

# Interest in STEM disciplines and teaching methodologies. Perception of secondary school students and preservice teachers

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## Abstract

The paper addresses the lack of interest that Secondary Education students display towards the academic disciplines of Science, Technology, Engineering and Mathematics (STEM). From the pedagogical standpoint, the origin of this problem may lie largely in the way these subjects have predominantly been taught, i.e. using expository strategies. The aim of this paper is twofold: first, to examine the retrospective perception that preservice teachers recall about the methodologies used for teaching STEM disciplines, coupled with analysis of the value these teachers give to a number of innovative activities used to encourage interest among their future students. A second objective was to compare those perceptions with a sample of high school students' assessment of the actual activities their teachers used in STEM disciplines. Our results revealed the predominance of traditional teaching activities in both teachers and students, although the perception of this is slightly lower among students. Practical and applied activities in laboratories and first-hand knowledge of technoscientific work were perceived as the most interesting activities, although teachers used these less frequently than other activities. Conclusions are aligned with the achievement of a range of varied and innovate learning opportunities seeking a more engaging way of teaching STEM.

**Keywords:** STEM; Secondary education; teaching methods; innovation in education; motivation

**Resum.** *Interès per les disciplines STEM i metodologies per al seu ensenyament. Percepció d'estudiants d'educació secundària i docents en formació*

L'article aborda la manca d'interès que els estudiants d'educació secundària mostren per les disciplines acadèmiques de ciència, tecnologia, enginyeria i matemàtiques (STEM). Des del punt de vista pedagògic, l'origen d'aquest problema pot situar-se en gran manera en la forma com tradicionalment s'ha tendit a ensenyar aquestes matèries. És a dir, mitjançant un predomini d'estratègies expositives. L'objectiu d'aquest article és doble: primer, examinar la percepció retrospectiva que els docents en formació recorden sobre les metodologies utilitzades per ensenyar les disciplines STEM, juntament amb l'anàlisi del valor que aquests docents donen a un seguit d'activitats innovadores que s'utilitzarien per enco-

ratjar l'interès dels seus futurs estudiants. El segon objectiu va comportar comparar aquestes percepcions amb l'avaluació d'una mostra d'estudiants de secundària sobre les activitats que els seus mestres feien servir en les disciplines STEM. Els resultats revelen un predomini de les activitats d'ensenyament tradicionals tant en mestres com en estudiants, lleugerament menys percebudes pels estudiants. Les activitats pràctiques i aplicades en laboratoris i el coneixement de primera mà de la feina tecnocientífica s'han percebut com les activitats més interessants, encara que els seus professors les utilitzaven amb menys freqüència que altres activitats. Les conclusions estan alineades amb l'assoliment d'una gamma d'oportunitats d'aprenentatge variades i innovadores que busquen una forma més atractiva d'ensenyar STEM.

**Paraules clau:** STEM; educació secundària; mètodes d'ensenyament; innovació en educació; motivació

**Resumen.** *Interés por las disciplinas STEM y metodologías para su enseñanza. Percepción de estudiantes de educación secundaria y docentes en formación*

El artículo aborda la falta de interés que los estudiantes de educación secundaria muestran hacia las disciplinas académicas de ciencia, tecnología, ingeniería y matemáticas (STEM). Desde el punto de vista pedagógico, el origen de este problema puede estar en gran medida en la forma tradicional en que predominantemente se han enseñado estas materias, es decir, utilizando estrategias expositivas. El objetivo de este artículo es doble: primero, examinar la percepción retrospectiva que los docentes en formación recuerdan sobre las metodologías utilizadas para enseñar las disciplinas STEM, junto con el análisis del valor que estos docentes dan a una serie de actividades innovadoras que se utilizarían para alentar el interés de sus futuros estudiantes. El segundo objetivo fue comparar esas percepciones con la evaluación de una muestra de estudiantes de secundaria sobre las actividades que sus maestros usaban en las disciplinas STEM. Nuestros resultados revelaron el predominio de las actividades de enseñanza tradicionales tanto en maestros como en estudiantes, ligeramente menos percibidas por los estudiantes. Las actividades prácticas y aplicadas en laboratorios y el conocimiento de primera mano del trabajo tecnocientífico se percibieron como las actividades más interesantes, aunque sus profesores las utilizaban con menos frecuencia que otras actividades. Las conclusiones están alineadas con el logro de una gama de oportunidades de aprendizaje variadas e innovadoras que buscan una forma más atractiva de enseñar STEM.

**Palabras clave:** STEM; educación secundaria; métodos de enseñanza; innovación en educación; motivación

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### Summary

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## 1. Introduction

One decade ago, the Report of the Commission on Science Education for the Future of Europe (Rocard et al., 2007) highlighted that numerous investigations had revealed an alarming decline in interest in scientific knowledge in younger students. This decrease was acknowledged as one of the greatest threats for the future of Europe, given the need to train professionals in these areas (e.g. as science technologists, engineers, or mathematicians), as well as the failure of basic scientific literacy in society as a whole. This concern has been also confirmed in current research (Osborne & Dillon, 2008; Krapp & Prenzel, 2011; Pedrinaci, Caamaño, Cañal, & De Pro, 2012; Taskinen, Schütte, & Prenzel, 2013; Potvin & Hasni, 2014; Vázquez-Alonso & Manassero-Mas, 2015; Ospina, 2018). The interest in Science and Technology, as well as Engineering and Mathematics – commonly referred to as STEM – is a central component for the future of advanced societies. For 20 years, the promotion of scientific and technological literacy has become a prerequisite to meet the basic needs of the population, whereby science knowledge must be combined with the ability to draw evidence-based conclusions in order to understand and make decisions about the natural world and the changes made to it through human activity (OECD, 1998). The purpose of this specific literacy is to enable young citizens to look critically at society and at the values that sustain it, in order to ask what can and should be changed to achieve a fairer and more democratic society and to ensure more environmentally sustainable lifestyles (Hodson, 2003, 2010; Caride, 2017).

At the beginning of the twentieth century, scientific literacy helped to redefine not only industrialised processes, but also economic and societal systems (i.e. the diverse changing forms of work and lifestyles) by transforming culture and even the proliferation of key ethical issues. The relevance acquired by scientific literacy and the role of the STEM disciplines to deal with these transformations, is currently a paramount issue. However, this literacy is dependent upon motivational and volitional processes around scientific knowledge and the way this knowledge is methodologically presented to the student. In other words, an increase in scientific literacy is achieved when the student acquires knowledge, decisions, and conclusions, which goes hand-in-hand with the interest generated by such scientific knowledge. Thus, the lack of student interest is a high priority matter (López, 2019) for addressing their engagement in the STEM disciplines and for future societal developments.

### *1.1. The origins of students' lack of interest in STEM*

The continuing decline of student interest in the study of STEM disciplines is a complex phenomenon that requires a dual research focus: first, on students' attitudes toward scientific knowledge and skills; and second, on the way these disciplines are taught, especially at high school, because these subjects are the platform for future vocational interests.

Regarding the former concern, some studies (DeWitt, Archer & Osborne, 2014; DeWitt & Archer, 2015; Said, Summers, Abd-El-Khalick & Wang, 2016) suggest that, during primary education, students are positively inclined towards scientific knowledge but that this interest diminishes as they progress to higher levels. There is also an apparent contradiction between students' attitudes to science in general – which are positive – and their attitudes towards school science, which is not always viewed so positively (Osborne, Simon & Collins, 2003).

With respect to the second concern, methodologies used by teachers are recurrent issues, with an argument emerging around the key role that traditional approaches still play, as opposed to the use of innovative pedagogical strategies and resources (Williams, 2011; Coca, 2015; Jauregui, Goienetxe & Vidales, 2018; Aguilera & Perales, 2018). From an educational perspective, the predominant approach for teaching science and technology has been closely linked to the use of expository strategies; this is probably a major factor causing lack of interest among students (Santillán et al., 2017). This is why the Rocard Report (2007) insisted on the need to redirect teaching away from traditional 'chalk and talk', because it has been found, with high levels of success, that innovative research-based methodologies (such as inquiry-based science education) will encourage more student involvement, focusing on the self-regulatory activities in the negotiated construction of knowledge (Feinstein, Allen & Jenkins, 2013) and an increase in participation, critical thinking, and satisfaction in the context of gamification (Vázquez-Alonso & Manassero-Mas, 2017). Complementarily, a growing body of research on motivational factors offers important clues to the kind of classroom environment and activities that might raise students' interest. However, as Osborne et al. (2003) pointed out, it is surprising that so little work has been done to identify the nature and style of teaching and activities that engage students. Similarly, as Hodson (2010) has stated, 'Learning Science and Technology' (acquiring and developing conceptual and theoretical knowledge) is not the same as 'Learning About Science and Technology' (developing an understanding of the nature and methods of science and technology; an awareness of the complex interactions among science, technology, society and environment; and social and ethical implications), or even 'Doing Science and Technology' (engaging in and developing expertise in scientific inquiry and problem solving).

The debates surrounding traditional teaching methodologies revolve around their transmissive pedagogy, decontextualised content, and the difficulty level of school science, as reported by students in different countries (Lyons, 2006; Marba-Tallada & Marquez, 2010; DeWitt et al., 2013; Said et al., 2016; Solaz, Del Campo & Sanjosé, 2016). Especially in compulsory education, science and technology need to be taught in a new way that broadens students' views of how that knowledge can be productive (Archer, DeWitt & Dillon, 2014). STEM learning is more than memorising facts; it should include the understanding and application of scientific concepts and methods (Bell, Urhahne, Schanze & Ploetzner, 2010; Talbot & Hayes, 2016). Hence,

in order to increase their interest in STEM disciplines, students need to acquire knowledge of how science is done as a common endeavour and they need to learn about the nature of science and scientific content (Bell et al., 2010), that is to say, they need to be assisted in contextualising content in terms of their own experience and applied uses of their learning – even establishing a connection between the science that is done in research centres and their classroom knowledge.

In addressing these concerns, it is important to consider that students' learning experiences in the STEM disciplines, from an early age (between 10 and 14 years), will generate expectations that could either trigger a strong link with these disciplines or, alternatively, reduce their interest and probably the future attractiveness of scientific professions (Beal & Crockett, 2010; Archer et al., 2012). For this reason, the study of teaching methodologies and the way they can demotivate student interest needs to be analysed in depth, in order to uncover possible negative attitudes or dispositions.

### *1.2. Motivations and goals of the study*

Our modern societies are characterised by incessant change that raises a series of challenges that need to be addressed from all educational institutions. Compulsory education institutions are undergoing a profound shift that reflects the one from an industrial-based economy to a knowledge-based economy that requires continuous innovation (Andrews & Criscuolo, 2013). Even more, modern societies face challenges that need to start to make a move towards a Learning Society visible, which inevitably entails processes of change in the way we think about learning, along with promotion of the growth mindset (Dweck, 2015). Focusing on learning as value, and based on the concept of lifelong learning, innovation in teaching methods is a key factor for maintaining a learning society (i.e. by providing new ways of accessing and managing knowledge for students to engage with learning in different areas, such as the sciences). Consequently, students need to be allowed to manipulate knowledge, implementing strategies to search for their information, choosing appropriate alternatives for specific contexts, learning permanently, and adapting their learning to situations of constant change (Kolb, 2014) – all of which have repercussions on teaching and learning methods in education institutions.

Specifically, this vision of a society requires a minimum scientific literacy, which shows the real value of learning science for future generations. More importantly, in terms of community and individual welfare, scientific literacy is a medium by which individuals can be empowered in the long term. In the near future, highly-developed modern societies will advance as a combined result of three indicators that directly correlate with science development: the level reached by science and technology, the existence of a critical mass of researchers, and a proactive attitude among society towards science (Acevedo-Díaz & García-Carmona, 2016). This premise was considered by education

systems in several countries; as a result, the competences, skills, and knowledge needed for scientific literacy are included in most school syllabi (by means of the STEM subjects and other transversal actions).

Despite this potential, a major challenge still persists: the lack of student interest in scientific issues and the decrease in vocational trajectories in the scientific and technological domains (Romero, Espinoza-Romo, Villanueva, García & García, 2018). Reasons for this decrease can be found in different areas; one of the most important, and which is the focus of the current research, is students' attitudes and, in parallel, the methodologies that teachers use to engage them and provide satisfactory learning experiences in scientific disciplines.

Our research sought to better delineate students' perception of scientific concepts and their practical application to everyday life situations and also the way they are being learnt and taught in secondary education. It does so by analysing the methodologies used for teaching-learning the STEM disciplines. This goal was twofold. On the one hand, we wanted to examine the retrospective perception that preservice teachers (students pursuing a master's degree in preparation to become high school teachers) recall about the methodologies used when they learned the STEM disciplines, coupled with analysis of the value these student teachers give to a number of innovative training activities, in order to encourage interest among their own future students.

On the other hand, we sought to compare those perceptions with the assessment by a sample of current high school students of the use of traditional or innovative teaching methodologies in the STEM disciplines.

## 2. Methodology

A comparative study was designed to collect the perceptions of preservice teachers and high school students in order to analyse the hypothesis that the lack of interest in STEM disciplines could be related to the use of traditional methodologies and that the use of innovative methodologies could increase student interest. The study is descriptive and correlational, and uses a questionnaire as its method of enquiry (Berends, 2006). It began with a review of other similar research instruments, based on the studies by Osborne, Simon & Collins (2003); Becker (2009) and, in particular, the questionnaire used in the study by Polino & Chiappe (2011) for the Latin American context. Based on this review, the questionnaire entitled 'Interest in scientific and technological knowledge among secondary school students' was designed and rewritten for this study in two versions, one for teachers and one for students.

The questionnaire has four parts (Muñoz, Hernández & Serrate, 2019) and was validated by five experts and six secondary school teachers of STEM disciplines. In addition, a first pilot study was conducted with 36 high school students. For internal consistency of the instrument, the Cronbach alpha coefficient was derived for each part of the questionnaire; these results confirmed reliability, with values above .877 in each section.

Data for this study were selected from the third part of this questionnaire, examining the respondents' evaluation of teaching activities in STEM classes (with eight dimensions: interesting, fun, useful, critical-development, creativity-development, difficult, need to invest time), along with an evaluation of traditional activities (textbook activities and exercises; teacher lecturing; individual work activities) and innovative activities (groupware activities; ICT-Information Communication Technologies learning activities; workshops and experimentation in the laboratory; exhibition activities by students; visits to laboratories, companies, or industrial centres; working with the news media; activities for the application of scientific and technological knowledge; projects to solve real life problems; debates on science and technology), in order to assess whether they were more or less frequent activities in, on the one hand, the retrospective perceptions of future teachers and, on the other, the current perceptions of secondary school students.

The questionnaire was answerable on a Likert scale of 1 to 4 points (from minimum to maximum agreement). The data analysis was descriptive and correlational and was performed with a parametric and nonparametric analysis.

### *2.1. Sample*

The study compared two samples. The first group comprised 210 preservice teachers (students on a master's degree preparing to be high school teachers, at the University of Salamanca), of which 44.7% were men and 55.3% were women. The majority of the participants were 25 years old (64.8%), while the remaining participants were between 26 and 40 years of age.

The sample of preservice teachers was divided into two groups depending on their educational background, i.e. whether they came from science, technology, engineering, and mathematics degrees (called the STEM group), for which the percentage was 43.3%; or whether they came from other degrees that are not related to these disciplines (called NON-STEM), with a percentage of 56.7%.

The other research sample was selected from a group of 280 public and private secondary school students in Salamanca. Specifically, the sampling process sought students in the fourth year of compulsory secondary education because, by this point, they had already chosen whether to study STEM disciplines or not. Students' age range was from 15 to 17 years old, 54.6% (n = 153) male and 45.4% (n = 127) female.

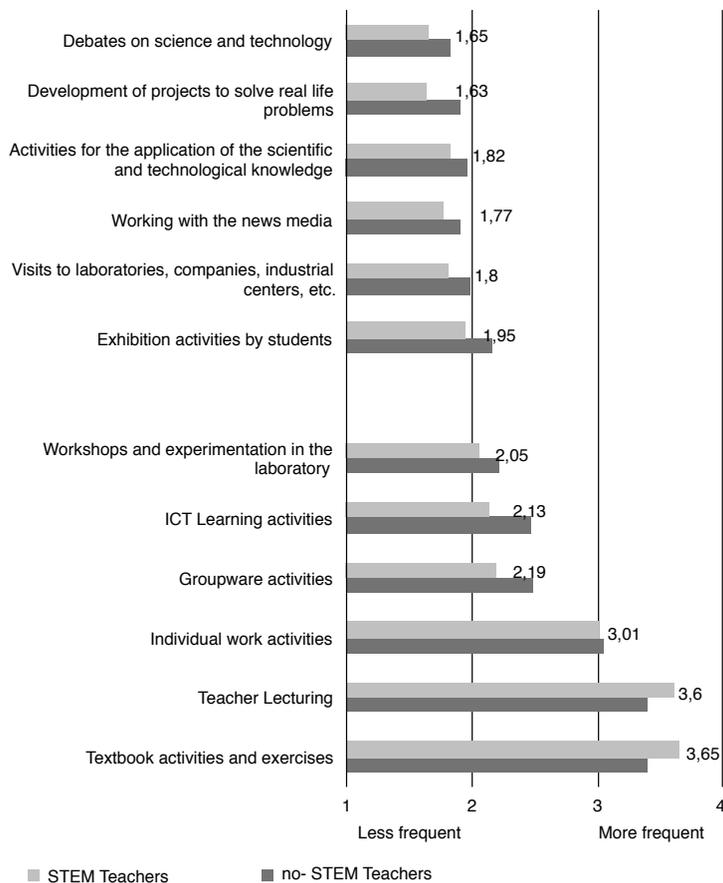
Accordingly, we chose a discriminating variable (decision to continue higher education in relation or not to STEM) and determined that 41% of the sample had decided to study a bachelorship related to science/technology (of which 61% were male and 39% were female); 46% would continue in non-STEM-related studies (46% male and 54% female), while 13% were still undecided and were hence excluded from the analysis.

### 3. Results

Firstly, in the retrospective study of preservice teachers currently taking a master’s degree in Teaching in Secondary Education, we analysed the type of activities that were frequently provided by their teachers when they were learning STEM subjects. We obtained a group of ‘frequent’ (normal or very often) and ‘infrequent’ activities (infrequent or hardly ever).

The frequent activities (See Figure 1) were mainly: teacher lecturing, textbook activities, exercises and individual work activities, which are all labelled ‘traditional’. We found significant differences ( $p < 0.05$ ) in the two traditional activities that were perceived as more frequent, which were remembered more by the future STEM teachers and less by the non-STEM group. The more important concern regarding these differences is that teachers could

**Figure 1.** Average frequency of activities in STEM (retro-study of Preservice Teachers)



Source: own elaboration.

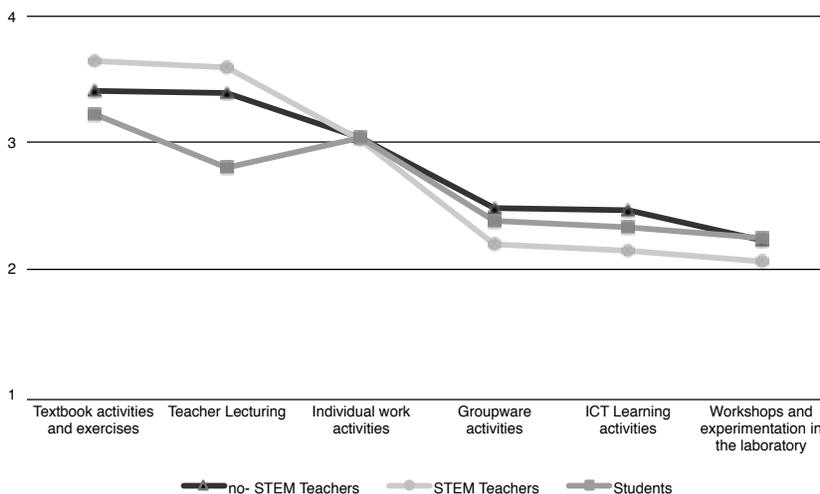
have considered these activities interesting or useful, because they had gone on to take a degree in these areas and were now preparing to become teachers of these subjects.

In addition, there were activities that students remembered as frequent but in a lower percentage: groupware activities, ICT learning activities, and workshops and experimentation in the laboratory, labelled as 'innovative'; and perceived as less frequent by STEM teachers and slightly more frequent by the non-STEM teachers. These differences were not significant; neither among the groups when they were separated by areas (STEM and non-STEM) nor by gender or age.

The less frequent activities (in Figure 1) were mainly either development of projects to solve real-life problems and debates on science and technology. Application activities and exhibitions seldom occurred. Also, despite the possibilities of working with news media (commenting on news, discovering scientific input that was published, etc.) this activity was rarely remembered. The same consideration arose towards activities that could raise their interest, such as visits to laboratories, companies, industrial centres, etc. When comparing the perceptions of preservice teachers with the actual vision of high school students (see Figure 2), there were no significant differences in the infrequent or very rare activities in STEM; however, the perception of those traditional activities was lower, which could indicate a slight decrease in traditional activities nowadays.

The perception of STEM subjects was also explored, asking participants to express their attitudinal perception of several appellatives used to describe it. Attitudes in the first group, the preservice teachers, were expected to be

**Figure 2.** Average frequency of activities in STEM (retro-study of Preservice Teachers)



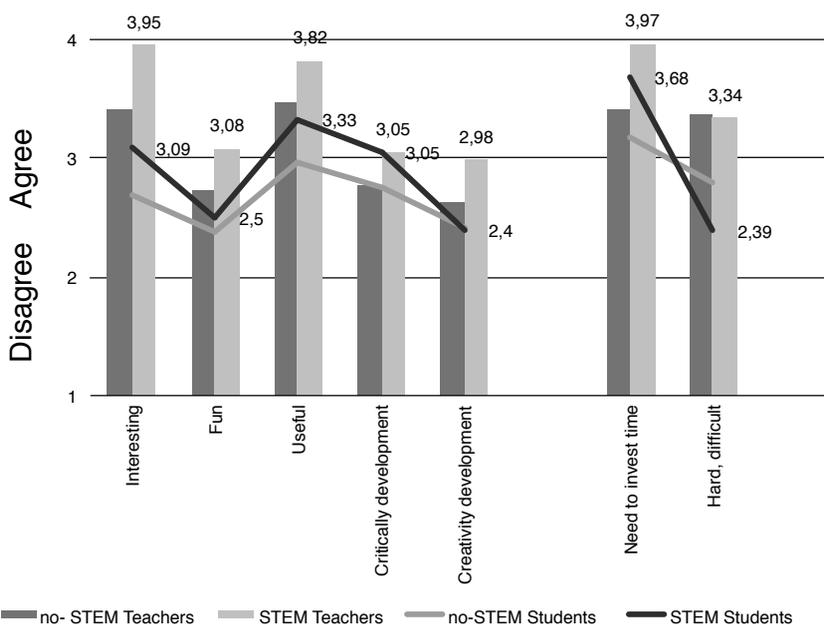
Source: own elaboration.

were more positive if they went on to take a degree in this subject; this hypothesis was confirmed. According to Figure 3, STEM preservice teachers found the subjects more interesting, fun and useful than their peers; the difference was statistically significant ( $p < 0.001$ ). Their perceptions were higher for all the parameters, except the last one regarding ‘difficulty’, for both types of teachers recalled STEM subjects as being hard to study. It is interesting to note that the ‘fun’ dimension was rated less often, although the future STEM teachers felt they had more fun than their peers did. They also agreed that these subjects develop both ‘creativity’ and ‘critical thinking’.

In sum, STEM subjects were fundamentally remembered as interesting and useful but requiring effort and many hours of study. Future teachers of STEM subjects also showed higher perceptions in all the dimensions except for the perception of difficulty; this positive attitude could be viewed as bias whereby they view their teaching roles as useful and motivational.

Figure 3 also depicts the perceptions of the students by differentiating between those who chose STEM disciplines for their bachelorship (dotted line), and non-STEM students (striped line) who chose other bachelorships. The students’ perceptions of STEM subjects were lower than those of teachers in all parameters. Non-STEM students showed the lowest values, except for the consideration of ‘hard, difficult’, where significant differences confirmed

**Figure 3.** Average perceptions of the STEM subjects by Preservice Teachers (columns) and Students (lines)



Source: own elaboration.

that STEM students considered it harder than their peers (which denotes awareness of the effort and the overcoming of predispositions). There is further relevant data concerning the value of agreement with the 'need to invest time' dimension, where STEM students (average = 3.68) gave higher scores than their peers: they were more convinced of this than the fact that subjects were difficult. Indeed, this was the most highly scored perception, followed by usefulness (average = 3.33).

Considering the aims of the study, one of the dimensions that was most thoughtfully analysed was the perception of 'interesting', for which the scores given by the future teachers and the students were considerably higher, both for STEM and non-STEM, even slightly higher than the perception of 'usefulness'. The highest agreement was with the awareness of how STEM subjects require the investment of a lot of time; from a retrospective perception, future teachers were more aware of that effort, although students were also aware of this. Neither the students nor the teachers showed a higher level of agreement that STEM subjects contributed to the development of 'creativity' or 'critical thinking'. Interestingly, when they were asked about 'fun', the rates were also lower, particularly for non-STEM groups.

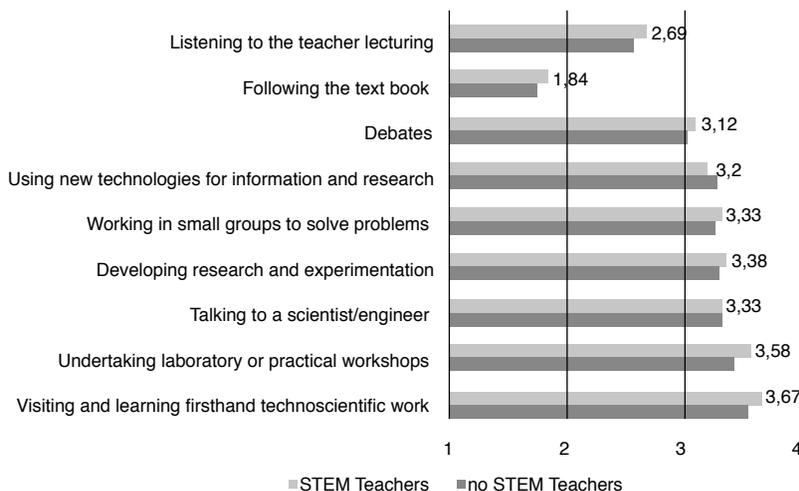
Finally, we analysed the preservice teachers' assessment of a number of teaching activities used to encourage high school students to take an interest in the STEM disciplines. No significant differences were found among groups in terms of demographic factors, neither between STEM graduates nor their peers.

Figure 4 shows the percentage suitability of different activities for increasing interest in STEM disciplines, rated by the preservice teachers' point of view. 'Visiting and learning first-hand from technoscientific work centres, laboratories, companies, industrial centres and professionals' was the activity that was deemed most highly adequate by almost all respondents (94%, average = 3.68). Also, 'Undertaking laboratory or practical workshops' and having the opportunity to 'Talk to a scientist/engineer who comes to class to tell students about their work' were highly rated activities by preservice teachers. Some activities used to connect STEM disciplines with real issues and environmental problems were rated lower, but were still considered adequate, such as: 'Debates for working with the news media, science-technology-society-environment relationships'.

Regarding traditional, transmissive or less active methodologies, such as 'following the textbook' or 'listening to the teacher lecturing', a large percentage of teachers rated these as not very adequate for raising students' interest (81% and 67%, respectively). Preservice teachers preferred more interactive activities such as: 'Research and experimentation by testing one's own hypothesis', 'Working in small groups to solve problems or do projects that encourage inventiveness and creativity'. Also, 'Using new technologies for information and research activities' is viewed as significant for increasing interest.

Both in the retrospective views of teachers and the perceptions of high school students, the results highlight the predominance of traditional teaching

**Figure 4.** Average rate of the adequacy of activities for increasing student interest in STEM disciplines from preservice teachers



Source: own elaboration.

activities (such as following the textbook, teacher lecturing, doing textbook exercises) over more innovative activities (such as visiting technoscientific research centres, doing projects and reports, problem-solving on real issues, doing research activities). Likewise, the preservice teachers' perceptions of how these predominant activities fail to connect with the students' interest is coherent with the need to promote more innovative activities that can do so, such as those that involve the application of scientific knowledge and skills.

#### 4. Discussion

Our results revealed the predominance of traditional teaching activities to be a possible cause of the lack of interest in STEM among high school students. However, both the students and teachers in our samples considered STEM subjects 'interesting' (with a range of values from 2.7 to 3.9 out of 4). When they rated activities on how much they increase interest, they showed disagreement on the more traditional activities: following the textbook and listening to the teacher. The use of these teaching activities in STEM could be unappealing to the students, as they are viewed as more passive and rigid than other more innovative activities.

In line with various studies (Osborne et al., 2003; DeWitt et al., 2014; DeWitt & Archer, 2015; Said et al., 2016) our results warn of the risk of positive attitudes to STEM being lost, because they are generally considered interesting, which is positive, but the methods for learning and teaching them are viewed as unappealing. Preservice teachers recalled the two most tradi-

tional activities (following the textbook and teacher lecturing) as the most frequent; and that is still the prevailing perception among current students, albeit somewhat less frequent, suggesting that the most common methodologies are still the same. These methods are unlikely to disappear altogether, as future preservice teachers do not rate them as useless, but merely as less motivating. In other words, they feel there are other more interesting methods, and which are more relevant, and as they are preparing to become teachers of these subjects, they are in a position to make methodological changes that can increase student engagement, emphasizing didactical changes as suggested in other studies (Marba-Tallada & Marquez, 2010; Jauregui et al., 2018).

There is concern that although STEM teachers might have a command of their subject, they also need strategies and skills in the use of other activities and a varied range of learning opportunities in order to encourage students. Motivation and enthusiasm for STEM subjects is by no means rare, as confirmed by the results on the perception of traditional and innovative activities, in line with other studies (Borges, Pires & Delgado, 2018). Future teachers – with their experience as former students and the expectation of improving their future teaching – considered practical workshops, laboratory work and doing research and experimentation to be highly engaging. These activities involve the student in an active role, and imply a shift in the teaching process towards a learning-centred model. This is a change not only in procedure, but also in attitudes, values, and ultimately, culture, both for teachers and for education institutions. Such a cultural renewal directly affects the methodology by seeking to alter the core of the learners' development. The predominant culture based on the academic logic of the disciplines needs to be questioned, and an education system that integrates academic, professional and life skills is needed in its place. In this innovative model, the goal will be to train students not only in knowledge of the different disciplines, but also in an understanding of what is needed right now to cope with ongoing challenges and future learning needs. The adaptation of STEM materials to students' everyday lives, and the use of debates to contrast the science-technology-society-environment relationship, were highly rated by the sample, as was the use of new technologies, for example, to integrate the methodology of flipped learning into research activities as a way to achieve meaningful, deep and constructive education, centred on autonomous, student-guided learning. As opposed to the conception of knowledge as a closed construct, the teaching of the STEM disciplines should prioritise open and flexible teaching and learning processes, albeit governed by reliable and justified criteria, thus generating a vision of knowledge as a constructive process.

The other side of the discussion on increasing interest in STEM is the vocational consequences of disengagement (Hernández, 2018). The guiding function of different professionals that stimulate students towards STEM professions and academic trajectories needs to be analysed, considering that teachers also motivate and guide vocational choices (Peña, Inda, Rodríguez & Fernández, 2016; Rodríguez, Peña & García, 2016). The guiding function probably also needs to be innovated, in order to offer an appropriate approach

to the professional reality and make STEM professions more accessible. Our sample views activities such as visiting science centres and the opportunity to meet and talk to scientists, technologists, engineers and mathematicians as highly engaging (scores of 3.67 and 3.33 out of 4).

In this vein, for future implications, one of the basic priorities of secondary schools must be the analysis of ways to innovate in order to achieve not only quality learner-focused training, but also engaging education designed to encourage the next generation of STEM workers. These approaches will need to counter the inertias that have shaped the status quo of the education system and led to such slow innovation, and which have generated such inequalities due to the insufficiency of both material and human resources, by instead developing effective innovations for every school, rather than being so heavily reliant on methodological revolutions coming from individual teachers that are the most motivated or forced to change.

## 5. Conclusions

The paper has examined the perception among preservice teachers of the methodologies for teaching STEM disciplines, coupled with those of high school students. In this analysis, the respondents confirmed the hypothesis that the traditional methodologies underlying the predominant teaching model, based on expository strategies, were the most frequently used activities in their past and actual learning processes, as opposed to other, more innovative activities.

The future teachers' assessments of a number of training activities designed to encourage interest among high school students in STEM disciplines suggest the need for more innovative activities that relate to the application of scientific knowledge. Teachers reported that the most attractive activities for increasing student interest in the STEM areas are different from those in which they were most frequently trained. Activities such as visiting centres and meeting scientists to learn about their work were perceived as the most stimulating and reachable.

The need to adapt compulsory secondary education to the characteristics and demands of a society ruled by the rapid development of technologies, the availability of a vast amount of information and the requirement to increase the population's scientific literacy are generating new training requirements that education systems must meet. Accordingly, the adaptation of teaching practices to learning paradigms that are better suited to the learning of STEM disciplines is one of the most urgent needs, because of the vocational implications for the future generation of scientists, and the danger of them losing interest in these areas during their academic life. As an implication, and considering that the students and teachers in our study agreed that STEM disciplines are interesting, but did not perceive them as fun but instead as hard and requiring the investment of effort, training methodologies should focus on holding student interest in science and technology by making it accessible and applying it to societal issues, along with the provision of dynamic support for those students who have difficulty learning and need to invest more time in their studies.

Teaching practices have yet to incorporate many of the advances in innovation. It should be recognised that every educational practice has its particular theory and most suitable methods, but student diversity and a wide variety of interests mean that different learning pathways need to be explored. The current socio-cognitive conception of learning, based on a socio-constructivist epistemology, is not so much about trying to reproduce reality as it is about reconstructing a function of the interaction between perceptual and interpretive schemes of knowledge (which is demanding active methodologies, as opposed to passive or unidirectional ones).

The promotion of a creative, critically-thinking, and reflective scientifically literate population will reveal the usefulness and social value of science that is brewing in education centres. These creative or critical aims were not reported very highly by the sample of teachers and students, probably because they view science as a means and not an end. A new vision of the usefulness and interest of science is required, whereby it is viewed as a possibility for more extensive learning and as a medium for attaining a variety of transversal skills.

Finally, as a major implication, students need to be provided with more opportunities to apply scientific and technological knowledge; a key factor here is the connection to research centres, which was one of the activities reported as most highly suitable for boosting interest in STEM. Possibilities to visit such centres and learn about the science done therein on a local, regional, or national level, would connect two poles that have a natural tendency to separate: doing science as opposed to teaching science will reduce the distance between the general public and the world of scientific and technological knowledge; this is a challenge for teachers. The integration of scientific and technological knowledge, procedures, and skills poses a requirement to motivate students to learn and will also foster continuing learning in the STEM disciplines and future vocational choices.

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