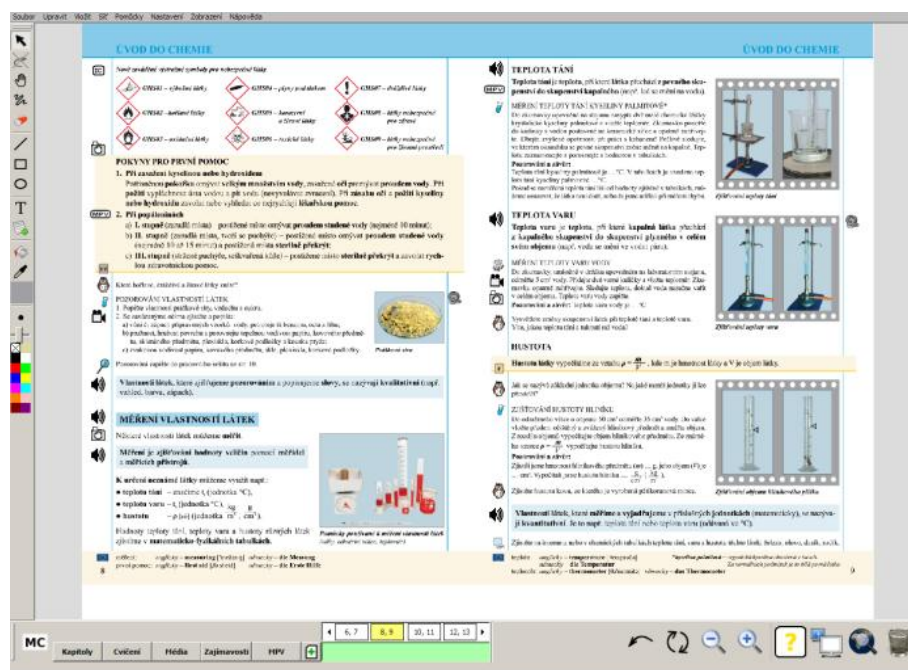


Figure 1. Chapter of IMT.

Now you can start using all the magic tricks of IMT to liven up your lessons. Individual parts of the text can be enlarged by clicking on them. You can shift the enlarged text, you can listen to it (pupils absorb the subject matter better if they can see it in front of them and hear it simultaneously) and underline the currently read text or highlight the currently taught subject matter at the same time. This is especially

important for pupils in back rows so that even they can fully follow the teaching. Nevertheless, this work with text can also be used while teaching visually impaired pupils or pupils who are hard of hearing (saving the teacher's vocal chords at the same time).

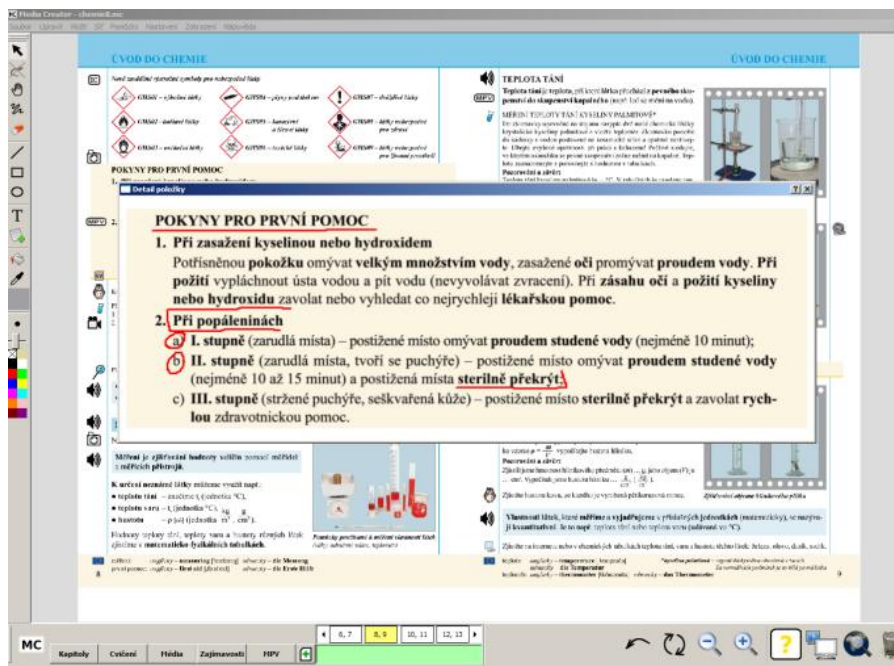


Figure 2. Enlarge selected part of the text

Similarly to working with texts, it is possible to work with photographs and pictures, which can then be also moved on the board, to enlarge, minimize (symmetrically as well as asymmetrically), or to rotate them and to draw into them.

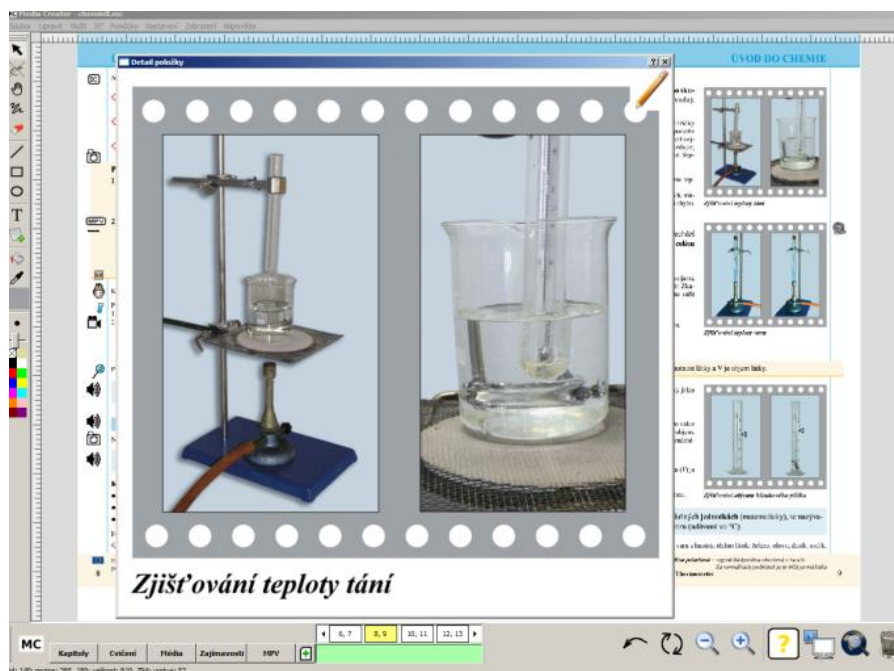






Figure 3. Work with photographs and pictures

This way you can work with parts which are identical to the printed version of the textbook (or the workbook) and you can use individual supplements in addition to them. Besides the listening parts  you can use Internet links (if your computer is connected to the Internet)  and switch to the Internet environment onto a page related to the currently covered subject matter, containing additional information, or you can move to any page in the given environment. Further, you can use additional photographs related to individual topics  which you can then work with in the same way as with the aforementioned pictures. You can also use one of the interactive exercises . It is up to the decision of the teacher how pupils will do the exercises – whether individually or whether a group of pupils do the whole exercise or whether pupils go to the board one by one.

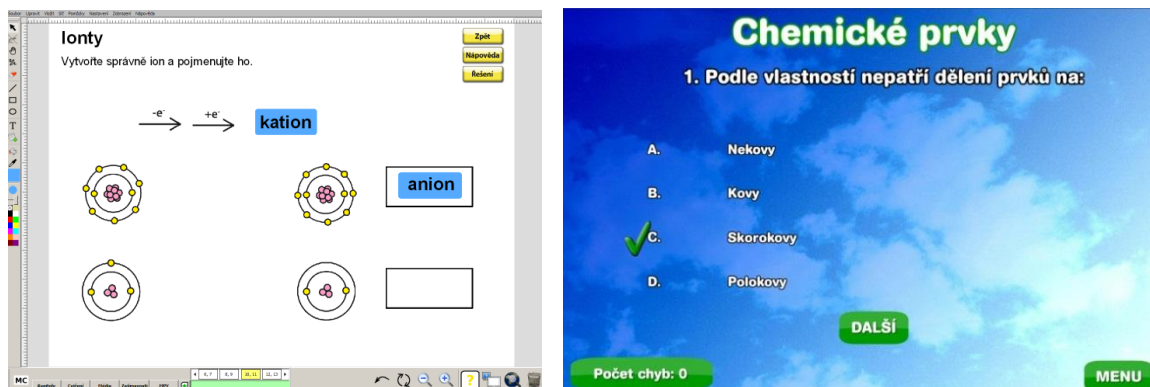



Figure 4. Example of the interactive exercises

You can also play a video . It contains recorded experiments which you can show to pupils beforehand so that they know what will take place during the experiment. It also includes recordings of experiments which cannot be carried out at school for different reasons (e.g. demanding character of the experiment, insufficient laboratory equipment).

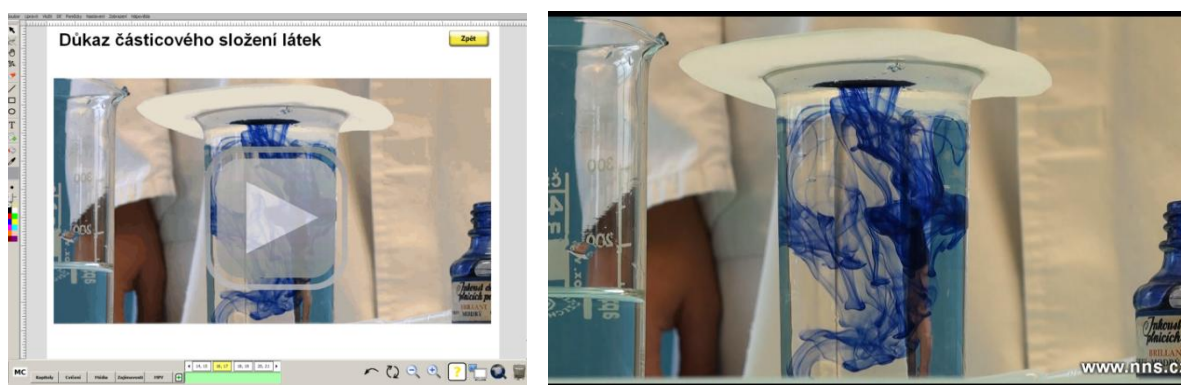





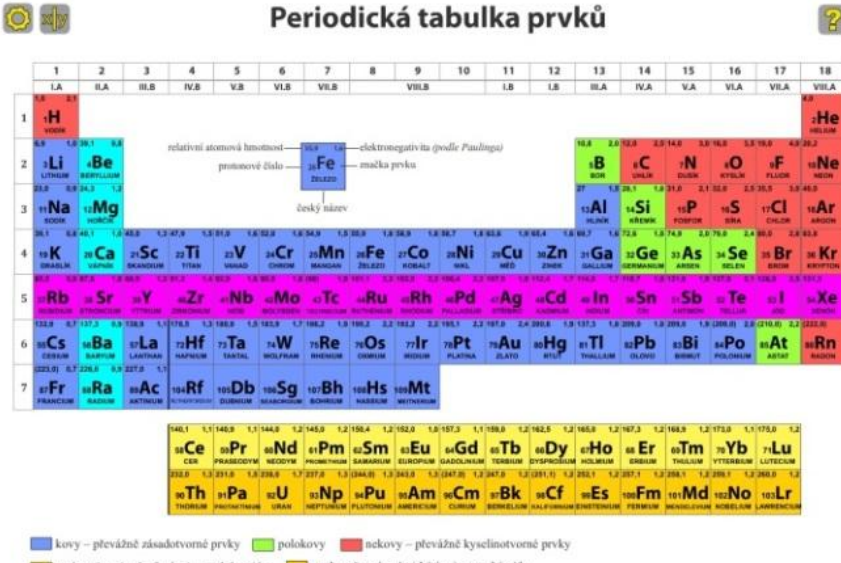
Figure 5. Video of chemistry experiment

You can also open a part of teaching material from another subject which is connected with the currently covered subject matter  as well as interesting facts about the given subject matter .

A part of IMT Chemistry 8 is also a special appendix – the periodic system of elements. This periodic system in a paper version is also part of the printed version of the textbook, however, it can be used in

the interactive format in IMT as well. After clicking on this icon  you can work with the periodic system on the interactive board (or in a computer). You can highlight periods and groups,

Periodická tabulka prvků



Legend:

- kovy – převážně zásadotvorné prvky
- polokovy
- nekovy – převážně kyselinotvorné prvky
- prvky zahrnuté za La (lanthan) – tzv. lanthanoidy
- prvky zahrnuté za Ac (aktinium) – tzv. aktinoidy

Figure 6. Special appendix – the periodic system of elements

after clicking on the symbol of an element you can read further information or view photographs related to an element.



ŽELEZO Fe

Iron / Eisen / Ferrum

Teplota tání: 1 540 °C

Teplota varu: 2 800 °C

Hustota (p): 7 870 kg/m³

Železo je jedním z nejrozšířenějších prvků. V přírodě se vyskytuje v železných rudách (např. magnetit, siderit, hematit). Železo je stříbrolesklý, magnetický kov. Snadno podléhá korozi, která ho znehodnocuje. Ve vysoké peci se z železných rud za přítomnosti koksu a vápence vyrábí surové železo. To se dále zpracovává na litinu a ocel. Litina i ocel jsou slitiny železa s uhlíkem. Liší se od sebe obsahem uhlíku – ocel ho obsahuje méně, je proto pružná a pevnější než litina. Z litiny se vyrábějí

Figure 7. Basic element information (example iron)

You can also compare two elements with each other

SODÍK	ANTIMON
23,0	121,8
0,9	1,9
Na	Sb
11	51
SODÍK	ANTIMON
Sodium (anglicky) / Natrium (německy) / Natrium (latinsky)	Antimony (anglicky) / Antimon (německy) / Stibium (latinsky)

Figure 8. Comparison of two elements

and, if necessary, adjust the periodic system according to the current needs (e.g. for examination of pupils).

Periodická tabulka prvků

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IA	IIA	IIIB	IVB	VB	VIB	VII B	VIII B	VIII B	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIA	
1 H																	He
2 Li	Be											B	C	N	O	F	Ne
3 Na	Mg											Al	Si	P	S	Cl	Ar
4 K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5 Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6 Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7 Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

[blue] kovy – převážně zásadotvorné prvky [green] polokovy [red] nekovy – převážně kyselinotvorné prvky
 [yellow] prvky zařazené za La (lanthan) – tzv. lanthanoidy [orange] prvky zařazené za Ac (aktinium) – tzv. aktinoidy

Figure 9. Periodic table changes as needed

RESEARCH

We conducted a quick research among lower secondary school teachers with the following hypothesis: There is growing interest in chemistry students using multimedia textbook?

Research was conducted through an interview when we asked teachers who use our textbook.

Teachers answered 5 basic questions:

1. You missed a multimedia textbook for teaching chemistry?
2. Increases students' interest in multimedia textbooks about chemistry?
3. Where do you see the greatest benefits of multimedia textbooks for students?
4. It helps to interdisciplinary textbook?
5. The multimedia textbook is useful for you.

With requests for interviews, we contacted 27 chemistry teachers from 18 randomly selected lower

secondary schools in the Czech Republic. Interview was attended by 21 teachers. Six teachers interviewed refused.

The results of the interview reveal that 68% of teachers lacked multimedia textbook for teaching chemistry in elementary school. The 74% of teachers expected to increase pupils' interest in books on chemistry. The greatest benefits for teachers of pupils in the ability to watch videos of experiments that are unworkable in practice (financial, security and time reasons) 98%. Students also perceive positively the possibility of cooperation with the interactive whiteboard (62%), possibility of full-text searching and sorting information in cooperation with the Internet (54%), possibility of animation (34%) and use self-evaluation tests (12%). Teachers believe that the textbook is an interdisciplinary and develops a possible cooperation with the Internet (82%). Also consider most teachers prefer to play textbook chemical experiments (92%). Most of their answers are complex. On the same level, sees the following advantages: textbooks is advantageous in the possibility of full-text searching and sorting information; better opportunities structuring the text; incorporation of color photographs, images, graphs, diagrams, etc., the possibility of using animations, hyperlinks, self-evaluation tests, the possibility of blended learning; the ability to insert himself a teacher of information and the use of interactive whiteboards. From interviews with teachers it is clear that teachers prefer to teach chemistry advanced multimedia support the classic teaching text. These were, however, worked well. Themselves to this view we identify, and we along with the classic textbook of chemistry and created a multimedia textbook. Due to modern trends (interdisciplinary relations) will be usable not only for teaching chemistry, but (partly) the teaching of other scientific disciplines, health education, geography, etc. The textbook meets the requirements. Teachers will be available to a number of current professional and didactic teaching materials, which are also graded according to difficulty (for students for gifted students, for those interested in a particular topic, teachers, etc.).

CONCLUSIONS

The interactive multimedia textbooks - Chemistry contain:

- complete graphic design of the printed version of the textbook,
- texts converted into an audio format – giving a possibility to listen,
- additional information – interesting facts,
- links to web pages related to the subject matter,
- interdisciplinary links – examples from textbooks for other subjects,
- photographs illustrating the covered topics,
- commented videos or flash animations in some chapters,
- interactive exercises with a key related to the covered subject matter,
- a free page for own creative work,
- a workbook (if it is published with the textbook)

and they enable to:

- move in the textbook by chapters and pages within chapters,
- enlarge and shift texts, photographs, graphs and illustrations,
- additional writing and drawing (also into enlarged texts, photographs, etc.).

Multimedia textbook is also possible, in comparison with classical textbook, much better to implement in practice, mainly due to price and ease of physical accessibility. An indisputable advantage is easy to update. This educational tool it can be, for example, based on feedback from teachers to further develop and improve. The final form of textbooks should be conditional on feedback from teachers and verification project in selected schools.

The performed research shows that the current state of the pupils' interest in chemistry in elementary schools is not satisfactory. In the work described multimedia textbook to support the teaching of chemistry is such an agent. A quick survey among teachers shows that pupils' interest in a form of teaching is increasing.

Compared to the classic textbook has many benefits this form - teachers can use prepared texts, images, and can also largely modified according to your wishes. Teachers need to perform dangerous or expensive experiments. Teachers can use ready animations, diagrams, pictures, tables and interactive tasks. Then there's the ability to easily update the text or the possibility of sharing learning materials created by teachers directly. The benefit is also the possibility of full-text searching and sorting information and implementation of other information.

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INTEGRATING SCIENTIFIC INQUIRY AND TECHNOLOGICAL DESIGN ACTIVITIES USING MICROCOMPUTER-BASED LABORATORIES

Italo Testa, Giovanni Chiefari, Elena Sassi

ABSTRACT

Research findings suggest the inclusion of design activities in science teaching to foster students' learning of scientific/technological contents. Integration with inquiry-based activities has also been suggested to improve engagement in authentic practices. We propose a Teaching-Learning Sequence (TLS), "The insulated house", which integrates scientific inquiry and technological design activities using a blend of traditional and microcomputer-based laboratories. The TLS was developed within an Italian National Project aimed at improving students' scientific literacy. The activities have involved 15 students (17-18 years-old) of a Technical School. The contents addressed are: heat, temperature, materials thermal properties. First, an experiment to describe/interpret cooling/heating of a water quantity was done with thermometers and temperature probes; data analysis allowed to identify the mathematical function describing the temperature vs. time trend and the physical parameters of the phenomenon (e.g. conductivity, exchange surface, thickness, etc...). Then, the students were asked to design the walls of an house to met certain temperature requirements in the inner rooms. A prototype "house" with 3 "rooms" separated by "walls" of different materials was built and tested to verify that the materials met the desired requirements when illuminated by an artificial "sun" (high wattage lamp). In each room a sensor measured the temperature. The students drew on the experiment results to investigate the influence of the walls' material on the heating curve of each room and identify the most suitable materials for walls' construction. Analysis of answers to an open question shows that the proposed integrated activities improved students' views about Science and Technology relationships.

KEYWORDS

Microcomputer-based laboratories, technological design, science & technology integration

INTRODUCTION

Several studies support the inclusion of design-based learning (DBL) activities to improve science teaching and promote a better understanding of scientific contents (Puntambekar and Kolodner, 2005; Schnittka and Bell, 2010). DBL is generally interpreted as a teaching approach centred on the search for a solution to a real-world problem and on the evaluation of possible solutions. With DBL approaches, due to the openness of the tasks and the absence of clear pre-determined solutions, students may develop skills similar to those involved in Inquiry-based learning (IBL) activities (ITEA, 2000; NRC, 1996). DBL and IBL approaches are deeply linked, both ultimately aim at constructing a model of the studied problem or of the investigated natural phenomenon (Roth, 2001). However, DBL approaches are still not integrated with IBL activities (Fortus et al., 2004).

The TLS "The insulated house" here presented is a possible contribution for an integrated DBL and IBL approach at secondary school level.

CONTEXT

The TLS here described has been carried out in the framework of the National Scientific Degrees Plan (PLS Piano Lauree Scientifiche³⁰) funded by the Italian Ministry of School and University since 2005. PLS initially aimed at contrasting the decrease in the enrolment of secondary school students in tertiary scientific education (Mathematics, Chemistry, Physics, Materials Science) and at motivating them to related professional careers. Recently it shifted to improve students' scientific literacy, particularly on laboratory activities and scientists' methodologies. The authors are involved in PLS-Physics.

In the school year 2010-11, five schools, eight teachers and about 80 students have been involved in a total of 100 hours of activities, both at school and University laboratories.

THEORETICAL FRAMEWORK

The theoretical guidelines inspiring design and experimentation of the activities draw from views of Nature of Science (NOS) and Nature of Technology (NOT) which envisage the close relationships between Science and Technology (S&T). The NOS view is inspired by Ziman (1978). Science, particularly Physics, is purposefully developed to use Mathematics as unambiguous language; only quantities numerically representable enter the Science and Physics theoretical constructions describing and interpreting natural phenomena. The field of research uses measurable quantities to which a number is linked; the choice of such quantities mainly warrants the reliability of the obtained results. Conversely, the reliability of scientific descriptions, interpretations and predictions of natural phenomena can be judged if measurable quantities are involved in these processes. The choice of measurable quantities leads scientists to select/disregard, in a lab-experiment, aspects of the investigated natural events and construct a model of the phenomenon specified by hypotheses and relationships amongst the chosen measurable quantities. Such model has to be tested to verify its predictions versus experimental evidence. In case of disagreement, the hypotheses of the model are changed or optimised to refine its relationships. In this view scientific inquiry is a process that starts from a problem and tries to solve it via a model of the studied phenomenon (Fig. 1, White & Frederiksen, 1998). The adopted IBL approach resembles such cycle.

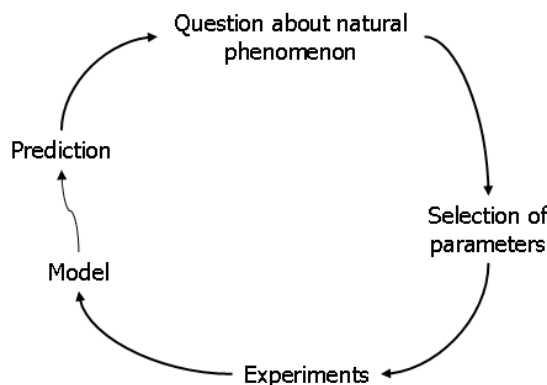


Figure 1. Representation of the inquiry process

The NOT view is inspired by Arthur (2009). Any technology can be seen, in a broader sense, as a system with a given finality and several components (combination); any component, even the most elementary part, is in itself a technology (recursivity); any technology internally exploits a physical law strictly related to a natural phenomenon (harnessing). For instance, optical fibres technology is based on total internal reflection, temperature probes works thanks to a thermistor, etc... This view elicits the solid S&T relationships: measurable quantities are needed to describe/interpret quantitatively natural phenomena; Technology builds on Science methods/contents to produce new developments while

³⁰ Information available at <http://www.progettolaureescientifiche.eu/>

Science exploits Technology to construct new instruments and methods of measurements for experiments and models. In this view, technological design is the mechanism through which new technologies are obtained re-combining and adapting existing technologies, each of which, at its very core, harnesses a natural phenomenon. Design, therefore, is at the basis of the evolution of technologies, triggered by searching suitable solutions to a given aim, using skills and resources successfully managed and increased with time. To design means basically to choose solutions taking into account available technological components as well as, e.g., economic or logistic constraints. The design process can be represented by five phases (Figure 2): formulation of a problem, identification of goals and evidences related to it, evaluation of different possibilities, design of the solution, testing and evaluation of it. The DBL approach adopted in the TLS is inspired by such design cycle.

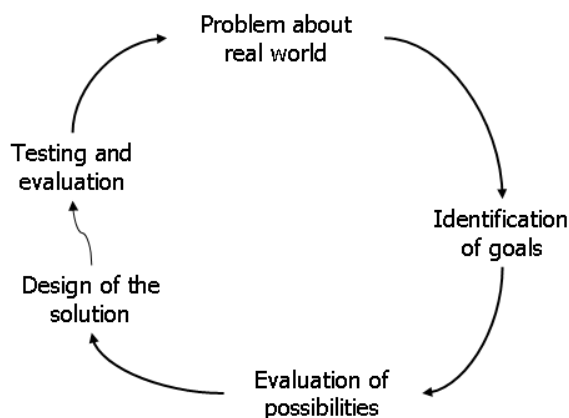


Figure 2. Representation of the design process

As shown by Figure 1 and 2, inquiry and design processes share an iterative structure: the designed solution and the proposed model are tested against experimental evidence. In case of disagreement, the cycle must restart to refine goals and possible solutions. In the TLS activities this common structure was used to engage students in both IBL and DBL cycles.

RESEARCH QUESTION, DATA COLLECTION AND DATA ANALYSIS

Drawing from the theoretical framework described above, we developed the TLS “The insulated house” to integrate S&T contents and exploit inquiry and design processes. The specific scientific content addressed was the cooling of a liquid, described by Newton’s law; the technological content was the construction of a temperature sensor circuit using the LM35C³¹ component. The learning objectives were to:

- describe the heating and cooling of liquids by an exponential model;
- recognise how scientists describe and interpret natural phenomena in terms of physical quantities;
- explain the basic of the design of electronic circuits used in thermal regulation of civil houses;
- justify the various stages of the design of a complex system;
- identify similarities and differences between inquiry and design processes

In this paper, we focus on the impact of the TLS activities on students’ understanding of the relationships between S&T. The specific research question was:

“Have the proposed TLS activities actually conveyed informed ideas about S&T?”

³¹ Datasheets available at <http://www.national.com/mpf/LM/LM35.html#Overview>

To this aim, an open question “what are the relationships between S&T?” was submitted at the beginning and at the end of the TLS activities. The same question was asked also two months after to check long-term effects. The students’ written answers have been analysed through categories (Gardner, 1994; 1999) which represent increasing degrees of understanding of S&T relationships (Table 1).

Table 1. Rubrics adopted to analyse students’ responses to the open question “*what are the relationships between S&T?*”

Category	Description
Level 2 (L 2)	S&T interact reciprocally
Level 1 (L 1)	Science precedes Technology, Technology precedes Science, S&T are independent
Level 0 (L 0)	No clear distinction or similarity identified

IMPLEMENTATION OF THE ACTIVITIES

The TLS activities lasted 24 school hours and involved 15 students (17-18 years old) and two teachers of one of the five secondary schools included in the PLS, a Technical Institute for Electronics and Telecommunication in the suburban area of Naples. All activities have been done at the school laboratory of Electronic Systems. Figure 3 shows the timeline and when IBL and DBL approaches have been used.

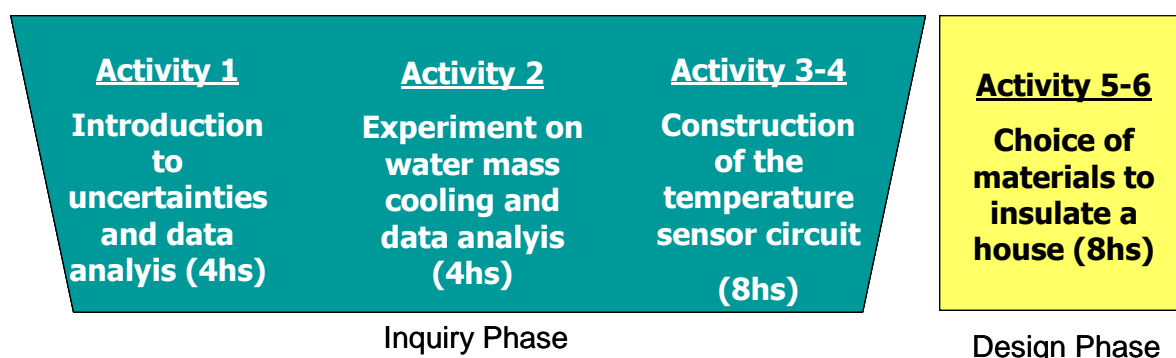


Figure 3. Activities timeline of TLS “The insulated house”

In Activity 1 (4 hours), firstly the TLS objectives and the links with the Physics and the Electronics syllabuses have been discussed with the students. Then, the basic elements of uncertainties, significant figures, scientific notation were addressed; the students also learned to use Logger Pro and Microsoft Excel to produce linear fits of experimental data.

In Activity 2 (4 hours), the students have been asked “*How a hot water mass cools down when left in an environment at about 20°C?*” The students, in small groups (3-4), measured, first with a thermometer and then with an on-line temperature probe, the change of temperature with time of water masses in a plastic cup, initially at $T = 60^{\circ}\text{C}$ and left to cool down in a quasi-constant temperature laboratory (approximately 23°C). Each measurement lasted about 20 minutes. With Excel or Logger Pro the students’ groups studied the collected data, modelled their trend by an exponential function, derived and compared the time constant of the cooling process in both thermometer and temperature probe experiments (Figure 4 and 5). To help students carry out the measurement and data analysis a worksheet was used. More specifically, the students were guided to relate the parameters of the modelling exponential function to the physical variables of the experiment (mass of the water, heat capacity, material of the cup, heat exchange surface, etc...). The inquiry cycle (Figure 1) was explicitly

discussed, with emphasis on how scientists construct mathematical models of observed phenomena. The results were recorded for the design phase.

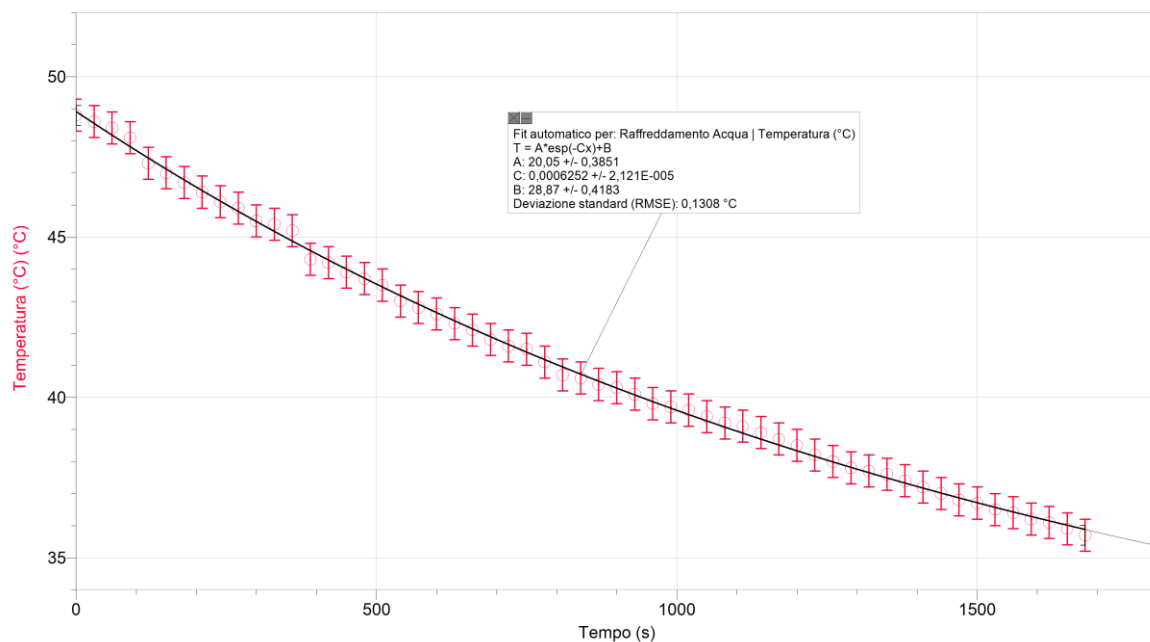


Figure 4. Data analysis of the water cooling, with a thermometer. Modelling function is:

$$T(t) = Ae^{-Ct} + B \text{ with } A = (20.0 \pm 0.4)^{\circ}\text{C}; B = (28.9 \pm 0.4)^{\circ}\text{C}; C = (62 \pm 2)10^{-5} s^{-1}$$

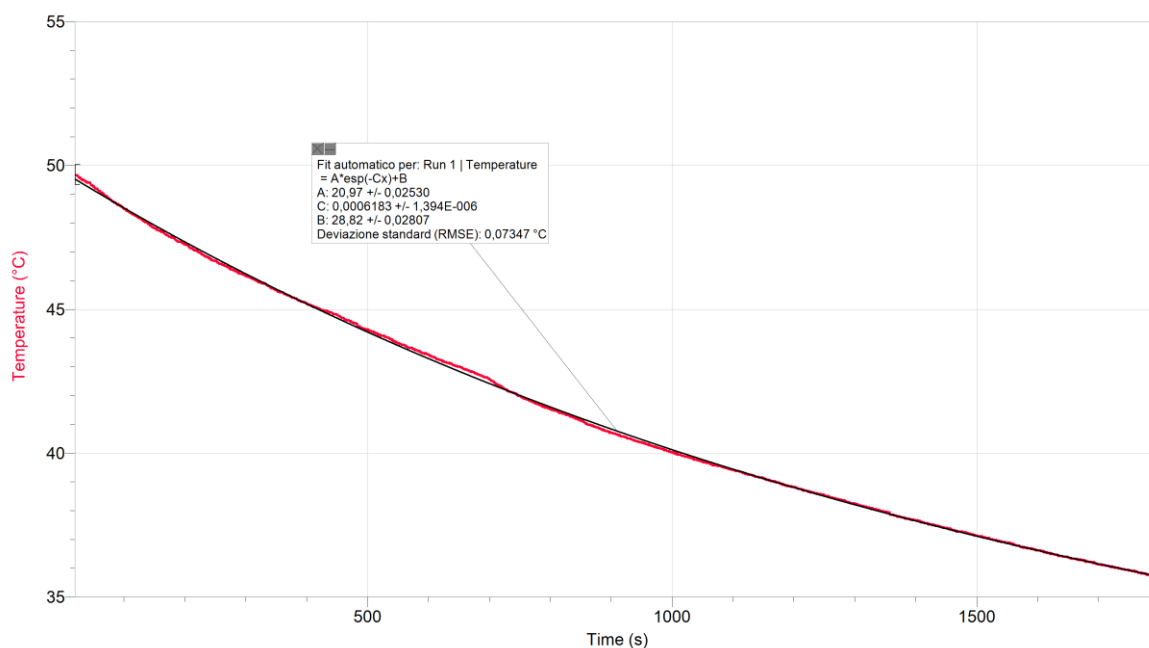


Figure 5. Data analysis of the water cooling, with a temperature probe. Modelling function is:

$$T(t) = Ae^{-Ct} + B \text{ with } A = (20.97 \pm 0.03)^{\circ}\text{C}; B = (28.82 \pm 0.03)^{\circ}\text{C}; C = (618 \pm 1) \cdot 10^{-6} s^{-1}$$

In Activity 3 and 4 (four hours each) the students constructed, with the Electronics Systems teacher, three temperature sensor circuits, using the integrated component LM35C, as part of the school syllabus. In these activities, the students used the schema of the circuits reported in their textbooks. The

design cycle (Figure 2) was introduced and similarities and differences with the inquiry process were discussed with students. The models of observed phenomena and of solutions to a given problem were identified as important links between S&T. Finally, a design problem was posed: *“Choose the most suitable materials for the walls of a house so that each room maintains a constant temperature of about 22 degrees when lighted up by the Sun”*.

In Activity 5 (4 hours) each group discussed possible solutions to the design problem and proposed their ideas to the class. The activity was carried out with a worksheet to help students identify the goals of the project and sketch possible solutions. After gathering together the students’ proposals, it was agreed to build up a prototype of a cardboard house with three “rooms”, each with a previously constructed circuit to measure the temperature.

In the final Activity 6 (4 hours), the students built the agreed prototype (Figure 6 and 7) and were asked to test it by changing the materials of the “walls” in order to maintain a constant temperature in the rooms when house was illuminated by an “artificial” sun, ~150W lamp. Using a worksheet, the students were guided to draw upon the experiments on the cooling of water in the cup, thinking of how the material of the cup influenced the temperature trend of the water. The students explored different materials and conditions to solve the problem of insulation. They investigated how a polystyrene “ceiling” affected the temperature of one room (Figure 8 and 9) with respect to that of the other two rooms left uncovered. An important role was played by both, the temperature sensor circuits previously constructed and the temperature probes connected to portable interfaces which allowed quick repetitions of measurements. After two cycles of trials and evaluations, the students proposed a refined prototype of the house with the thermal behaviour requested. At the end of the activity, the inquiry and design cycles were again showed to the students in order to strengthen their understanding of the similarities/differences between the two processes.

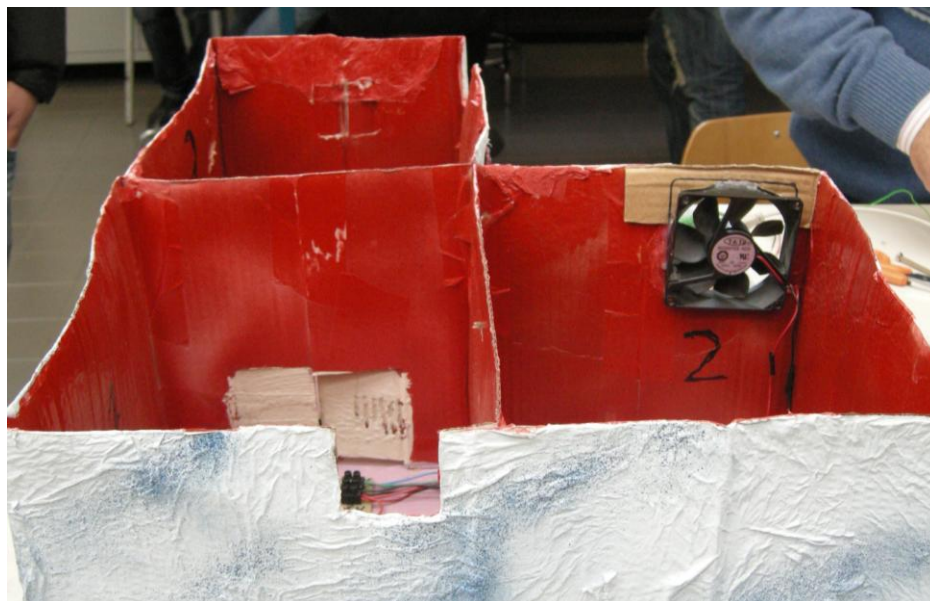


Figure 6. Prototype of the cardboard “house”. The fan cools down one of the “rooms”

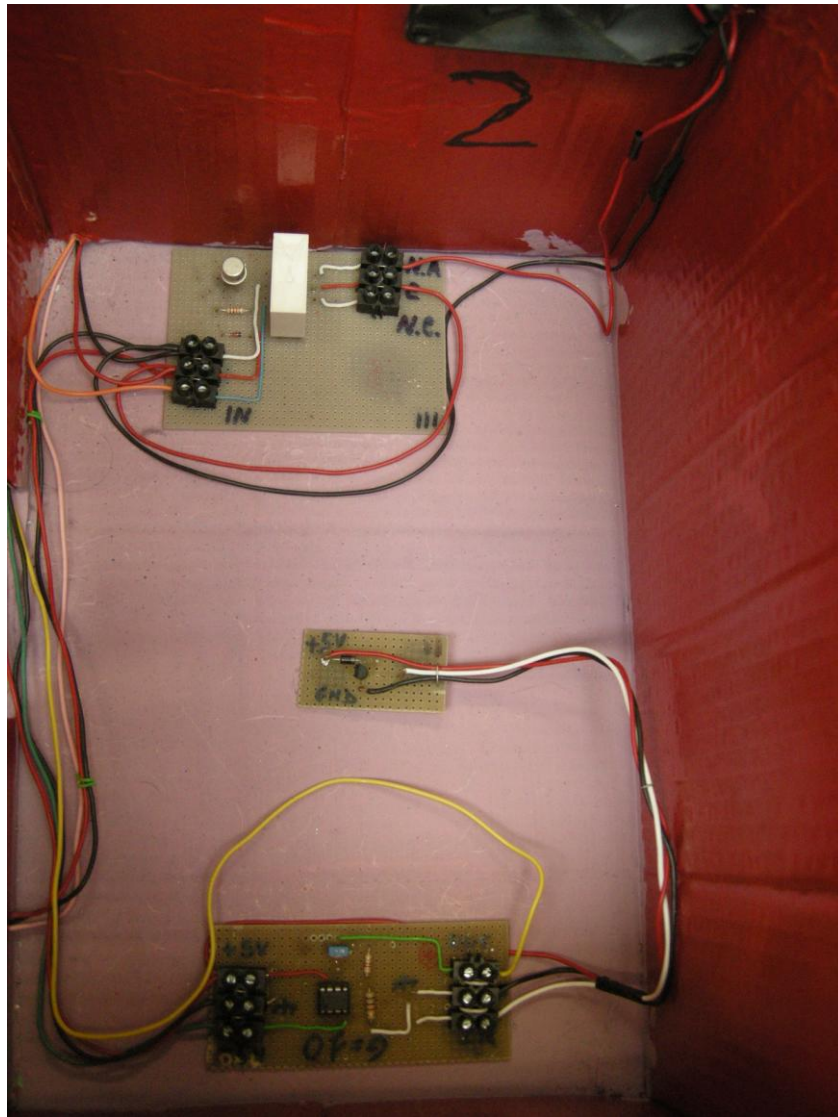


Figure 7. Temperature sensor circuit designed and built by the students, in a room of the “house”



Figure 8. Test of the effect of a material during the design cycle. Room 1 is covered by a polystyrene “ceiling”, the others are uncovered. The “house” is illuminated by the 150W lamp (the “Sun”).

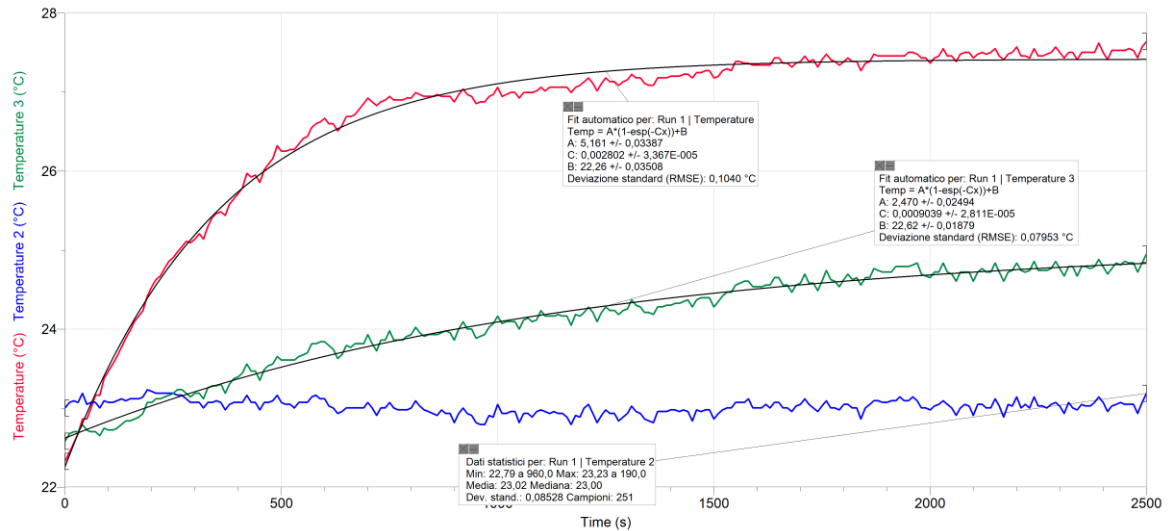


Figure 9. Real-Time measurements of the temperature in the three rooms of the “house” illuminated by the high wattage lamp (Figure 8): room 1, with the polystyrene ceiling (red); room 2, the farthest from the lamp (blue). room 3 illuminated as room 1 by the lamp but without the ceiling (green). The red and green data set can be modelled by an exponential function $T(t) = A(1 - e^{-Cx}) + B$; with

$$A = (5.16 \pm 0.03)^\circ\text{C}; B = (22.26 \pm 0.04)^\circ\text{C}; C = (280 \pm 3) \cdot 10^{-5} \text{ s}^{-1} \text{ (red) and}$$

$$A = (2.47 \pm 0.02)^\circ\text{C}; B = (22.62 \pm 0.02)^\circ\text{C}; C = (90 \pm 3) \cdot 10^{-5} \text{ s}^{-1} \text{ (green).}$$

The temperature in room 2 (blue data) is almost constant: $T_2 = (23.02 \pm 0.09)^\circ\text{C}$. The time constant for room 1 is $(357 \pm 4)_s$ while for room 3 it is $(111 \pm 3) \cdot 10_s$. From the experimental settings used by the students, this difference between the time constants can be attributed to the polystyrene “ceiling”, both the rooms being at about the same distance from the lamp.

FINDINGS

The results of the analysis of the students’ answers to the open question “What are the relationships between S&T?” are reported in Figure 10.

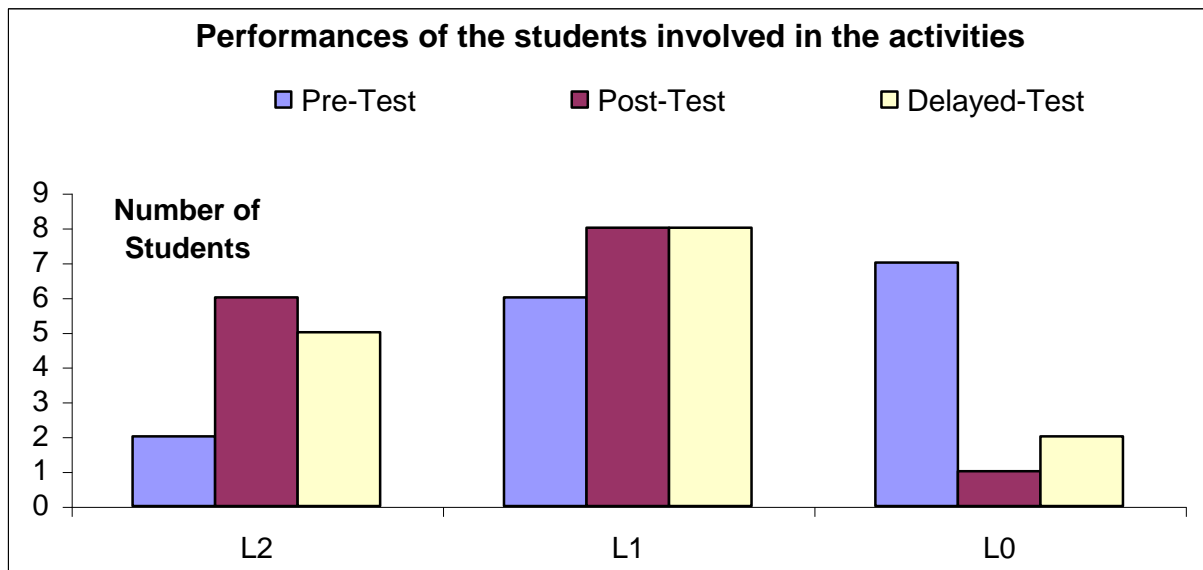


Figure 10. Distribution of students’ answers to the questionnaire about S&T

Results show that after the activities, the number of students with an informed view about S&T epistemological relationships (L 2 level) increased (from two to six) and that this number had not decreased significantly after two months the end of the activities (from six to five). Examples of answers are:

“.... there is a strong link... Technology is based on some scientific phenomena and on results of scientific inquiry... work in Science is based on the high progresses of Technology...”

“... the more advanced the Technology... the more the Science can deeply study natural phenomena on which Technology is based... however, Technology depends on the growth and development of Science”

“Science and Technology are strictly linked... thanks to Technology the work of scientists is facilitated since it is possible to better reproduce natural phenomena in laboratory...”

“Technology and Science are linked one to the other because thanks to Science and its studies we can discover new phenomena and hence use them for new technologies which in turn allow deeper scientific studies”

Correspondently, the number of students with naïve ideas about S&T relationships decreased between the pre- and post-test from seven to one. An example of these L 0 answers is:

“.. Technology is an artificial representation of nature”

However, the slight majority of the students in the post-test and delayed-test still had only partially correct ideas about the links between S&T. Exemplar excerpts of these L 1 answers are:

“... Science discovers the things of Earth, Technology makes experiments on an object...”

“Science is the inquiry... Technology only applies the studies of Science”

CONCLUSIONS

The start of this study is the fact that S&T education in school practice is often very fragmented and few teaching proposals deal with the S&T relationships. Such separation plays against both S&T learning and teaching. On the one hand, scientific concepts, laws and theories are taught in a decontextualized and socially neutral way, with poor effects on students' learning and motivation. On the other hand, teaching of electronics, engineering systems, telecommunication, informatics are not yet included in the syllabuses of not vocational schools. The TLS presented here, in the framework of the Italian National Scientific Degree Plan, adopted an integrated approach to S&T, in particular Physics and Electronic Systems, from the inquiry and design viewpoints.

Other authors explicitly support the inclusion of technological design into science teaching. Cajas (2001) reports that the “bridge project”, where students are offered the opportunity to simulate the design and testing of a bridge, may be a useful context to learn contents as gravity, forces and tensions, properties of materials. Benenson (2001) reports the “City Technology Curriculum” where the students are involved in activities as: how to create maps of a city, how to design circuits and control devices, packaging issues and graphic coding useful for street signs. Silk, Schunn, & Strand (2009) reported positive results in students' learning outcomes after the implementation of a design-based unit on electronics and simple electrical circuits in an urban setting.

However, in most proposals, DBL, crucial for Technology education, is not adequately integrated with IBL, essential for science education.

The presented TLS mainly aimed at engaging students in: inquiry and design tasks; relating the results from the inquiry activities to the search and evaluation of possible solutions of the design activities. An important educational role has been played by the integration of electronic measurements with more traditional ones. The possibility to observe the abstract representation of the phenomenon (cooling of water) while it was happening, helped students identify important features (e.g., the time constants of the temperature trends) used later in design tasks. The results suggest to integrate real-time measurements also in Technology education, to facilitate the construction of scientific models of the studied phenomena to be exploited when evaluating the solutions to design problems.

The activities aimed also at convincing students that: inquiry and design approaches are deeply interrelated; S&T nowadays strongly depends one on the other. This epistemologically informed idea actually emerged from the students' post and delayed questionnaires; consequently, a positive effect of TLS on the students' ideas about S&T relationships can be inferred. However, it has also been found that the slight majority of the students maintain partially incorrect ideas about S&T relationships, in agreement with previous studies (Constantinou, Hadjilouca, & Papadouris, 2010; Di Gironimo, 2010). Such result suggests that further explicit emphasis on S&T links at epistemological level should be put forward to students in similar activities.

Overall, the results reported in this paper are encouraging and support the introduction of IBL and DBL integrated approaches into school practice.

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THE USE OF ICT IN PRESCHOOL EDUCATION FOR GEOMETRY TEACHING

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ABSTRACT

The aim of this study is to reveal the use of ICT in Greek pre-school education and explores the implementation of a software application for geometry education. The application consisted of several activities including those with computers, which were designed following the background of van Hiele's levels for geometry concepts, referred to as the 'Kindergarten Shape Model' (KSM). In addition, we use a mathematical test referred to as the 'Kindergarten Shape Test' (KST) to explore the use of ICT in the preschool classroom for teaching basic mathematical concepts. The KST is a task orientated test which attends to measure the level of early geometry competence developed for kindergarten. Pupils in the control group received only the traditional science instruction about a variety of topics concerning fundamental geometry concepts. Pupils in the experimental group received only the geometry instruction with the use of ICT for the same geometry concepts. Both the experimental and the control groups consisted of classes from the same participating schools. Our research is in progress and the first indicative results show that teaching and learning through ICT is an interactive process for children at the preschool level and has a positive effect for geometry education.

KEYWORDS

Information and communication, technologies, geometry teaching; kindergarten

INTRODUCTION

Teaching and learning in the 21st century requires new competencies, new cultures and new ways of experiencing teaching and learning as well as requiring motivation and specific strategies on the part of those involved in education. The innovations which have been occurring through recent decades in Information and Communication Technology (ICT) have awakened the interest of the educational community which has in turn felt the need to evolve in its theoretical areas and pedagogic practices.

Research suggests that the mathematical difficulties students encounter later are connected with insufficient development of mathematical thinking in the early years (Van de Rijt & Van Luit, 1998; Zaranis & Kalogiannakis, 2011). Various research results relate the appropriate use of computers with the ability of students to more efficiently understand the different mathematical notions (Clements & Sarama, 2002, Fisher & Gillespie, 2003, Zaranis & Oikonomidis, 2009). Thus, it becomes obvious that kindergarten emerges as a very attractive environment of investigating the computer use in education of mathematics. Indeed, a vast number of studies show a positive correlation between the use of computers and the development of mathematical thinking in kindergarten (Clements, 2000, 2002, Zaranis, 2011).

THE LEVELS OF UNDERSTANDING GEOMETRY

In the whole trajectory, four levels of understanding geometry concepts are involved. These should be the main focus of the learning and teaching procedure concerning geometry in kindergarten. The four levels arise from the combination of the theories presented below. The theory of van Hiele model deals specifically with geometric thought as it develops through several levels of sophistication under the influence of a school curriculum (Clements & Battista 1992). The van Hiele model uses five levels;

however, for the kindergarten only the first two levels were used. In the Visual Level students were to identify figures such as squares and triangles as visual gestalts, for instance, they might say that a figure is a rectangle because 'it looks like a door.' In the Descriptive/Analytic Level, students were to identify shapes from their properties, for example, a student shows a rhombus as a figure with four equal sides. In this research, using the above theory for geometrical concepts, the model was suggested based on the first two van Hiele levels for preschool. Moreover, our model is based on the five skills proposed by Alan Hoffer. He has proposed a set of five categories of basic skills (Hoffer, 1981) relevant to school students: visual, verbal, drawing, logical and applied skills.

Following the above model, the four level model designed for this research was inspired by the framework of the levels of van Hiele model for geometrical concepts, referred to as the 'Kindergarten Shape Model' (KSM). In the first level, young students were introduced to visual recognition, verbal presentation and drawing skills of the shapes. They were also implicated with problem situations in which questions of comparisons or 'what is this' questions were posed in a way to be meaningful for children. Examples of such activities could be as follows: 'Draw a square.' 'Bring me something that is a circle from the classroom.' 'What is the shape of the door?' etc.

In the second level, students should be able distinguish shapes from their figure, separating them from a set of objects and fitting together several figures under certain conditions. This can be realized by performing activities such as playing with constructing blocks, working with cut-outs and tangram. Examples of such questions could be 'make a dog from these triangles', 'find the shape by touching it', 'find the correct shape', etc.

In the third level, students should be able to face direct questions such as 'find the properties of square' and 'find the shape with three sides' and answer them. Attention is focused to quantification where the involvement of properties is immediate. As a result, questions should relate to distinctive objects or quantities such as 'how many angles does a triangle have' or 'which shape has four sides'. At this level students should be able to organize the properties of objects using clear patterns as to avoid mistakes. In the last level students do not need the physical presence of objects any more, but the 'mental representations,' of the objects like their properties. Also they understand the concept of shared properties, like 'the square is a rectangle' etc.

METHODOLOGY

The study was carried out during the 2011-2012 school year in two public kindergartens located in the city of Rethymno (Crete, Greece). The sample consisted of 68 kindergarten children (38 girls and 30 boys). There were two groups in the study, one control and one experimental. One school was selected as the control group (n=32) and the other as the experimental group (n=36). In the control group there was not a computer available for the students' use, while in the experimental there was one.

The present research was conducted in three phases. In the first phase the pre-test was given to the class during the beginning of December 2011 to isolate the effects of the treatment by looking for inherent inequities in the geometry achievement potential of the two groups. The first twenty questions of the test were based on the model proposed by Allan Hoffer (1981) and the other twenty two questions were from the test that was used in the research by Clements, Swaminathan, Zeitler - Hannibal and Sarama (1999). This whole test is referred to as the 'Kindergarten Shape Test' (KST). Due to the young age of the students the pre-tests were administrated individually to each student like an interview. The focus of the interview was on the children's responses while they were performing shape-selection tasks. These were pencil-and-paper tasks in which the children were asked to mark the shapes that are circles on a page with various geometric figures (see Figure 1). If the child was silent, the interviewer repeated the question.

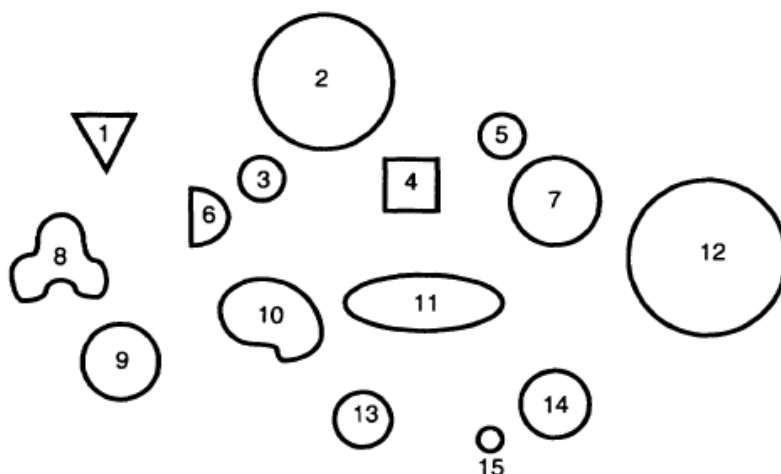


Figure 1. Student marks circles.

After the child marked some circles, the interviewer asked if there were any more. When that question was answered negatively, the interviewer asked questions such as the following: ‘Why did you mark that one?’ ‘How did you know that was a circle?’ ‘I see you didn’t choose this one. Can you tell me why?’ A similar procedure was conducted for squares, triangles, and rectangles. Each interview lasted about 25 minutes. The responses were scored and coded, and the first data set was created by scoring the children’s selections for correctness.

In the second phase the control group coordinated with traditional teaching. Group and individual activities were given to children every day. The experimental group covered the same material at roughly the same time, according to the ‘Kindergarten Shape Model’ (KSM). The content of the four week syllabus was about shapes including circles, triangles, rectangles and squares.

The first level of the KSM started with the educational software which was designed using Flash 8 Professional Edition. It was a story about ‘The Family of Shapes.’ In this story, the daddy was Mr. Triangle, the mama Mrs. Square and their daughter Miss Circle. Miss Circle was a dance teacher and in a performance she met Mr. Rectangle and fell in love with him. They got married and had many children that looked like their parents and grandparents (see Figure 2 - left). Then a drawing activity was performed by the children where the students drew the ‘The Family of Shapes’ (see Figure 2 - right). Next the nursery asked the children to bring things which look like circle, square, triangle or rectangle and asked questions like the following: ‘What is the shape of this door?’, ‘What is the shape of the clock?’ etc.



Figure 2. Educational software for shapes (left), and the child was painting Mrs. Square (right).

The second level of the KSM included an activity where a child had to draw a shape from a bag and to find out the name of the shape without seeing it (see Figure 3 - left). Then, the children split in groups and each group had to construct a dog or a man from a set of shapes (see Figure 3 - right). At the end of this level a computer activity followed where the child had to recognize shapes and to choose the correct shape among triangles, circles, squares or rectangles (see Figure 4).

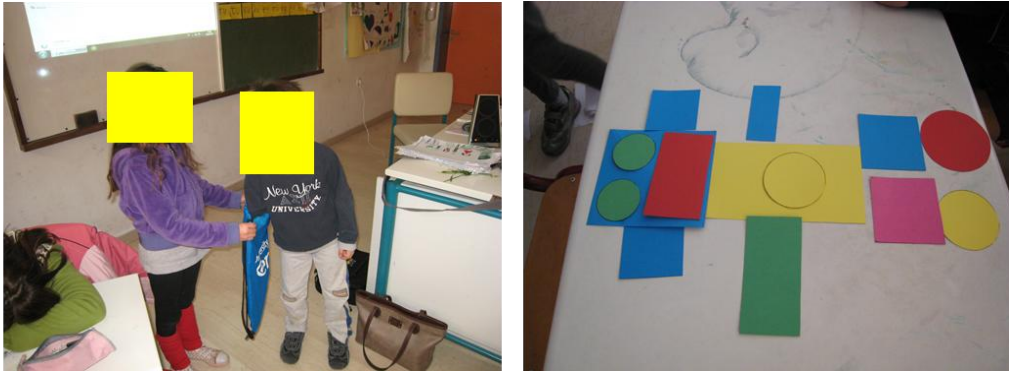


Figure 3. The child was drawing a shape from the bag (left), and a 'man' of an activity (right).



Figure 4. Second level's activities of the KSM.

The third level of the KSM had a software activity in which each shape represented its properties (see Figure 5). Next, the children were separated into groups and made a shape with their bodies on the floor (see Figure 6 - left). In addition, they were given cut-outs with all kinds of shapes and offered them to the rest of the children (see Figure 6 - right).



Figure 5. Third level's activities of the KSM.



Figure 6. The children were drawing a triangle with their bodies (left), and cookies' activity (right).

In the last level of the KSM the kids played cards (see Figure 7 - left). There were two kinds of cards: the white cards with the properties of sides and the pink cards with the properties of angles. The cards had shapes on them and at the end the child who had the majority of cards was the winner. Afterwards, there were computer activities where the children had to recognize the shapes from their properties (see Figure 7 - right).

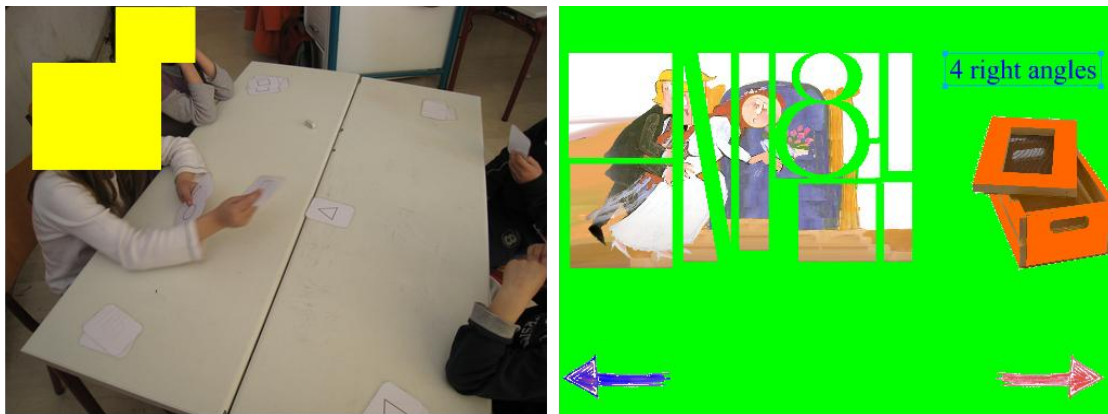


Figure 7. The children playing cards (left), and the third level activities of the KSM. (right).

Regarding the educational software represented above, once an activity is selected, the problem is announced and directions are given to the user through a recorded message. The feedback users get after following these directions is represented by two different screens, one positive and one negative followed by corresponding audio messages, from which the user can navigate out of by clicking on the arrow at the bottom right side of the screen. In the first case the user gets a 'well-done' message and on the second a 'try it again' one. In both cases, though, there is an effort these messages to be as less emphatic as possible so that children's interest is focused more on the mathematical procedure of the application rather than their result or the competition. However, drill and practice applications, as the described software, can be beneficial on promoting competence on certain mathematical skills while they encourage taking turns and competition (Clements & Nastasi 1993, Zaranis, 2011).

During the third phase of the study after the teaching intervention, the same test (post-test) was given to all students to measure their improvement at the beginning of March 2012. This was used to test the geometry achievements for the experimental and control groups. The independent variable was the use of educational software. The main purpose of the software is to foster young students' geometry concepts and to engage them in self-regulated learning. The dependent variable was the students' KST scores. The pre and post-tests were administrated individually to each student.

RESULTS

Our research is in progress and the first indicative results show that teaching and learning through ICT is an interactive process for children at preschool level. The KST was taken by 68 students. Analysis of the data was carried out using the SPSS (ver. 19) statistical analysis computer program. An independent sample t-test was conducted. The independent variable had two levels: exposure to educational software (experimental group, $m_{EG} = 162.56$) and no exposure (control group, $m_{CG} = 169.00$). The dependent variable was the student's KST score. The t-test for equality of means was also not significant ($t = -1.07$, $p = 0.28$) indicating no significant differences initially in geometry achievement between the experimental and control groups. Though the control group had a mean score higher than the experimental group, the mean difference in the KST scores was 6.44.

Similarly, an independent sample t-test was conducted. The independent variable had the same two levels as in the previous test: experimental ($m_{EG} = 190.68$) and control ($m_{CG} = 181.91$) group. The dependent variable was the student's post- KST score. The t-test for equality of means was significant ($t = 2.17$, $p = 0.03$) indicating significant differences in KST scores between the experimental and control groups. Results of this study expand the research on the effects of appropriate programs embedded in a computerized environment.

CONCLUSIONS

The purpose of the study was to investigate the impact of the intervention of KSM to the geometry competence of kindergarten children. The results obtained from the statistical analysis support our initial hypothesis, considering that students of the experimental group, as opposed to those of the control one, displayed a greater improvement on the post-test measurement.

The current findings add to a growing body of literature supporting the effective role of educational software in kindergarten education and more specifically in mathematics (Clements, 2000, 2002, Zaranis, 2011). Furthermore, the undertaken computer assisted educational procedure revealed an extended interest for the tasks involved from the part of the students which transformed the whole procedure into a thorough, focused, quiet, independent learning environment, reinforcing previous research conclusions (Clements & Sarama, 2002, Fisher & Gillespie, 2003, Zaranis & Kalogiannakis, 2011). Our findings in this report are subject to certain limitations though. We have to acknowledge that a larger sample examination would have provided us with more solid results.

Considering the above limitations of this work and the fact that a research trend of developing and implementing specific, theory-based and effective software tools, a necessity to expand research towards this direction emerges. Our research is in progress and the first indicative results show that teaching and learning through ICT is an interactive process for children at preschool level and has a positive effect for the teaching of geometry concepts.

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GAZE TRACKING METHOD IN MARINE EDUCATION FOR SATISFACTION ANALYSIS

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ABSTRACT

The modern research methods on the cognitive neuroscience framework are based on recording parameters that activate the human brain. The use of gaze-tracking methods is also part of the cognitive neuroscience with important results. The development of an evaluation model of the user's satisfaction via simulation system (Matlab environment) use in marine education is an important research subject. The proposed research is a combination of qualitative – quantitative methodology (INFW), on one hand, and a use of neuroscience tools (use of gaze tracker), on the other hand. The suggested interpretation framework (INFW) aims at interpreting, determining and evaluating the figures of the biometric tool in combination with the conventional methods (qualitative, quantitative) results based on the factors that are possible to influence the user's satisfaction (happy-unhappy). Therefore it is essential to continuously and thoroughly analyze factors & parameters that contribute in the determination of the user's satisfaction level aiming at the evolution of the interpretation framework into a complete interpretation & evaluation model of the students-users' satisfaction in marine education. The main goal would be the use of her research results from the marine education sector (IMO), the adult education sector scientists, as well as the learning systems developers in order to improve their work in the educational projects.

KEYWORDS

Gaze tracking, satisfaction, simulator MATLAB, marine education.

INTRODUCTION

In the marine education and training, in particular, the user's satisfaction based on objective criteria poses an important research subject because via this we can determine the background that explains the satisfaction phenomena, recommending at the same time new considerations that will expand the up-to-date educational conclusions on the adult education in educational programs and software development (IMO, 2003; Papachristos and Nikitakos 2010). International bibliography provides many sources on the Eye-tracking research in education. For instance, some researchers used an eye-tracker to investigate gender interfaces in attention behavior for textual vs. pretorial stimuli on websites.

An investigate outcome argues that when the participants were asked where in the interface they thought they looked their perceptions often differed from reality, showing that accurate attention patterns could only be found with an eye-tracker. Other researcher explores issues surrounding the real-time processing of eye data such as efficient noise reduction and the organization of gaze information into tokens from which relevant data may be extracted. He then discusses the potential of eye-tracking as a tool in several forms of interface manipulation, including object selection/movement, scrolling text and navigating menus (Conati and Merten 2007; Salvucci and Anderson 2000; Schiessl et al., 2003).

In the field of learning and instruction, eye tracking used to be applied primarily in reading research with only a few exceptions in other areas such as text and picture comprehension and problem solving. However, this has changed over the last years, eye-tracking is starting to be applied more often, especially in studies on multimedia learning. Because eye tracking provides insights in the allocation of

visual attention, it is very suited to study differences in intentional processes evoked by different types of multimedia and multi-representational learning materials (Van Cog, 2010; Halsanova et al., 2009).

RESEARCH METHODOLOGY

The optical perception includes the stimulant’s natural reception from the external world and the process/explication of that stimulant. The optical measurement concentrates on the following: (a) the eyes’ focus points, (b) the eyes’ movement patterns and (c) the pupil’s alterations. The measurement targets are the computer screen areas definition, easy or difficult to understand. In particular the eyes movement measurements focus on attention spots, where the eyes remain steady for a while, and on quick movement areas, where the eye moves quickly from one point of interest to another (Dix et al., 2004; Koutsabasis, 2011). The measurement methodology must fulfill all three requirements of the cognitive neuroscience (experiential verification, operational definition, repetition) and include data-tools: (a) Recording device: might include special glasses with the recording camera or a web camera, (b) Registration data process - analysis software and (c) data process software. In the following figure is shown the optical data registration and analysis procedure:

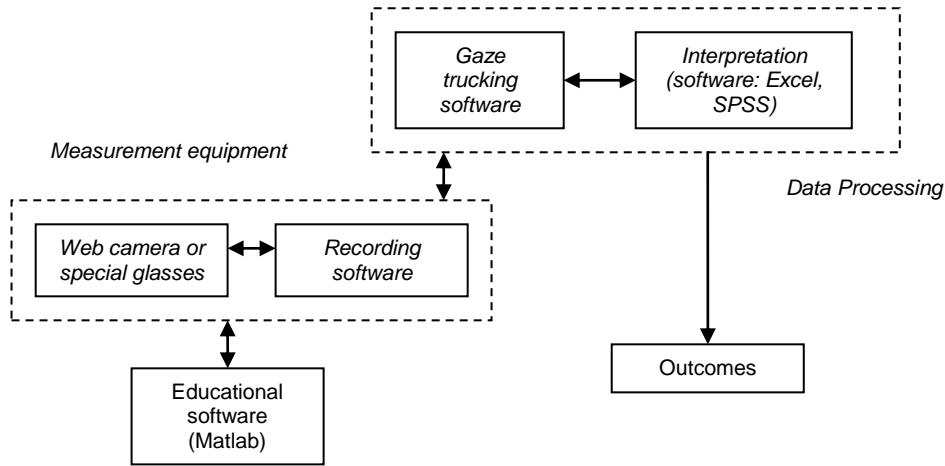


Figure 1. Optical data registration and analysis procedure

In the experiment the optical data registration will be conducted by the “Face Analysis” software that was developed by the IVML Lab of the National Technical University of Athens, in connection with a Web camera set on the computer in which there is the subject of the research (educational software i.e. MATLAB) (Asteriadis et al., 2009). We focus on the following parameters that refer to the user’s eyes and head movement: (a) eyes movement: vertical & horizontal eye movements (Eye gaze vector), (b) user’s head position in regard to the eyes up/down – right/left movement (Head Pose Vector: pitch, yaw), (c) eye distance from the computer screen (Dist_monitor) and (d) rolling of the head (eye angle from a horizontal level): right – left (Head roll) (Fig.2).

		Description	Interpretation
		Eye gaze vector (horizontal, vertical)	Quality parameter (eye gaze trucking) values (horizontal)~0: mean out of screen values (horizontal)→10 view of the center of the screen
		Schedule of eyes & head pose	~0 attention in screen ~1 & >1 no attention
		Distance from monitor	>1 close to the screen <1 away from the screen
		Eye Level, EL	Values >10° degrees, (high mobility) Values <10° degrees (attention depending on the scenario EL
		Head roll (angle), HR	HR= ----- HL
		Horizontal Level, HL	

Figure 2. Biometric tool parameters interpretation (“Face Analysis”)

The recommended research procedure aims at the modeling of the students-users’ (subjective) satisfaction of the marine education via user interface evaluation of several types of educational software. The research is a combination of qualitative – quantitative methodology, on one hand, and a use of neuroscience tools (use biometric tool - gaze trucker), on the other hand. This aims at the combination of the positive aspects of the corresponding methodologies: aiming at countable results & variable check (quantitative, questionnaire use), interpretative, explanatory (qualitative, interview use) and more objective measurements by “observation” of the user’s physiological data (gaze trucking use) (Papachristos and Nikitakos, 2011).

In the beginning of the procedure each user-student is given a series of questionnaires which include: (a) experiment participation acceptance statement, (b) medical-learning profile questionnaire, and (c) software educational evaluation questionnaire. Next, the scenario is executed by each student-user and the procedure is recorded by the special software with the use of a web camera. The scenario is based on the educational material (according to the STCW’95 corresponding standard) tutored in the E’ Semester of the Marine Academy of Aspropyrgos (Merchant Faculty) aiming at the following “Educational Goals - EG”:

- EG1- Automatic control mathematical tools application / use,
- EG2-Automatic control model development,
- EG3-Model analysis & simulation.

The scenario consists of supportive material (in digital & printed version) and involves the following activities: entry the following transfer functions (tf) to MATLAB and computation the total transfer function ($G_{ol}(s)$). Furthermore, calculating the response (image) of the $G_{ol}(s)$ in which there is a unitary feedback ($H=1$) and a step function entrance. The data processing is conducted with the use of a computer in Excel environment.

THE PROPOSED INTERPETATION FRAMEWORK

The INterpretation FrameWork (INFW) of the present research consists of several possible factors that pose an effect on the satisfaction case (Fig.3). In the international bibliography one can find a thorough research on the factors that involve in the students satisfaction. The suggested INFW aims at interpreting, determining and evaluating the figures of the biometric tool in combination with the conventional methods (qualitative, quantitative) results based on the factors that are possible to

influence the user's satisfaction. Therefore it is essential to continuously and thoroughly analyze factors & parameters that contribute in the determination of the user's satisfaction level aiming at the evolution of the interpretation framework into a complete interpretation & evaluation model of the students-users' satisfaction in marine education (Aldridge and Rowely, 1998; Conati and Merten, 2007; Lin, 2008; Butt and Rehman, 2010; Van Gog and Scheiter, 2010).

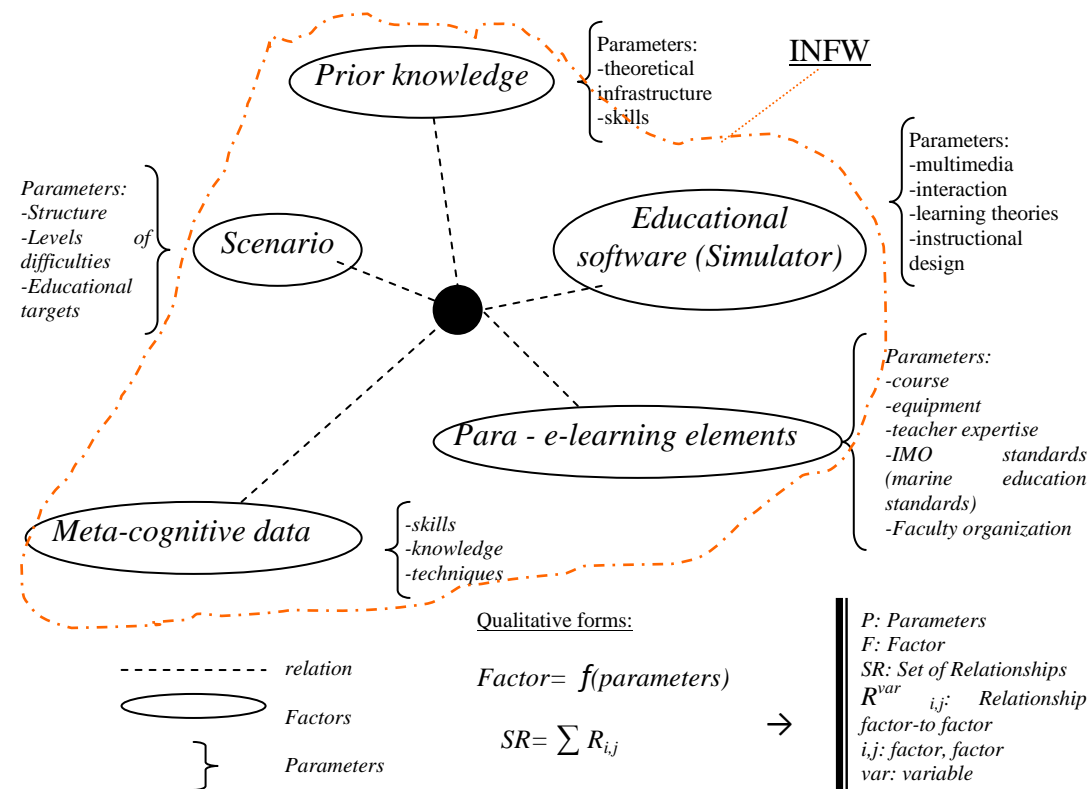


Figure 3. INterpretation FrameWork (INFW)

RESULTS

The random sampling took place in January 2011, in the Marine Academy of Aspropyrgos Computer Systems Lab. The sample consists of 20 students (17 Male, 3 Female) that were subjected to the specific experimental procedure, completed the questionnaires and gave interviews. Their learning – medical profile is shown, the sample's and educational characteristics (that resulted from the interview) are shown in Tables 1 & 2 and whereas the optical data registration results after a processing are shown in Table 3.

As observed in Table 1 there is a major percentage of students among the sample that suffer from an eye disease or face a learning problem. Only 50% of the sample has a past experience in the simulator use (entertainment, education, work). Regarding the Matlab software usability, a percentage of 75% of the sample is characterized as easy to handle. Regarding the mathematics knowledge it seems that 65% of the samples have an average rating of between 5 and 6 (low rating). Regarding the software learning, 95% of the sample describes it as easy process.

Table 1. Structure of medical-learning profile & educational characteristics

Number of Question	Medical – Learning profile /educational characteristics	Male (n=17)	Female (n=3)
1	Strabismus	1	0
2	Monochromatic	0	0
3	Eye disease	5 (3-myopia, 1-hypermetropia, 1-astigmatism)	3 (2-myopia, 1-astigmatism)
4	Eye operation	0	0
5	Dyslexia	4	0
6	ADHD	0	0
7	Simulator experience	9	1
8	Usability	13	2
9	Math knowledge (grades)		
	5-6	12	1
	7-8	5	2
	9-10	0	0
10	Learning to Matlab (easy – not easy)	16 (easy)	3 (easy)

Table 2. Scale of Satisfaction (Matlab, Scenario)

Numerical Scale	Scenario	Matlab
1	M ^{**} (1) [*]	M(1)
2		-
3	M(1)	-
4	M(1)	M(1)
5	M(2)	M(4)
6	M(4)	M(3)
7	M(4)	M(4)
8	M(2)	M(2), F ^{***} (1)
9	-	-
10	F(1)	-

^{*}(n):frequency in sample ^{**}M:Male, ^{***}F:Female

The above table shows the gradation of the satisfaction (16 users responded to the interview) in a 10th scale about the scenario & Matlab used by the users in their answers (extensive breadth scale in order to cover all possible user choices - breadth of choices).

As determined by Table 3, women need more time in the execution of the scenario in Matlab comparing to men. The Eye gaze vector parameter (horizontal) approximately shows that regardless of the gender, the students see inside the monitor and not outside of it, with the men focusing more in the centre of the monitor, indicating a bigger average (the vertical parameter of the tool doesn't offer credible figures and is not used). In Head pose Vector parameters (pitch, yaw) is discovered that the users are focused in the scenario execution (their attention is not distracted). In a distance from the monitor (dist_mon parameter) it is observed that both men and women approach the screen (>1) and keep a relatively close distance (figures homogeneity).

Table 3. Sample Structure (general population)

	Time approx. (min)	Eye gaze vector horizontal	Head pose Vector pitch	Head pose Vector Yaw	Dist_ Monitor	Head roll
Average	F [*] (11), M ^{**} (8.5), T ^{***} (8.9)	F(1.86), M(5.17), T(3.5)	F(0.18), M(0.15), T(0.165)	F(0.11), M(-0.006), T(0.058)	F(1.27), M(1.32), T(1.29)	F(0.78), M(0.97), T(0.87)
Standard Dev	F(4.6), M(4.6)	F(21.4), M(31.6)	F(0.43), M(0.37)	F(0.48), M(0.32)	F(0.31), M(1.078)	F(9.34), M(12.97)
CV	F(0.41), M(0.54)	F(11.5), M(6.11)	-	-	F(0.24), M(0.81)	F(11.9), M(13.37)

F^{*}: Female, M^{**}: Male, T^{***}: Total

In the following variable a balance in the head declination is indicated ($\sim 0^\circ$) in both genders with women having a better figure (homogeneity). The CV agent of the group samples (Male, Female) in female sample indicates a larger homogeneity in the parameters Time, Dist_Monitor, Head roll, while in the male sample a larger homogeneity is indicated in the Gaze vector horizontal parameter. In data about Satisfaction (Matlab, Scenario) an improvement (with some discontinuity) of the eye Gaze vector (horizontal) parameter is observed as the satisfaction scale grows whereas in the other parameters (Head pose, Dis_monitor, Head roll) there's a relative stability-homogeneity in rates. In addition it is concluded that there is an increase in the Time parameter as the satisfaction scale (Scenario & Matlab) grows.

DISCUSSION

The interviews indicate a variety of answers, comments and observations. The answers vary between the Matlab value as a control systems education tool and its usability and performance as a tool. Furthermore the students focus on an education plan that aims at a systematic learning of the Matlab software and an increase in the level of the mathematics knowledge offered.

With the application of INFW to the data so far (optical data registration, interview) for the qualitative research of the users' satisfaction it is established that:

- Visual attention (VA) is probably connected indirectly (positively) with the Satisfaction scale (Sc)³²:

$$(VA \uparrow \approx Sc \uparrow) \quad (1)$$

That is shown by the qualitative relations between VA, Eye Gaze vector (horizontal) (eGv-h) and the satisfaction scale based on experimental measurements. That is probably explained with the contribution of some simulator elements in attention, such as multimedia elements, interaction function, interface design, as shown in the interviews as well (*simulator*).

- Respectively there is a connection between interest (Inter) and the Satisfaction scale (Sc):

$$(Inter \uparrow \approx Sc \uparrow) \quad (2)$$

That is extracted by the qualitative relations between VA – Inter – satisfaction scale. That is probably explained by the simulator elements that contribute in the interest growth such as multimedia elements, interaction function, interface design, on one hand and the education planning & program and the tutoring quality as shown in the interviews, on the other hand (simulator, para – e-learning elements).

³² >> much more , \uparrow increase , \downarrow decrease , \approx approximately equal, connection

- Possible connection between a simulating experience (SimExp) and the satisfaction scale as the qualitative relations show on the dist_monitor & eye Gaze vector parameters behavior in correspondence with the relations with a positive or negative connection (depending on the gender) with the VA & Inter. increase. The characteristics of the simulator pose a probable effect on that (simulator).
- VA is probably influenced by the mathematics knowledge as shown in the qualitative relations as well as in the interview responses and therefore in the control system course tutoring, the prior theoretical substructure and the corresponding course program and planning (prior knowledge, para – e-learning elements).
- Respectively, there is a possible relation between VA – mathematics knowledge level – satisfaction scale from the qualitative relations that led to the connection between VA & satisfaction level and the interview responses as well. Here it is observed a connection between many factors (comprehension of cognitive subject, theoretical substructure, interface, teaching quality, course program) that also explain the low rate of success in the complete execution of the scenario (prior knowledge, para – e-learning elements, simulator, scenario, meta-cognitive data).
- Confirmation between a possible connection between head roll - interface and the interview responses (negative answers on interface). The head roll parameter low rates seem to be a result of a scenario with small graphic expansion (only in last stages there is a graphic expansion that only reached <10% of the students) on one hand and the lack of mathematic and cognitive subject knowledge and therefore in the lack of more practice (20% of the sample demanded more of that) and improvement of the course program planning (prior knowledge, para – e-learning elements, simulator, scenario).
- Possible connection between eye diseases & dyslexia with VA and therefore with the satisfaction scale (tends to a negative relation) according to the qualitative relations. That necessitates that the Academy has bear in mind those parameters (para – e-learning elements, simulator).
- The Time (T) parameter is directly and proportionally connected to the Satisfaction scale (Sc):

$$(VA \uparrow, \text{satisfaction scale} \uparrow, \text{Inter} \uparrow \approx \text{Time} \uparrow) \quad (3)$$

That is probably ought to scenario structure, the mathematics and control system knowledge, in education and course planning, in the individual simulator elements. The users' answers reveal the possible factors (prior knowledge, para – e-learning elements, simulator, scenario).

CONCLUSIONS

The paper argues for the necessity of a mixed approach to satisfaction evaluation of users-student in simulating environments and proposes a generic, but practical framework for this purpose. The main elements of the proposed approach include:

- Registration and interpretation of user emotional states (satisfaction scale),
- Gaze tracking and interpretation,
- Questionnaires (medical & learn profile, appraisal) and
- Wrap-up interviews.

The approach is general in the sense that it can be applied in various types of systems. It is also pluralistic in the sense that it provides the evaluator with complementary sources of data that can reveal important aspects of the user satisfaction during learning practice in simulators. The experimental procedure presented here is a primary effort to research the satisfaction phenomenon of the users-students in simulating environments. Firstly, regarding the analytical framework unfolded over Matlab and the experimental measurements and the interview responses, it is established that:

- Visual Attention (VA) is connected indirectly (positively) with the Satisfaction scale,
- there is a connection (positively) between interest (Inter) and the Satisfaction scale (Sc),

- mathematics knowledge is an important factor of influence (positive) on the user's behavior (Matlab is a mathematics tool),
- the Time (T) parameter is directly and proportionally connected to the Satisfaction scale (Sc) and
- the knowledge of the cognitive subject matter is also an important factor.

Finally from the processing of the experimental optical data so far it is established that visual attention (VA) seems to relates with the users satisfaction and INFW factors (prior knowledge, para – e-learning elements, simulator, scenario) each in different rate seem to participate in the interpretation of the influence in the users' satisfaction.

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PLANNING EDUCATIONAL ACTIVITIES FOR NATURAL SCIENCES USING ICT TOOLS: TEACHING VOLCANOES IN EARLY CHILDHOOD

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ABSTRACT

Under the global trend for scientific literacy education should play a structural role in shaping well-trained people and in promoting social attitudes. The environmental education programs involved with awareness of environmental issues are fundamental to shaping attitudes of the child-friendly environment. Earth is the result of numerous geological events that combined to create earth, as we know it today. In this article, we present the planning and application of a teaching intervention, introducing geo-environment knowledge in kindergarten school about a basic geological concept, the volcanoes, using ICT (Information and Communication Technologies). The specific topic of volcanoes was chosen due to the volcanism of the Greek territory. Beyond the cognitive scientific part of this approach, is attempted the involvement of social aspects by having as orientation the changes of children's attitudes in relation to the quality of life and the geo-environment. The intervention consists of the following three steps: first to form is the pre-test of pre-existing perceptions and alternative ideas of children on basic concepts related to volcanoes using semi-structured interviews. In the second stage, we create a science laboratory for the implementation of various activities and conduct experiments with simple materials in a safe way such as a virtual explosion in a model volcano and the observation of the lava process. In addition with the mentioned activities, using ICT as a rich source of authority in various formats (images, video, etc.) indirect observation of the natural phenomenon and source of information search (google, google earth, virtual museums) children learn about the Greek volcanoes by enriching their experiential cognitive representation using and the concept map software kidspiration. In the third stage, the evaluation of the teaching intervention (post-test) takes place in order to identify the transformation on children's existing ideas and addressing cognitive barriers to the construction of scientific knowledge. In the framework of this article we present in detail the proposed activities of the second phase of the teaching intervention.

KEYWORDS

Early Childhood Education, ICT, Volcanoes, Geology.

INTRODUCTION

Fundamental to the development of children-friendly attitudes towards the environment is the scientific knowledge related with it and especially to the geo-environment. The geo-environment, an integral part of the natural environment of earth, is a dynamically evolving system, consisting of data and processes in continuous interaction and interdependence. These elements create all necessary conditions for the development of life. Understanding the geo-environment changes is considered critical for the survival of man on earth. The fundamental characteristics of geological phenomena in their great length, much longer than human life (several of them began with the formation of the earth 4.5 billion years ago and continue today) and their evolution have been in large areas on and within earth (Doutsos, 2000). The geo-historical evolution of our planet remains unknown to the general public and it is difficult to understand it by following the traditional educational system.

In recent decades, the Greek educational system has had fairly limited access to knowledge in geo-environmental (Rekoumi et al., 2010). In the framework of the present research, a teaching intervention

is designed, introducing the geo-environmental knowledge in kindergarten, teaching the concept of volcanoes with the use of ICT (Information and Communication Technologies) and other hands-on activities in authentic learning environments. By introducing ICT in early childhood education and by creating appropriate educational scenarios, we argue that education in geo-environmental can be improved. In addition, ICT both enriches the educational process with endless sources of educational materials and communication tools and also improves the quality of the teaching process. In-service and pre-service Greek early childhood teachers express positive attitudes towards the use of ICT in everyday practice (Gialamas & Nikolopoulou, 2010). We argue that it will be very interesting to plan and implement a teaching intervention in order to introduce the concept of volcanoes in kindergarten.

RATIONALE

In the science education literature, learning as conceptualised in a constructivist framework is dependent on authentic experiences that help learners make these critical connections between scientifically rigorous concepts and their own sense-making (Vosniadou & Brewer, 1992). Children are naturally curious about the natural and social environment. A volcano is often perceived by children like a cone-shaped relief (Bezzi & Happs, 1994); a double origin of the volcanic structure: the up thrust mechanism given as important a role as the accumulation of eruption products (Blake, 2005) and the origin of the lava at the centre of the earth (Dal, 2006). According to research on preschool children's ideas about concepts and phenomena of geological science, children form their own ideas before they are taught these concepts and these views still exist in older ages (Giannaletsou et al., 2011).

The necessity to apply appropriate teaching intervention in preschool children about volcanoes but also for various geological concepts is supported by recent research (Rekoui et al., 2010; Kalogiannakis et al., 2011; Giannaletsou et al., 2011). By introducing ICT in teaching, important tools are added to the experiences and interests of everyday life of children. Furthermore, ICT act as cognitive tools, which can be used as "objects to think with" (Papert, 1980). The main objective of the proposed intervention is the utilization and empowerment of children's availability to explore and learn by providing the appropriate stimuli and experiences.

We choose this specific thematic unit of the volcanoes because the Greek area is made of a very complex geological structure. In Greece, there are a total of 39 active and extinguished volcanoes and almost daily low or high intensity earthquakes are recorded (Doutsos, 2000). This geo-environmental framework has crucially affected the initiation, growth and development of our civilization. Besides the scientific part of the cognitive approach, an involvement of social parameters-oriented in order to change the attitudes of the children on the quality of life and geo-environment is attempted. This enables the study of the influence of man in the relief of the earth's surface and in the management of natural resources over time so that children can extract safe conclusions about what we need to do in the future (Rekoui et al., 2010).

METHODOLOGY

Semi-structured interviews were conducted one-to-one in private, with 24 children, aged from 4 to 6 years selected, in a preschool classe in Korinthos (Greece). It took about half an hour for each interview. Classroom observations were also arranged. The proposed curricular intervention for teaching volcanoes in kindergarten is implemented in 3 major phases:

- (a) After interviews with 24 children aged from 4 to 6 years, identification of the pre-existing perceptions and the alternative ideas of children (pre-test) we designed the teaching intervention.
- (b) Implementation of the intervention by exploring and enriching the topic volcanoes using ICT.
- (c) Evaluation of the intervention by interviewed children and using the concept map software kidspiration (post-test).

During the third phase of the study (post-test) after the teaching intervention, the same test of the first phase was given to all students to measure their improvement. Due to the young age of the children the

pre and post-tests were administrated individually to each child. Within this article, we will present in detail the proposed activities of the second phase. At this phase increasing scale simple activities are used such as simple experiments in serial sequences.

PROPOSED ACTIVITIES - INTRODUCTION OF ICT

It is suggested that children during the teaching intervention videotape each activity and keep photographs of the experimental process. This creates a computer database which can be used in the evaluation. The teaching intervention used open-source software design Tux Paint and/or Revelation Natural Art which are easy for children, with well-organized and creative environment interfaces design (stamps, brushes, shapes) and management tools (printing, storage, presentation) that allow the user to modify its content. Figure 1 below, shows the children's representations of volcanoes using the software Tux Paint (post-test). We propose to use Tux Paint and/or Revelation Natural Art in the activities of the teaching intervention.



Figure 1. Children's representations of volcanoes using Tux Paint.

OBSERVATIONS OF CHANGES IN MATERIALS ON A SMALL SCALE

1st activity: working with simple cooking materials.

The materials/instruments of the activity are coloured plates, as many in number as the groups of the children, sugar, salt, flour, soda, baking powder, lemons in the same quantity as the teams of children, spoons and labels. The kindergarten teacher along with each group prepares labels with the names of the cooking materials and puts them on a plate next to them in a small quantity (about half a tablespoon) of the respective materials. Then, the children squeeze drops of lemon over the materials and discuss the changes that occur and the intensity of developing these changes. Children can observe that the lemon juice dissolves the sugar, salt, flour and creates foam only with the soda and the baking powder.

2nd activity: working with natural materials.

The materials/instruments of the activity are coloured plates, as many in number as the groups of the children, powdered white chalk, marble dust, plaster dust, fine sand, sea lemons, spoons and labels. The kindergarten teacher prepares the labels with each team with the names of the natural materials which will be used in the activity and puts them on a plate. Next to them, the teacher puts small quantities (half a tablespoon) of the respective materials. Children are encouraged to ask what will happen if they squeeze a few drops of lemon in materials, to exchange ideas and to make various hypothesis.

Then, they squeeze a few drops of lemon over these materials which then foam and by progressively adding more drops the phenomenon is repeated. They investigate the changes that occur and compare them with the results of the materials of the previous activity. Through this activity, children understand by discussing that earthy materials have similar reactions with the materials of our daily lives.

OBSERVATIONS OF CHANGES IN MEDIUM-SCALE MATERIALS

3rd activity: creating imprints.

The materials/instruments of the activity are a magnifying lens, marble pieces with smooth surfaces, oranges, lemons and tangerines, labels. Children observe with the magnifying lens the pieces of marbles and place them in a horizontal fixed position. We prefer the marbles to be of different colours and at least one surface must not be polished. Then, cut the oranges, lemons and mandarins in half. Then, we ask from each group of children to put a piece of orange, a piece of lemon and their label on the piece of marble and explain that they must not move the pieces until a couple of days pass.

In the second phase, after about 4 days, we look at the pieces of oranges, lemons and mandarins and observe the surface by using the lens. We place them on dry surfaces in order to distinguish the marble's dust on them. Then we thoroughly clean the surface of the marble with water and let it dry. Each team is asked to observe the imprints left on the marble. Children can observe the impressive designs that are left over marble the lemons and oranges, since the peel and the nerves are not sour. Also they can notice the white powder found on the surface of the lemons and oranges used in this activity. The juice of the sour fruit slowly wears away the rocks and turns them into dust. Through this activity children learn to compare and relate the various phenomena and to realize that many effects in nature are slow and therefore we do not observe them at once.

4th activity: working with vinegar.

The materials/instruments of the activity are small stones, small shells, two medium-sized test tubes, a bottle of vinegar with a small opening and a couple of stands for the tubes. The kindergarten teacher, with each team, pours the vinegar in the tubes until the vinegar reaches the middle of the tube and places them on the stand. Then, the children throw the stones in a tube and the shells so that the surface of the vinegar is above them. Children can observe the production of bubbles from the surfaces of the shells and stones which disappear when they reach the surface of the vinegar. The stones and shells are made from a mineral called limestone and vinegar converts it into new substances. One of the new substances which are formed is a gas named carbon dioxide and it is contained in the bubbles that seem to arise in the vinegar.

OBSERVATION OF CHANGES IN MATERIALS ON A LARGE SCALE

5th activity: working with cork.

The materials/instruments of the activity are a piece of chalk, a bottle of vinegar with a small opening, a medium sized test tube, three corks to fit the opening of the tube and a bracket. This activity is suggested to be executed, for security reasons, only by the teacher. The kindergarten yard is suggested as the most suitable place for this activity. The kindergarten teacher puts the chalk and vinegar in the tube and immediately closes the opening with a cork. After a few minutes the cork is ejected and then the teacher sequences the second and the third cork and the phenomenon is repeated. The chalk is composed of limestone which when in contact with the vinegar a carbon dioxide gas is formed which is contained in the bubbles that we can see and which pushes the cork. Then a discussion follows with the children who have observed that the reaction produced gas which pushes the cork and then there are questions for discussion as why it pops the cork and in which other case may the same result occur.

6th activity: creating a virtual volcano.

The materials/instruments of the activity are a clear glass bottle, a cork to fit above the opening of the bottle, transparent plastic, an elastic band, vinegar, three chalks with the colour of each group of children, a water bottle, a magnifying lens and a video camera. The kindergarten yard is suggested as

the most suitable place for the creation of the virtual volcano. Initially each group, with the teacher's help, will make its own volcano.

First, we collect the sea stones which we place on a flat surface in the courtyard of the kindergarten. In the center we place the glass container, add the vinegar and cover the pot with transparent plastic. Stabilize the plastic in the opening of the bottle with the elastic band and cut the piece of plastic that covers the bottle and remove it. Cover the plastic surface after spraying with water mixed with gypsum dust. We place stones, foil and flower petals to create the image of a landscape. Then, break the chalk into small pieces and add them in the glass container which is closed with the cork. We move away from the virtual volcano and film the whole process (Figure 2).

In the second phase, after some time has passed, we collect wet leaves and petals from the liquid and stick them in the gypsum which has dried. We also propose to visit online the Natural History Museum of the Lesvos Petrified Forest (<http://www.lesvosmuseum.gr/>). Lesvos Petrified Forest is one of the finest monuments in the world of natural geological heritage. This forest is a unique example of forest ecosystem Miocene age worldwide (Doutsos, 2000). Children can admire a variety of petrified logs and volcanic geotopes created by volcanic activity 20 million years ago. The ultimate objective is to learn and admire the beauty of the avios world, for the children to formulate and adopt behaviors to promote and protect the monuments of nature and geological heritage.



Figure 2. Image of a virtual volcano made in the yard of the kindergarten.

OBSERVATIONS OF CHANGES IN REAL SCALE MATERIALS

7th activity: film projection about volcanoes.

We project the video in the classroom with the creation of the virtual volcano from the previous activity. Children learn that some phenomena in nature occur suddenly and violently (volcanic eruptions and earthquakes) but have been preparing a long time ago inside earth. Also, they realize that all volcanoes are not the same and that earthquakes occur in areas where volcanoes exist. Based on the above elements, interesting questions arise as to discuss what to do at the time of an earthquake and what to do if an earthquake happens while we are at school.

Children with the teachers' help are suggested to visit the website of the agency Earthquake Planning and Protection Organization (EPPO) (<http://www.oasp.gr>). Then, using the application Google earth we suggest finding several volcanoes on the map of Greece (Nisyros, Santorini, Milos, Methana, Sousaki Corinth, etc.) and adding a pin so they can easily be identified (Figure 3).

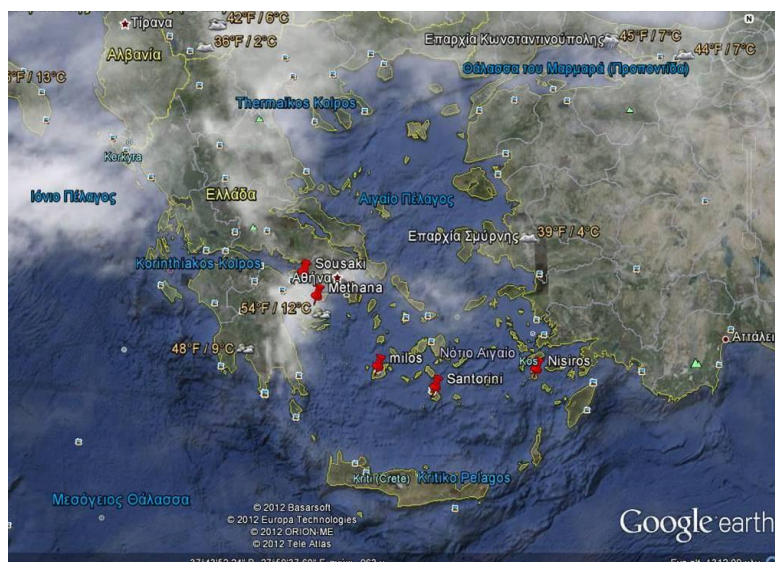


Figure 3. Identification of the volcanoes in Greece by using the application Google earth.

VOLCANOES ENHANCE PEOPLES' LIVES

8th activity: benefits from volcanoes.

Each group of children, with the teacher's help, chooses to work with one of the following topics: hot springs, volcanic minerals and mining minerals, Santorini's volcano and tourism. Children learn how to decide, to choose by justifying their views and at the mean time pay attention to the opinion of others. At the end of the activity each group presents their work in class by using presentation software (power point). In this activity, we aim for children to understand that volcanoes although they are associated with disasters, they still offer significant benefits. Children also gain fluency in using ICT, promote self-motivation and boost their confidence.

DISCUSSION - PERSPECTIVES

The specific approach of volcanoes, and of earthquakes at the same time, is carried out by specialists, but their knowledge affects us all, because it relates to our lives. We argue that the conquest of this knowledge is important to be implemented in the early childhood education. Through the activities of the proposed intervention, children begin to debunk these phenomena and learn how to address them with the necessary calm. At the same time, the use of ICT can help children to create new, important and innovative projects. Some interest and the effectiveness of science in early childhood education is associated with the expression of curiosity, the ability to concentrate, the sense of confidence and efficiency and the possibility of individual and team work abilities.

In this phase, we implement the proposed curricular intervention in the prefecture of Corinthos' kindergartens and the first results from the evaluation are very encouraging.

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PLAYING ON THE JOURNEY OF SOUND: A TEACHING PROPOSAL FOR CHILDREN IN EARLY CHILDHOOD

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ABSTRACT

In this study, we develop an educational scenario for teaching sound to young children by using ICT (Information and Communication Technologies). The principles of the “New School” of the Greek Pedagogical Institute (recently called Institute of Educational Policy [IEP]) are mainly theoretical tools for creating this scenario. Sound is a very important thematic area of natural sciences for kindergarten. The proposed curricular intervention propels communication and interaction among children, and therefore the configuration of interpersonal relations allows emotional expression connected to music, as well as the exchange of thoughts. Also, it propels to children the possibility of exchanging arguments and negotiating their ideas and opinions. Specifically, in this scenario, through systematic activities for children, we developed certain ways of acquainting them with hearing, one of the most basic human senses. The main goal is to teach children to appreciate the value of hearing and to understand the fundamental methods of creating sound. Another intention is to teach children to become more sensitive with people with hearing problems, more sensitive to noise pollution and to be more respectful during quiet hours. Sound, as teaching material, can extend the cultivation of incentives that activate the participation of young children. Furthermore, it can reclaim children’s previous knowledge and experiences and guide them to the configuration, design and organization of chances to enrich various learning fields. With the proposed scenario children produce original work using ICT as means of expression, like conceptual mapping software, websites, videos and other ICT tools.

KEYWORDS

Sound, Early Childhood Education, ICT, Curricular Intervention.

INTRODUCTION - RATIONALE

Sound is a particularly interesting and complex module of natural sciences (Hewitt, 2001), for the early childhood education. As a teaching tool, sound can motivate preschoolers to involve in courses and to use their existing knowledge and experience. Through teaching sound, preschoolers can be led to plan and organize opportunities in order to enrich different ways of learning and even produce original projects by using ICT.

In the proposed educational scenario we developed a series of activities so that children of the early childhood education will experience one of people’s fundamental senses, hearing. With the proposed activities we hope that preschoolers will appreciate the value of hearing and of the quiet hours of noon, they may also become respectful to people with hearing problems and also understand the foundations to create sounds.

THEORETICAL BACKGROUND

Science education is too important to be left to older children and students (Ravanis, 2005; Roth et al., 2012). Scientific experiences need to be designed in order to stimulate curiosity, since it gives meaning to objects and reveals their significance (Hadzigeorgiou, 2001). He argues that scientific knowledge cannot only be built through pedagogically appropriate activities, but needs to have the element of

intellectual curiosity. The scientific process can only be taught through direct experience (McDermott et al., 2000) as it is proposed in our educational scenario. So, in order to unite theory with action we employ the Cultural Historical Activity Theory (CHAT) (Roth et al., 2012), which is our base to accomplish the present scenario's teaching activities. The framework provided by activity theorists is a coherent theoretical framework which establishes science education as participation in the community (Roth & Lee, 2006). This theory therefore goes against the idea of teaching simple operations and skills before allowing someone to engage in the more complex actions and activities (Roth, 2010) like in the proposed curricular intervention.

The integration of science and mathematics is particularly relevant and appealing in early childhood education. For Jones et al. (2003) this is because the same fundamental concepts developed during the early childhood years underlie a young child's understanding of science and mathematics. Sound and sound propagation can be considered abstract concepts, because in a similar way to them material properties are often attributed. Learning such concepts requires the students to reconstruct their ideas related to matter into process views, and such reconstruction involves conceptual change (West & Wallin, 2011).

In the proposed sound's curricular intervention, ICT, which are integral parts of preschool class in today's digital age (Oikonomidis & Zaranis, 2010), are used in several activities. This curricular intervention for helping young children appreciate focused mainly on children's use of ICT in early childhood education. Our scenario has been developed in detail on the following website: <http://karecha.yolasite.com>.

This teaching intervention is based on the project method and follows our previous researches for the early childhood education in science through environmental education (Kalogiannakis et al., 2010). The introduction and use of ICT by children and adults in early childhood education should be grounded in a clear understanding of the purposes, practices, and social context of early childhood education (O'Hara, 2004) and this is the main purpose of the curricular proposal of our study.

The Greek "New School"

New curriculums exploit the interests, the ideas and the experience of children (Ravanis, 2005). Thus, children learn how to find solutions for their concerns through creative research processes. According to the new curriculum in Greek education, "New School" emphasizes on the social role of the teacher, who should promote digital communication and learning through art (<http://digitalschool.minedu.gov.gr> in Greek).

The teacher should also become a colleague of the preschooler, by shaping conditions of concern. Moreover, the teaching tools should be closer to children and connect with their everyday environment. Initially, we carried out a literature review on teaching sound in early childhood and we tried to include all these baselines in the proposed curricular intervention.

OBJECTIVE - DESCRIPTION OF THE EDUCATIONAL SCENARIO

The main objective, of this educational proposal, is to stimulate preschoolers to approach the sense of sound by acting like young explorers and to propose ways in developing best practice in the use of ICT to support positive learning experiences for children. The proposed duration to accomplish the scenario is two days.

Although, because every class is different, the duration the proposed curricular intervention depends on the interest, the possibilities and the proposals which children will make, through their interactive role. So this instructive intervention is concluded when preschoolers and the teacher define it. In addition, the teacher should encourage children to repeat any activities that satisfy them and help in achieving the educational objectives.

Educational activities of the 1st day

1st activity: discovering with the ear the sounds around us

Initially, an introduction about the basic organ of the human's body, the ear, is very important. Then, preschoolers would listen carefully and try to guess several simple sound recordings of nature (e.g. rain, wind, ocean, river, thunder, etc.), of everyday life (e.g. classroom, public transport, musical instruments, clocks, etc.) and of themselves (e.g. breathing, heart beating etc.). The previous recordings lead the children to a brainstorming, by guessing - using their imagination - several sounds that they hear. Thereafter, the children are divided in small teams and they search in the school's library or/and on the internet for pictures of human or animal ears. Furthermore, they can search for pictures of dolphins, whose vision is not as good as their hearing and they develop sounds for their orientation. Additionally, they can watch short TV shows or the news in sign language.

Main objective of this activity is that preschoolers get in touch with one of the most basic human senses, hearing. They can correlate the ear with the hearing and understand the role of their ear, as the receiver of sounds. Likewise, the aim is for children to recognize basic sounds of nature, of everyday life and of themselves as well as sounds which are created by different sources. Additionally, they learn to appreciate the value of hearing as a sense.

2nd activity: hearing and the rest of human senses

With the help of the teacher, small teams of preschoolers use blocks, crayons, fragrant plants, various herbs and try to paint sounds from their environment by imagining their shape, color and taste. Subsequently, still in teams, they are asked to enrich any known poems with music (simple musical rhythms). The main objective is that children can connect their hearing with their other senses. They must learn to define their environment through observation and by collecting data and also express their feelings about sound.

3rd activity: production of simple and complex sounds

In this activity, the class plays a game in which children express their opinions with some simple questions, such as "how can we produce sounds?" After compounding every different opinion, the class is led to commonly accepted conclusions about sound production. Then, preschoolers, in small teams, try to implement the different forms of sound production. Simple experiences in sound production, which may have not been discovered, are given (e.g. singing, hand or feet flapping, knocking of different materials located in class, etc.).

In addition, it is proposed to collect data from the website of the digital school (in Greek): <http://digitalschool.minedu.gov.gr> and from the internet in general (e.g. sound-stories and any musical excerpt) and even more from the website: <http://www.poissonrouge.com> which is an interactive digital playground.

The method of asking-answering sets as main objective for preschoolers to think how to produce sounds and to help the communication and cooperation amongst them. They should become capable of producing simple sounds, understanding that sound is not only a result of musical instruments and creating sound-stories of small duration.

4th activity: experiments on sound production

On a first step, small teams of children produce sounds by using simple materials. Particularly, they produce sounds by using strained bands (from a guitar), horns of toys, stones or pieces of wood knocking each other, paper or plastic bags, castanets, cymbals, bottles with nuts and many more. On a second step, the teacher may place a piece of clean film on the mouth of an empty open cylindrical box, like a drum (Figure 1). With the film stretched, the teacher pours grains (e.g. of coffee).

Then, he/she hits the side of the "drum", in order to make the grains vibrate from the audio waves. After that, the children can repeat the experiment in order to describe what they see and discuss their opinions

about it, with the teacher directing them towards the desired path. Preschoolers learn that they are able to produce simple and complex sounds with several ways (experimental procedures). They also work in teams on their investigations about sound.



Figure 1. Drum made of a box of cookies and clean film

Educational activities of the 2nd day

5st activity: quiet hours

This activity attempts the connection of several ways of producing sound with the quiet hours of noon. Therefore, the children perform a theatrical game, in which they imitate voices of their classmates and even sounds that they are impressed by. Then, they try to discover their limits, when sounds become annoying, by increasing or reducing their voice volume. They work in teams in order to create a list with pleasant and annoying sounds from the previous activities or even from their experiences in general.

Furthermore, they can use a concept mapping software, like kidspiration, which has an adequate interface for early age children; it enables the use of pictures and the creation of libraries with audio files for example, and provides the ability to cooperate through the web. Through this activity, the children learn the valuable function of hearing and they understand the value that quiet noon hours have. They also evaluate the uncomfortable results of excessive volume increase.

6th activity: legends - the bride Echo - sirens

The teacher will recite several legends. A legend says that there was a bride called Echo, who was known for her melodic voice. Echo was walking around the forests of a Greek rocky landscape, when she met Narcissus and fell in love with him. But Narcissus was in love only with his looks, so he neglected Echo's interest. Echo continued roving around singing, trying to be perceived by Narcissus, but she never became. So finally her voice stayed in those landscapes and we can all listen to her, repeating our words (Figure 2).

Another legend that shows the importance that ancient Greeks have given to sound and music is the legend of Odysseus and sirens. This legend reveals that when Odysseus was coming back to Ithaca, he passed by the island of the sirens. To pass that test he shut the ears of his companions and he asked of them to cord him to a mast of their boat, in order to listen to the sirens' melodic and divine songs but not losing their goal at the same time.

Continuing, preschoolers should work together, by searching legends of different nations, related to sound. They can use the website atlas wiki: <http://atlaswikigr.wetpaint.com> (in Greek). The teacher should also show several pictures and photos of Greek ancient theatres which have been built in a shape that then gave them special acoustics. Even today, shows are carried out without the help of electronic sound systems. Following, the children can make a play simulating the journey of sound through mythology or/and dramatize any legend of the above and/or else.



Figure 2. John William Waterhouse: Echo and Narcissus (1903)

Children should learn to appreciate the cultural dimension of science and understand several legends and pictures which are associated with sound. They may also learn to keep up with the narrator-teacher, to understand a narration and the importance of a complete story. Moreover, they will be able to compose a story using their experience, as a team, express their perceptions about their plays and participate in discussions about sound legends.

7th activity: professions exposed to annoying sounds - noise pollution - green cities

Preschoolers should work in teams and search for pictures of professions particularly exposed to noise in the library and/or on the internet (Figure 3). They should also search for photos, audios and related documents of green cities and in contrast with cities which are penetrated by highways (Figure 4).

In addition, each team will create a catalog with instructions about listening and enjoying music without bothering people around them and even with protective measures from noise. Children need to appreciate hearing and also learn to protect themselves and people around them from noises, by shaping simultaneously environmental conscience.



Figure 3. Coal Field



Figure 4. Highway near town

8th activity: film clips

Foremost, the class can watch film clips of the movie “The Chorus” (“Hamsarayan”, 1982), by the Iranian director Abbas Kiarostami. In this movie, a hard of hearing elderly man goes shopping, to the bustling souk of his town. It seems that the town moves too fast around him but he persists to his slow pace. While the noise becomes too loud for him he closes his hearing aid, so he can sink in his valuable silence and isolate from everyone. He also does the same thing, when he returns home and the irritating noise of a pneumatic drill, invades in his place. He can now enjoy his cup of tea in tranquility, but he can’t hear the sound of his bell ringing by his granddaughter. Because, his granddaughter can’t stop

until she sees her grandfather, she mobilizes the help of her classmates' voice. Then, that chorus of children, calling the grandfather, overlaps the drill's noise and also the grandfather's silence, who finally listens to them, interrupts his isolation and becomes really happy.

After the movie, children are separated in teams so they can summarize and try to imagine different versions of the story. Finally, it can be set up as a game which aims for the children to be quiet for 3-5 minutes, but still be able to communicate. Children will imagine how their life would be if they could hear nothing and learn how valuable hearing is. They will also become sympathetic with people with hearing problems and find ways to communicate without talking, using other visual means of expression.

ICT' EXPLOITATION IN THE PROPOSED TEACHING INTERVENTION

In this teaching intervention ICT can be exploited by the use of suitable educational material found on the Greek digital school's website: <http://digitalschool.minedu.gov.gr> and on other websites like: <http://www.poissonrouge.com> and <http://atlaswikigr.wetpaint.com>. Any related recordings from the internet can be used (e.g. <http://youtube.com>) and/or made by the teacher through any educational software, like kidspiration.

PERSPECTIVES

It is highly likely that ICT will continue to be a significant presence in children's learning environments throughout their schooling and into their adult lives. In this proposed educational scenario about sound, science strongly contributes to the cultivation of preschoolers mind so that they can estimate daily problems and evolve in social responsibility, understand the connection between science and human activities, develop arguments about their opinions. Children also express their emotions through music, with a view to the configuration of interpersonal relationships.

Finally, we deem necessary further systematic research and practice in classes for the proposed curricular intervention. We followed a recent interest in science education to reach young audiences, especially at the kindergarten level. We argue that with this scenario preschool teachers provide children with opportunities to explore sound. This may help children to notice the inconspicuous features and hence obtain the whole picture of the phenomenon. Thereafter, we will try to evaluation this curricular intervention. Further investigation of ways to use ICT to teach sound in early childhood education and application of the proposed curricular intervention could provide useful information and understanding.

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COMBINING CONCRETE AND ABSTRACT VISUAL REPRESENTATIONS IN A SIMULATION-BASED LEARNING ENVIRONMENT: EFFECTS ON STUDENTS' LEARNING IN PHYSICS

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ABSTRACT

In this study we aimed at identifying when abstract representations of abstract objects need to be used in a simulation to support students' conceptual understanding in a subject domain that involves phenomena with intangible concepts and underlying mechanisms, such as the domain of Light and Color. A pre-post comparison study design was used, involving 69 participants assigned to two conditions. The first condition consisted of 36 students who had access to a simulation with representations of concrete objects, whereas the second condition consisted of 33 students who had access to a simulation with representations of both concrete and abstract objects. Both conditions used the same inquiry-oriented curriculum materials, consisting of three sections that included physical phenomena with increasingly complex underlying mechanisms, so that the third section's mechanisms were more complex in nature than those in the first two sections. Conceptual tests were administered to assess students' understanding before, during and after the study. Results revealed that the presence of abstract objects was not necessary for the first two sections. In contrast, it was found to be essential for the third section, whose phenomena involved the most complex concepts and underlying mechanisms. These findings suggest that the effect of using abstract objects in a simulation appears to be influenced by the complexity of the mechanism underlying the phenomenon under study.

KEYWORDS

Representations, reification, simulations, inquiry-based experimentation, conceptual understanding

INTRODUCTION

Computer simulations' positive impact on students' science learning has been confirmed through numerous studies (e.g. van der Meij & de Jong, 2006; Zacharia, Olympiou, & Papaevripidou, 2008). According to Olympiou & Zacharia (2012), simulations' positive impact on students' science learning can partly be attributed to the unique affordances that emerge from their multi-representational nature. For example, only simulations can provide the manipulation of representations of both concrete and abstract objects, as well as displays that present the data that emerge through the manipulation of these objects (Hsu & Thomas, 2002).

Recent literature has pointed to the added value of simulations' multi-representational nature (Ainsworth and van Labeke, 2004), while at the same time it has outlined a number of challenges and calls for a new line of research to study the implications of learning while using these representations (Huk et al., 2010). One unique and valuable asset of simulation-based learning, as many researchers have acknowledged (e.g., Finkelstein et al., 2005; Olympiou and Zacharia, 2012), is the possibility to represent abstract objects (reification/transformation of conceptual constructs into perceptible representations, e.g., molecules, vectors, etc.). However, no research thus far has examined whether the presence of representations of abstract objects, along with the presence of representations of concrete objects (objects that exist in the physical world), is always necessary in a learning process that involves

studying physical phenomena that include intangible constructs (e.g., molecules or light rays). Up until now, researchers have tended to provide representations of abstract objects to students throughout the learning process (e.g., Limniou et al., 2009; Wu et al., 2001), but we can also imagine that the constant presence of abstract objects could prevent students from constructing these abstract entities themselves. In this study, we seek to understand when abstract objects are needed in a simulation learning environment to support students' learning in a physics domain that involves phenomena with abstract constructs.

SIMULATIONS AND MULTIPLE REPRESENTATIONS

A number of studies emphasize the advantages of using multiple representations in simulation based environments for learning. According to Ainworth and Van Labeke (2004), multiple representation simulations are better than single representation simulations because they provide varying information that affords learners multiple ways of visualising and understanding complex domains. In this respect, multiple representations come to complement one another with regard to information or processes (Tsui & Treagust, 2003).

Petre, Blackwell, & Green (1998) asserted that having to make the mental translation between representations forces reflection beyond the boundaries and details of the first representation and an anticipation of correspondences in the second. Van der Meij and de Jong (2006) further argued that the deeper the level of cognitive processing of multiple representations, the less the likelihood of missing information related to the domain under study. Consequently, it is expected that learners using multi-representational simulations will benefit from the properties of each representation and that this will lead to a deeper understanding of the subject domain being taught (de Jong, Ainsworth, Dobson, van der Hulst, Levonen, Reimann et al., 1998). Another advantage of multiple representations in a simulation learning environment is that they could support different tasks, alternative strategies and individual differences, which increases the possibilities of enhancing students' learning (Ainsworth, 2006). Goldman (2003) argued that, given the extensive research on representations, the issue is not whether multiple representations are effective but rather concerns the circumstances that influence the effectiveness of these representations.

REPRESENTATIONS OF ABSTRACT OBJECTS IN SIMULATIONS

Representations of abstract objects are commonly used in simulations to complement representations of concrete objects. They represent the abstract entities (e.g. vectors, particles, light rays) that cannot be experienced in the physical world, which provides students with an insight into the conceptual context of a phenomenon (e.g., abstract concepts, the mechanism underlying the phenomenon). In other words, the representations of abstract objects make what in reality is invisible visible. This translates into an advantage that only simulations (and not any other means of experimentation) can offer (Olympiou & Zacharia, 2012).

There is ample evidence in the literature of this research domain to support the argument that representations of abstract objects bring added value to the science learning process. For instance, Finkelstein et al. (2005) and Zacharia (2007) used simulations that provided direct perceptual access to the concept of current flow in electric circuits. The reification of current flow allowed students to study the concept of current flow and understand how electric circuits work. Specifically, Finkelstein et al. (2005) compared two groups of students, those who used physical manipulatives and those who used a computer simulation that explicitly modeled electron flow, in terms of their understanding of physics concepts and their skills with physical equipment, and found that students who used the simulated equipment outperformed their counterparts both on a conceptual survey of the domain of electric circuits and in the coordinated tasks of assembling a physical circuit and describing how it worked.

The use of abstract representations of abstract objects for learning purposes has also been shown in chemistry and biology. For example, Wu et al. (2001) and Limniou et al. (2008) used representations of

abstract objects (representations of molecules) to study chemistry at the molecular level, and Minogue, Jones, Broadwell, & Oppewall (2006) used representations of abstract objects to study the cell and its constituent parts at the micro-level. Their findings have pointed to the need to access and visualize the micro-level (e.g., molecular level) in order to be able to understand the phenomena encountered at the macro-level. Jaakkola, Nurmi & Veermans (2010) argued in favor of using representations of abstract objects because they found through their study that representations of abstract objects provide a more transparent view of the concepts and mechanism underlying a phenomenon than any other learning tool (e.g., physical laboratory experimentation).

In light of such findings, researchers have asserted that computer simulations have the potential to promote cognitive dissonance and conceptual understanding more effectively than direct experience especially for scientific concepts that are counterintuitive, abstract, and/or not easily accessed through direct observation (Zacharia & Olympiou, 2011). Obviously, for such concepts, representations of abstract objects are needed in order to visualize and conceptualize intangible entities, which do not exist in reality and thus are not easy to apprehend (Ainsworth & Van Labeke, 2004).

THIS STUDY

The purpose of this study was to investigate when, in regard to the complexity of the abstract concepts and mechanism underlying a physical phenomenon, to use representations of abstract objects in a simulation-based learning environment. Specifically the goal of this study was to answer the following question:

- Should abstract representations of abstract objects always be present in a learning process that involves intangible entities (concepts and mechanisms) or does the supportiveness of the presence of abstract representations of abstract objects relate to the complexity of the phenomenon under study? By complexity we refer to the number of concepts (abstract or concrete) that a student should consider when mentally constructing the underlying mechanism of a phenomenon.

METHODOLOGY

Sample

The number of participants of the study was 69 undergraduate students, who were enrolled in an introductory physics course that was based upon the *Physics by Inquiry* curriculum (McDermott and the Physics Education Group at the University of Washington, 1996). First, the participants were randomly and evenly distributed over the study's two conditions, namely, the experimental condition (Simulations with representations of Concrete and Abstract objects condition or SCA condition, 36 students) and the control condition (Simulations with representations of Concrete objects condition or SC condition, 33 students), and second, the students in each condition were further randomly assigned to groups (three persons in each group) as suggested by the curriculum being used (McDermott et al., 1996). None of the participants had taken college physics prior to enrolling in this course.

Curriculum materials

For the purposes of this study, three sections of the module of *Light and Color* of the *Physics by Inquiry* curriculum were used (McDermott et al., 1996, p. 225-258). The first section focused on an introduction to light, the sources of light, how light travels, and how it behaves when masks and screens are involved. The second section focused on the formation of shadows, while the third section focused on colored paint and colored light.

Concrete and Abstract Representations

The simulation (virtual laboratory) *Optilab* (Hatzikraniotis et al., 2007), along with a very small number of other interactive simulations that complement *Optilab*, were used for the purpose of this study. The selection of *Optilab* was based on the facts that it allowed the set-up of most of the experiments in the

curriculum material used and that it included visual representations of both concrete and abstract objects (see Figure 1).

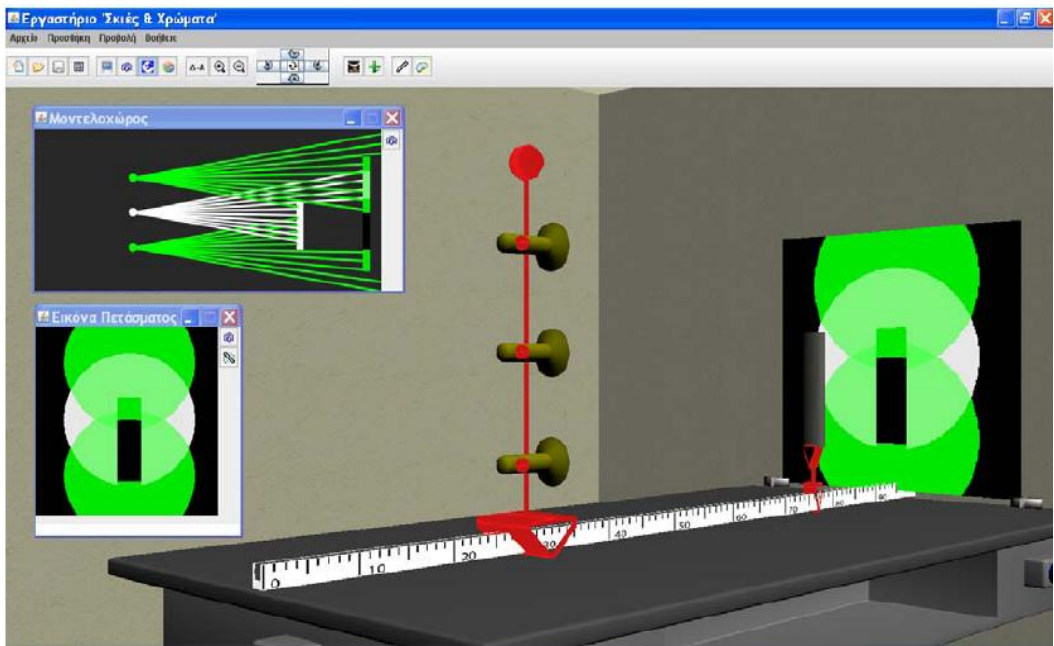


Figure 1. The Optilab environment

With regard to representations of concrete objects, *Optilab* provided a virtual work-bench on which experiments could be performed, virtual objects to compose the experimental set-up, virtual materials whose properties were to be investigated, and virtual instruments (e.g., rulers) or displays (e.g., screen) as illustrated in Figure 1. All materials represented through *Optilab* were the same as those found in a physical laboratory.

With regard to representations of abstract objects, *Optilab* contained an extra window in which conceptual objects were presented (e.g., ray diagrams). Simultaneously with setting up the concrete objects on the virtual bench and running the experiments, the abstract objects window presented a simplified/idealized schematic representation of the concrete objects in the experimental set up, as well as the corresponding ray diagrams (when light was involved).

Experimental Design

A pre-post comparison study design was used for the purposes of this study that involved two groups, SC and SCA, according to Figure 2. All groups worked in the same simulation-based environment that hosts both concrete and abstract representations of the domain after study.

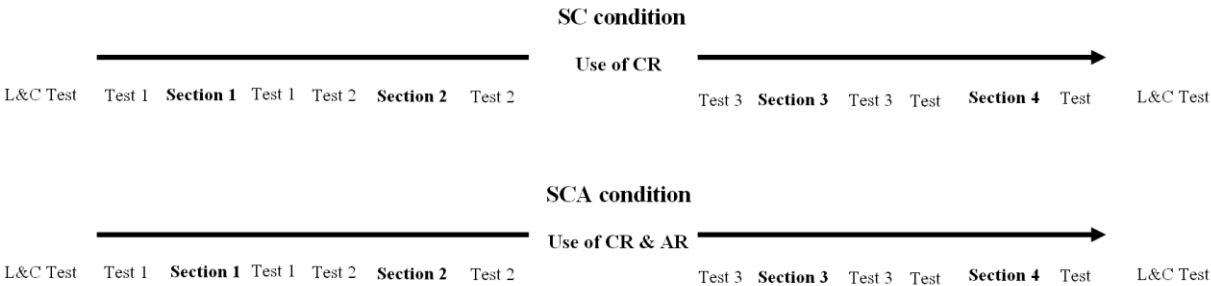


Figure 2. The experimental design of the study

Data Collection

This study involved the collection of data through the use of conceptual tests before, during, and after presentation of the curricular material (for details see Figure 2). The tests were developed and used in previous research studies by the Physics Education Group of the University of Washington (McDermott et al., 1996).

Procedures

Throughout the study both conditions shared the same five instructors, who were previously trained in implementing the *Physics by Inquiry* curriculum and had experienced its enactment for at least two years. The duration of the study was 13 weeks. Students met once a week for 90 minutes. The time on-task was the same for both groups. Even though, the SCA participants were able to discuss and investigate representations of both concrete and abstract objects while conducting experiments (instead of only concrete objects as in the SC condition), this fact had no significant effect on the time consumed in each experiment.

Data Analysis

The data analysis involved quantitative analysis. Specifically, we used (a) independent samples t-tests for the comparison of the pre-test scores of the two conditions on each test, (b) paired samples t-tests for the comparison of the pre-test scores to the post-test scores of each condition across all tests, and (c) one-way ANCOVAs for the comparison of the post-test scores of the two conditions on each test. For this last procedure, the students' scores on the corresponding pre-tests were used as the covariate.

RESULTS

The independent samples t-test indicated that the two conditions did not differ in pre-test scores across all of the study's tests, $p > 0.05$. The paired samples t-test showed that both conditions improved students' understanding of concepts concerning light and color both after each section and after completion of the entire presented curriculum ($p < 0.001$ for all comparisons). Students' scores on the post tests 1, 2 and 3 as well as on the L&C post-test were subjected to an ANCOVA with L&C pre-test scores as covariate. The analysis revealed no effect of condition in tests 1, 2 and L&C, $F(1, 66) = 0.028$, $p = 0.867$, $F(1, 66) = 0.130$, $p = 0.719$, $F(1, 66) = 3.617$, $p = 0.062$.

For Test 3, the ANCOVA revealed a main effect of condition, $F(1, 66) = 6.985$, $p = 0.01$. The results of Test 3 were also confirmed from a second analysis we ran with the L&C test. Specifically, we isolated the items that tested the same concepts as Test 3, calculated the corresponding scores for each condition and compared them through the use of an ANCOVA. The results of this latter analysis revealed a main effect of condition $F(1, 66) = 11.191$, $p = 0.001$. These findings indicate that the presence of representations of abstract objects was essential only when understanding concepts concerning colored light was at issue (the third section of the curriculum).

DISCUSSION

In this study we investigated whether the representations of abstract objects were needed for enhancing students' conceptual understanding throughout a simulation-based learning environment that involved studying physical phenomena with abstract concepts in the subject domain of *Light and Color*. The findings of the study revealed that the presence of abstract objects was not necessary for the first two sections of the study's curriculum. In contrast, it was found to be essential for the third section. The SCA students were found to outperform the SC students in Test 3, which implies that SC students were not able to conceptualize the abstract concepts and mechanism of the colored light phenomena as the SCA students did. For instance, without a coherent model of the underlying mechanism, no SC student could explain why a certain color appears in a certain shape at a certain place on the screen of the experimental set-up. Apparently, SCA students, due to the presence of the abstract representations of abstract objects, managed to construct these coherent models, at least for most of section 3, whereas SC

students had problems mentally constructing such coherent models on their own. These findings suggest that the effect of using abstract objects in a simulation appears to be influenced by the complexity of the mechanism underlying the phenomenon under study.

These findings accord with the findings of prior studies that showed that multi-representational dynamic simulations afford learners new ways of visualizing complex domains (Ainsworth and van Labeke, 2004; Goldman, 2003; van der Meij and de Jong, 2006; Petre et al., 1998). In fact, it appears that the functions of multiple representations (Ainsworth, 2006) also apply in the case of combining representations of concrete and abstract objects, since our students were able to construct linkages between these representations and eventually conceptualize the underlying mechanism of the phenomena under study.

Finally, it appears that a framework about the combination of representations of abstract and concrete objects in simulation-based environments needs to include information about the complexity of the underlying mechanisms of physical phenomena. Of course, further research is needed to identify what other factors (e.g., age, prior knowledge, cognitive and metacognitive skills) need to be considered in order to reach to a solid framework.

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EFFECT OF DISCIPLINARY CONTENT OF A SIMULATION ON OPEN-ENDED PROBLEM-SOLVING STRATEGIES

Marc Couture

ABSTRACT

There is a long-standing debate about so-called generic vs. domain- or context-specific problem-solving skills and strategies. To investigate this issue, we developed a pair of structurally and functionally similar computer simulations and used them in an experimental study with undergraduate students from all fields of study. One, described to users as a teaching tool based on current entomology research, featured three species of ants whose tasks could change as a result of encounters with each other. The other, which we call a non-disciplinary simulation, featured three types of abstract moving shapes whose color could change after a collision. Users received no information about the latter, not even that it was a simulation. Both simulations, which students used in succession, allowed users to change the number and types of objects, and to move them freely on the screen. We told students that the problem was to describe and explain what occurred on the screen, and asked them to explain, while they were working with the simulation, what they observed, what they did and why. We conducted a first, quantitative analysis of various “surface” indicators that can be related to patterns or strategies: computer-generated traces of significant events, including user interaction; users’ operations (meaningful sequences of actions); basic characteristics and factual content of students’ verbalizations. We found significant differences between the two simulations for a number of indicators, which are being used as guides in the next part of the study: an in-depth analysis of students’ strategies.

KEYWORDS

Problem solving, simulations, strategies

INTRODUCTION

There has been a long-standing debate over the relevance, or even the sheer existence of *generic* or (domain-independent) problem-solving skills and strategies ever since the notion was introduced in the work of Newell and Simon (1972). Most ensuing studies which didn’t dismiss the notion altogether questioned the possibility that learners acquire general problem-solving competencies which would enable them to apply these skills and strategies in various domains or contexts (Mayer & Wittrock, 1996; 2006; Taconis, Ferguson-Hessler & Broekkamp, 2001). Note that these strategies include not only procedures, which are arguably often discipline- or context-based, but also self-regulation activities related to metacognition and motivation (Adams & Wieman, 2007; O’Neil, 1999), more prone to transfer between disciplines, contexts, or problem types.

While many studies relied upon standard, well defined problems (the game “Tower of Hanoi” being one of the favourites), other used more open-ended situations in which problems may be ill-defined. This was often obtained through computer environments including simulations (Tennyson & Breuer, 2002), microworlds (Rieber, 2004), virtual laboratories (Meisner & Hoffman, 2005), or computer games (de Castell & Jenson, 2007; Sauvé, Renaud, Kaufman & Marquis, 2007). These are the same computer tools as the ones used for research on inquiry (de Jong, 2006; Reid, Zhang & Chen, 2003; van Joolingen, de Jong & Dimitrakopoulos, 2007) and problem-based learning (Lehti, Lehtinen &

Murtonen, 2005; Maxwell, Mergendoller & Bellisimo, 2004; Rendas, Rosado Pinto & Gamboa, 1999; Soderberg & Price, 2003).

Most simulations used in education, whether or not specifically designed as learning tools, depict natural phenomena and, as they generally aim at teaching a subject matter instead of generic problem-solving skills, they are based upon discipline-specific knowledge, namely models, laws, and theories. These simulations are thus not very useful to study or assess generic problem-solving skills; as Adams and Wieman (2007) rightly point out, “student’s content knowledge is inextricably intertwined within these skills”.

Although a handful of studies used so-called “domain-independent” or “content-free” simulations (Anderson, 1982; Kluge, 2008; Moher, Johnson, Cho & Lin, 2001; Szumal, 1999) or other tools (Adams & Wieman, 2007; English, 1992), there has been no systematic approach to the issue of the educational potential of these non-disciplinary learning tools.

To investigate how discipline-based content knowledge (taken here in a very broad meaning, which includes even scientific misconceptions) interfere with the expression or generic skills, especially those involved in planning and conducting effective problem-solving strategies, we designed two structurally similar computer animations and used them in an experimental study with undergraduate students from all domains. These simulations were based in large part upon a set of simulations previously developed in a less controlled research context (Couture & Meyor, 2008).

The simulations

The first simulation, named simAnts, features in its “problem screen” (Figure 1) three species of ants differing by their color and shape and sharing a common territory which extends outside the screen. Although it is not a “real” disciplinary simulation, as it was designed by the author, who has no formal training in entomology, it is based upon actual research results regarding the allocation of tasks between ants. Inside each species, identical-looking ants perform any of three possible tasks, and any may switch to a new task as a result of its encounters with same-species ants; the probability of such a change is related to the number of same-species ants previously encountered that were actually performing this task. The ants’ motion was empirically designed to look like what the author could easily observe in his backyard.



Figure 1. SimAnt's problem screen, showing the three species (black, red, brown) and three categories (A, B, C) of ants.

For the sake of the simulation, ants performing a given task are said to be part of the same *category*. The categories are related to the area covered by moving ants: those of the first one travel far and fast, going constantly out of the screen and back, while the others stay inside, ants of one category criss-crossing all over the screen and the other remaining in a small part of it. To make the observations more tractable, considering the short duration of the experimental session, a letter (A, B or C), following each ant, indicates its category; it flashes for a few seconds when the category changes.

The second simulation (problem screen shown in Figure 2), which will heretofore be called *Things*, presents three types of abstract moving objects, each in three different color versions. Following an encounter between two same-shape objects, the color of one or both may change. Objects' shapes and motions are defined by simple mathematical rules, with a single parameter accounting for the different shapes or trajectories. As these three abstract shapes are very difficult to name, we added to each a unique, simple geometrical pattern (dots, lines or squares). Here, the probability of color change is a constant, different for same- and different-color encounters; the new color is also fixed, each color changing to the next in a circular chain. Like before, the category (color) is related to differences in covered area.

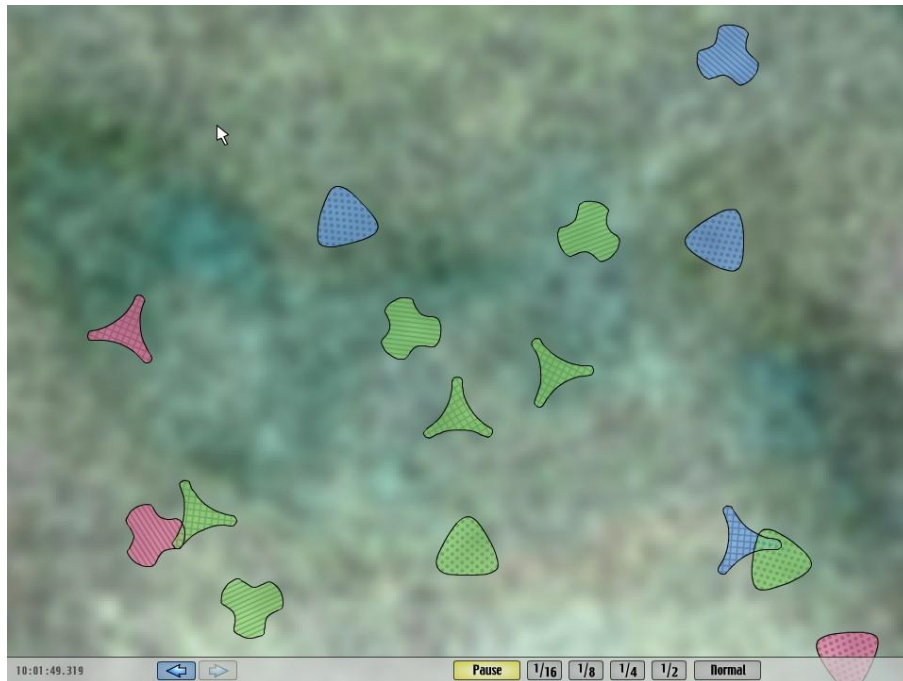


Figure 2. The problem screen of the non-disciplinary simulation, showing the three species (distinguished by their shapes/patterns) and three categories (red, green, blue) of entities.

So one can say that the two simulations are structurally similar, as they both feature a 3×3 matrix of species and categories, with the category, related to territory covering, changing (or not) as a result of an encounter between same-species entities. In both, entities can be moved freely on the screen, and the configuration (number of entities of each species and category), initially selected in the part of the interface named “configuration screen” (Figure 3), may be modified at any time by going back to that screen, which resets the simulation.

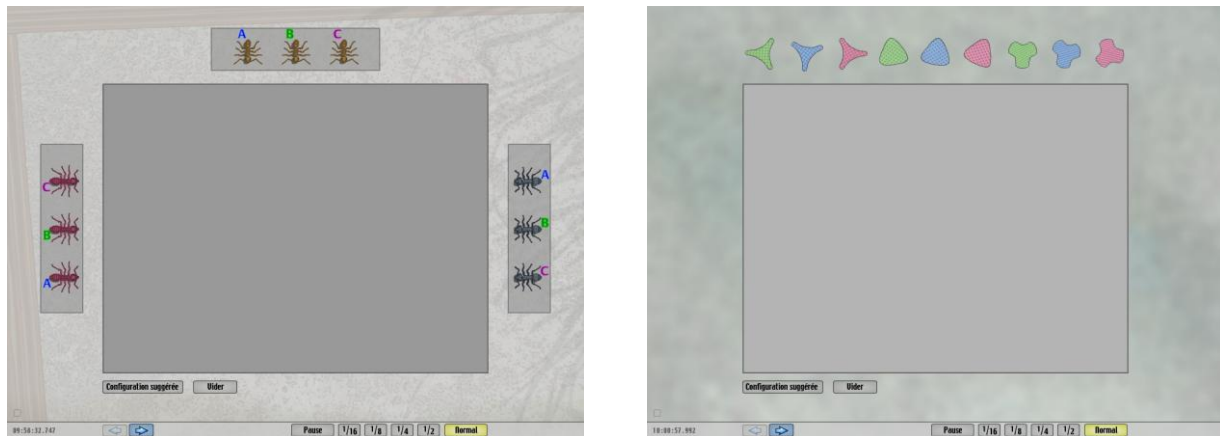


Figure 3. The configuration (start) screen of the two simulations.

Users select the configuration they want to study in the problem screen by dragging into the large rectangle as many entities as they wish of each species and category.

The laws governing category change, along with other minor characteristics, were made intentionally different in the two simulations to lessen the possibility that participants, who used both in succession, conclude at the onset of the second session that “shapes are just ants in disguise”, and thus that they have already solved the problem. This design choice proved relevant: while many participants commented upon the similarities of the two simulations, all tried in the second session to solve the “new” problem on its own.

THE METHOD

Thirty-five participants were recruited for the experimental sessions. In order to avoid biases and to make the “sample” as representative as possible of the target population (Quebec’s undergraduates), we advertised the study online and controlled the participants on the basis of gender and domains of study: arts, social sciences, business, science (general) and computer science.

We had to drop the results of five participants: four due to a bug in one of the simulations which we thought could significantly influence the strategies, the other because of difficulties she had in understanding the task. All 30 remaining participants used both simulations in a cross-over design, 15 of them starting with the ants. Each of the two sessions lasted 40 min, with a 10-min pause, but participants could end the session when they thought they “were through”. Only two did so, in the first session only, both after about 30 min.

Before each session, we showed participants the functional characteristics of the simulation, then asked them to do some simple actions, like selecting entities and dragging them on the screen. Before the “ant” session, participants were also invited to read a web page featuring pictures of simulated ants and their real counterparts and describing the simulation as research-based and used in biology courses. By contrast, we restricted the explanation of the non-disciplinary simulation to its functional characteristics, using carefully chosen, neutral words (like “entities”) to avoid any hint as to its nature or purpose.

In both sessions, we told students that the problem was “to describe and explain verbally what occurred in the problem screen” We also asked them to explain, while they were working with the simulation, what they observed, what they did and why.

This definition of a problem is not straightforward, and some participants didn’t even think there was a problem stated. In these cases, we gave an explanation based upon Meyer’s (1992, cited in Adams & Wieman, 2007) definition of a problem as “a goal when no solution method is obvious to the problem solver”, the goal being here to give (to the experimenter) a verbal description and (or) explanation.

Participants were also offered a pad and pencil in case they “wanted to take notes”, which 20 of them did.

We felt that experimentations and explanations related to category change would constitute the richest part of the study. However, we had observed early in the validation phase that there was a real risk that a participant’s choice of configurations resulted in category changes occurring very late in the session, if at all. Thus we (1) included in the configuration screen a button placing a “suggested configuration” with 15 entities and (2) made sure participants realized during the demonstration that a category not included in the configuration we had selected would appear at some time in the problem screen.

All along the session, participants were recorded on video; the screen content was also captured. Furthermore, the simulations generated a timed record of all category changes and details of relevant user actions: selecting a configuration, dragging entities, slowing/accelerating the simulation. The interviewer stood next to the participants for the entire sessions; he or she asked questions for specific purposes: (1) clarifying the participants’ wording (2) reminding them to explain what they were doing.

DATA TREATMENT AND ANALYSIS

The complete utterances were transcribed. As we didn’t ask participants to speak aloud all their thoughts (as in type I verbalization), there was huge differences between participants in the number of words per session: it ranged from 300 to 3500, with a mean/median of about 2000. The difference between the simulations was less than 1 %.

Each session was divided into *scenes*, corresponding to an observation/experimentation period with the same configuration; a section could comprise a single or many *takes*, when the participant went from the problem screen to the configuration screen and back with the same configuration. Each take (or single-take scene) was divided into two parts: *preparation* and *experimentation*, when the participant works (or talks) in the configuration and problem screens, respectively.

In a first stage of analysis, more prone to statistical treatment, we considered elementary speech and behaviour units. The transcripts were divided into short speech units, each containing the description of a single observation, a statement about a characteristic, or a relation between two or more observations or characteristics. Some longer units contained more complex or general reasoning. The range in unit count was similar to that of the word count: 15 to 225 units; mean 80; difference of less than 1 % between simulations.

Each speech unit was coded as to (1) the subject(s) of the utterance, for instance an element or a characteristic of the simulation, the problem, or the participant himself or herself; and (2) some characteristics deemed relevant for the subsequent analysis of the strategies:

- the unit is a simple factual description of something just happening on the screen;
- the unit expresses a judgment or an evaluation;
- the unit includes a model, defined as an explanation referring to something which is not part of the observable phenomena;
- the unit includes a recall, a comparison, or an announcement of future actions;
- the wording expresses doubt or uncertainty.

Behaviour units, called actions, were also coded in the same table; some codes, like the detail of the selected configurations, were directly obtained from the simulation-generated records; others, like note taking or the type (or purpose) of entity dragging, were manually coded upon observation of the screen capture and video recording.

After a first joint work on a sample of session transcripts to stabilize the codes, unit coding was done by the author or an assistant, and validated by one of the assistants or the author; a maximum of 10 % of

the codes were modified at the validation stage. We ended up with 25 subject, 8 characteristics and a dozen action codes. Subject coding gave us a further criterion for unit splitting: when more than four subject codes were needed, a unit was split into two shorter ones.

These codes were used to generate a number of indicators. Some were simply the “raw” codes, for instance: the number of entities dragged to force or favour encounters; the number of speech units mentioning or describing a model. Others were defined through simple calculation: for instance: mean number of entities; percentage of speech units tagged with the code for “speed of entity”.

Using Excel’s statistical package and custom formulae, various statistical data were computed for all 100+ indicators: mean, median, mean difference between the simulations or the sessions. Various statistical tests were also run: *t*-tests (paired and unpaired) and a non-parametric test (Wilcoxon signed-rank) on the means; confidence intervals for the differences in the means. Graphs (scatterplots, boxplots and histograms) were also produced for every indicator.

For all indicators, we carefully reviewed the results of the various statistical tests, using the graphical representations of the data to detect any characteristic or anomaly that could help interpret or validate these results. We were interested in finding indicators (1) which could provide an overall view of the participants’ behaviours or (2) reveal relevant and, ideally, statistically significant differences between the means of the two simulations.

Table 1 shows these results for a few indicators, called action indicators, related to the way participants interacted with the simulations. One observes a tremendous disparity between participants for all these indicators. Some participants worked with one or two entities at a time; others preferred a more crowded screen. Some spent as much as one fourth of the total time in the configuration screen, others less than 2 %. Some participants used a unique configuration in a session, others tested dozens; without surprise, this indicator was well correlated to the previous one, especially for the non-disciplinary simulation ($R^2 = 0.48$). Many participants dragged very few or no entity at all in the problem screen during their two sessions; others dragged several hundred during each. Some participants never paused or changed the rate of the simulation, while others used that feature extensively, mainly to facilitate observation or note taking.

Finally, two of the action indicators revealed a statistically significant difference between simulations over the 20 % threshold we have fixed as worth investigating: number of scenes and number of entities dragged. Due to its peculiar, long-tailed distribution, the latter was log-transformed after elimination of the 5 participants who had not used this feature at all. Note that the original values gave a much larger difference in means, with a *p* value (obtained from Wilcoxon signed-rank test) of just over 0.05.

Table 2 gives an overview of the characteristics of participants’ utterances. Again, huge individual differences are observed for many indicators, and significant differences in the means are found in two of them: comparisons and models.

Finally, Table 3 presents all action or speech unit codes (including some already displayed in Table 1) for which a difference of 20 % or more between simulations (statistically significant or not) is observed.

Table 1. Main characteristics of the distribution and difference in means between simulations for some relevant action indicators.

Indicator	min	max	mean (s.d.)	median ^a	Diff. in means ^b	<i>p</i> (≤ 0.05)
Mean number of entities in participant-selected configurations	1.6	15	6.6 (3.0)	–	+17 %	–
Percentage of time devoted to “preparation” (configuration screen)	1	34	14 (8)	–	–16 %	–
Number of scenes (configurations)	1	38	13 (8)	–	– 27 %	0.02
Number of entities dragged to force encounters	0	985	89 (175)	16	+116 %	0.05
Number of modifications of rate of simulation	0.0	80	16 (18)	10	–27 %	–
Log (1 + number of entities dragged to force encounters)	0.0	3.0	1.4 (0.9)	–	31 %	0.045

a. If more than 10 % different from mean.

b. *Things* minus simAnts.

Table 2. Characteristics of the distribution and difference in means between simulations for all speech unit characteristics indicators.

Indicator	min	max	mean (s.d.)	median ^a	Diff. in means ^b	<i>p</i> (≤ 0.05)
<i>Percentage of speech units:</i>						
– coded as simple factual descriptions	0	64	25 (15)	–	–8%	–
– coded as including:						
▪ doubt or uncertainty	0	59	21 (10)	–	+4%	–
▪ a comparison	2	43	17 (9)	14	–17%	–
▪ an evaluation	0	37	10 (7)	–	+9%	–
▪ a recall	0	30	10 (6)	–	–9%	–
▪ announcement of a future action	0	18	5 (4)	–	+10%	–
▪ a model	0	16	4 (4)	2	– 50%	0.03

a. If more than 10 % different from mean.

b. *Things* minus simAnts.

Table 3. Characteristics of the distribution for all indicators with at least 20 % difference in means between simulations.

	min	max	mean (s.d.)	median*	Diff. in means**	<i>p</i> (≤ 0.05)
<i>Actions</i>						
% of 2-entities configurations	0	61	8 (15)	0	−60%	0.02
Log (1 + number of entities dragged to force encounters)	0.0	3.0	1.4 (0.9)	–	31 %	0.04
Number of scenes (configurations)	1	38	13 (8)	–	−27 %	0.02
<i>Subjects in utterances</i>						
Trajectories of entities	0	37	7 (8)	3	80%	0.01
Speed of entities	0	19	4 (5)	2	−52%	0.01
Entity dragging	0	53	7 (10)	3	36%	–
The simulation itself	0	11	2 (3)	1.4	24%	–
Species	0	46	17 (12)	13	−23%	–
Area coverage	0	27	7 (7)	4.5	−18%	–
Category	3	70	21 (13)	–	−23%	–
Spatial distribution of entities (at a given time)	0	51	7 (12)	2	25%	–

a. If more than 10 % different from mean.

b. *Things* minus simAnts.

DISCUSSION

Even if all the indicators of our “surface” analysis cover a huge spectrum, a number of them show a significant difference between the two simulations. Some of these indicators can arguably be related to differences in problem-solving strategies: for instance, the number of configurations tested, the number of configurations with two entities, the number of entities dragged to force encounters, the percentage of speech units including a mention of a model. Also, indicators like “trajectories of entities”, “speed of entities”, “area coverage” and “spatial distribution of entities” could be related to prior conceptions about ants. These could make some issues simply not judged worth pursuing (everybody knows how an ant “walks”, so there is nothing to study here), while stressing the importance of others (“territories” are important in many animal species).

However, it is hard to reach any solid conclusion on this sole basis. Notably, one has to make sure that a difference is really due to the disciplinary nature of the simulation, and not to some practical differences in their functioning, as they were not completely identical. For instance, the difference in number of scenes (configurations) could reveal a difference in the way of experimenting, but it could also be due to the fact that it takes more time in one of the simulation, with the same configuration, to observe the number of events required to take the decision to stop observing and try another configuration. An in-depth analysis, not restricted to elementary units, is thus required.

CONCLUSION

Our experimentation of a pair of similarly structured simulations, one disciplinary and the other non-disciplinary, used in the context of an open-ended problem, revealed huge differences in the way undergraduates from all fields of study interpret and tackle this kind of problem. A “surface” analysis of

students' behaviour and utterances reveals significant differences between the two simulations for a number of indicators which can be related to problem-solving skills and strategies.

An in-depth analysis taking these indicators as guides to pinpoint fruitful areas of investigation has been undertaken. At the time of this writing, it is still in its early stages.

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STUDENTS' DIFFICULTIES ON READING IMAGES FROM COMPUTER SIMULATIONS

Víctor López Simó, Roser Pintó Casulleras

ABSTRACT

When secondary school students use simulations for physics learning, they have to read and understand the visual representations displayed in these educational tools. In this study, we analyse how students read three physics simulations and we identify the difficulties involved in this reading process, intending to relate them with their understanding of the three physics models which students are expected to construct supported by the use of each of the simulations. We have analysed these visual representations through different perspectives (social semiotics, psychology and science education) and we have carried out individual interviews in order to identify, categorize and analyse the most relevant visual features that bring up reading difficulties. Our final aim is to support science teachers to develop critical visual reading in the science class.

KEYWORDS

Reading images, visual representations, educational simulations, physics education.

INTRODUCTION

Rationale

Many secondary school physics teachers use free online available educational simulations (ES) for physics instruction because these educational tools include visual representations (VR) that can be very useful for enhancing students' comprehension of scientific models (Smetana & Bell, 2011). This central role of visualizations in physics education is due mainly to the fact that science language is multimodal by itself, and images have been always used for scientific communication at all levels (Gilbert, 2005; Lemke, 1998; Phillips, Norris, & Macnab, 2010).

However, this extended use of visualizations in physics education leads many science teachers to assume that these visual representations are always correctly read by students, and, for this reason, the understanding of simulations' content (scientific models) is usually given for granted in schools. Sometimes, words like "read" and "understand" are used as synonyms, what reveals an extended misconception about the reading of scientific images. Previous researches on science education have contradicted this conception, showing that when students read scientific VR, their understanding may differ from the original meaning (Ametller & Pintó, 2002; Cook, Wiebe, & Carter, 2008; Martínez Peña & Gil Quílez, 2001; Ryoo & Linn, 2012). According to these previous researches, any reading problem can affect to the conceptual understanding of the scientific models which are expected to be learned by students.

Research questions

In this context, our research question is: *Which reading difficulties appear when 14-16 years old students use some physics' educational simulations?*

THEORETICAL FRAMEWORK

Difficulties in the reading of VR have been studied in different fields, and their results have been often stated as general principles. For the purpose of our study, we can summarize the main contributions saying that:

- Social Semiotics has analysed the grammar of visual designs, the compositional structure of images, the salience of their visual elements, the framing of the visual syntagmas and the modality makers (Kress & van Leeuwen, 1996; Moles, 1991).
- Multimedia learning theory has developed general principles about learning with multimedia materials (Mayer, 2001), such as redundancy principle, the contiguity principle or the modality principle.
- Studies on animated visual representations have analysed the effect of dynamism in the reading process (Lowe, 2003; Meyer, Rasch, & Schnotz, 2010).
- The theory about multiple external representations (MER) has analysed the functions and tasks of multiple representations (Ainsworth, 1999, 2006) that can support complementary roles, constrain interpretation or construct deeper interpretation than single representations.
- Gestalt Theory has analysed the self-organizing tendencies of human brain and their influence in reading images (Winn, 1994), which lead readers to optical illusions.

METHODOLOGICAL DESIGN

The research methodology adopted in this study is qualitative since we are doing a diagnosis study that should inform us about the existence of reading difficulties but not a study about the prevalence of these difficulties.

First of all, we selected three simulations from an online library (<http://phet.colorado.edu/>). The selection process was done according to some curricular and educational criteria: content level, modality of their representations and minor importance of mathematics formalism. The three selected simulations were:

- Simulation A: Heating by friction (figure 1).
- Simulation B: Electromagnetic induction (figure 2).
- Simulation C: Propagation of sound through mechanical waves (figure 3).

Later on, we developed a visual and content analysis of the three simulations in order to identify their relevant features, which were listed in a codification system.

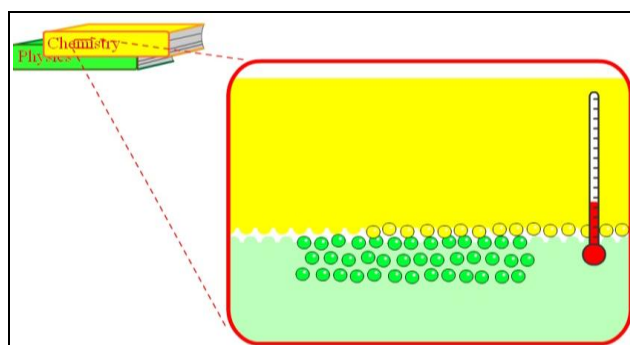


Figure 1. Simulation A: Heating by friction

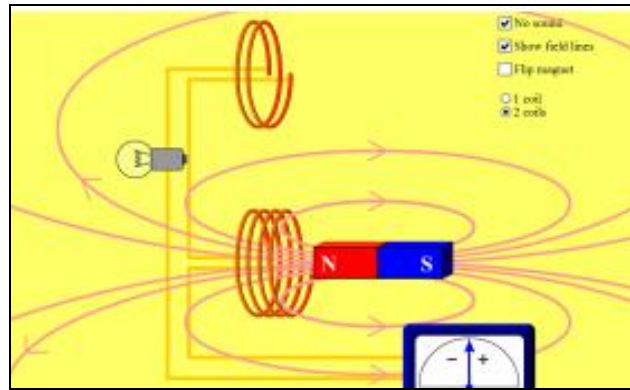


Figure 2. Simulation B: Electromagnetic induction

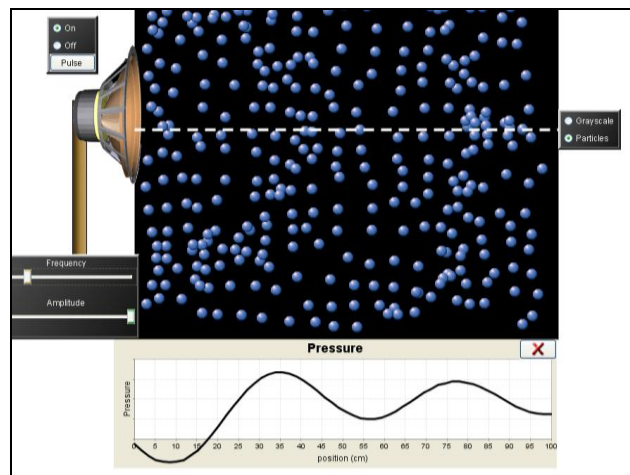


Figure 3. Simulation C: Propagation of sound through mechanical waves

Then, we selected 40 students (14-16 years old) with some prior knowledge about these three scientific topics but not expert on them. We carried out a 20 minutes individual semi-structured interview per student, and these interviews were video-recorded. Following, interviews were transcribed and analysed through the software *Atlas.ti*, developing a content analysis.



Figure 4: Picture of the interview process.

During the analysis process, we selected, coded and classified pieces of interviews according the previous codification system based on the visual features of the simulations, but, at the same time, some categories emerges from the content analysis. So, we followed a combination of “top-down” and “bottom-up” category system. In table 1 an example of the analysis process is shown.

Table 1: Example of analysis process for one specific analysis unit from simulation A

Relevant feature of simulation A	Quote	Researcher comment
Two surfaces in contact are represented, and students are asked to rub them. Then, some represented particles increase their vibration (microscopic representation of temperature rising) but some other particles disappear (mesoscopic representation of the surface erosion of any friction process).	<p><i>R: So, what can you observe when you rub the surfaces?</i></p> <p><i>S: I can observe the evaporation of some particles.</i></p> <p><i>R: Evaporation?</i></p> <p><i>S: Yes, some particles leave the screen.</i></p>	This student confuses “erosion” with “evaporation”. She has problems to distinguish between two different dynamic representation that have different modality because two different scientific scales (mesoscopic and microscopic).

So, at the end of this process, we generated a collection of difficulties faced by students during the reading process. We have collapsed the difficulties into six independent dimensions (See Table 2).

RESULTS

We have the dimensions and the category system that allows us to answer the research question about which reading difficulties appear when students use the three physics’ educational simulations. We have included an specific example from simulations A, B or C.

CONCLUSIONS

A wide range of typologies of reading difficulties have been identified, and each difficulty is associated to one or more visual features. There has been evidenced that science’s specificities (such as models, scales and the nature of scientific representations) play an important role in the reading process. Thus, general statements about difficulties in reading images have to be reviewed from the point of view of content.

Furthermore, although these difficulties come from specific simulations around three scientific topics, it has been possible to infer categories that appear in different situations, and for this reason they could be extrapolated to other physics’ simulations. For example, the reading difficulty that we had classified as “*Confusing different scientific scales*” can potentially appear in other situations where students use a simulation that include representations of different scales. In the future, we expect to be able to formulate more general patterns.

Finally, once again we realise the important role of the critic reading of images that teachers should develop when their students use scientific simulations, scaffolding the images’ reading process.

Table 2: Summary of the most relevant difficulties in reading each simulation.

Dimensions	Reading difficulty	Examples from simulation A, B or C
D1. Compositional structure of the VR and framing of its visual elements	Not connecting the different parts of the compositional structure	<i>Lack of recognition of the interdependence of the elements of an electric circuit (B)</i>
	Not identifying one of the parts of the compositional structure	<i>Interpreting the ground black square as a box (C)</i>
D2. Salience of the visual elements of the VR	Over-attention to surface features	<i>Interpreting the behaviour of the system in terms of the colour of the magnet (B)</i>
	Over-attention to the text	<i>Trying to explain the visual information in terms of the embedded text (A)</i>
	Over-attention to the decorative elements	<i>Interpreting the decorative shine of atoms as the atom's nucleus (A)</i>
D3. Modality and visual value of the visual elements of the VR	Confusing different scientific models	<i>Confusing corpuscular and continuous models of matter (A)</i>
	Confusing different scientific scales	<i>Confusing meso, micro and macro scales (A)</i>
	Confusing extensive and intensive ranges	<i>Confusing atoms representation with atoms existence (A)</i>
	Confusing different visual values	<i>Conceptualizing magnet-field lines as real objects (B)</i>
D4. Dynamism of the visual elements of the VR and	Confusing between position and movement of visual elements	<i>Interpreting the behaviour of the system in terms of position instead of in terms of movement (B)</i>
	Non-perceiving the non-linear changes	<i>Lack of perception of the asymptotic rate of decrease of the thermometer (A)</i>
D5. Interaction and relationship between multiple representations	Non-connecting complementary information	<i>Lack of connection between particles representation and wave front representation (C)</i>
	Non-discriminating different information presented at time	<i>Confusing particles vibration and particles leaving (A)</i>
D6. Distortion of the visual elements of the VR	Distorted perception of the shapes	<i>Considering that the central hole of the coil implies that the circuit is opened (B)</i>
	Distorted perception of the movement	<i>Visual confusion between frequency of vibration and velocity of propagation (C)</i>

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