ParentSTEM

STEM for Pre-Schoolers and Their Families

Key Points for STEM

in Early Childhood Education and Involving Parents: A Guidebook for Early Childhood Educators

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KEY POINTS FOR EARLY CHILDHOOD STEM EDUCATION and INVOLVING PARENTS:

A Guidebook for Early Childhood Teachers

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This guidebook is prepared to be used as a resource to create a vision for European STEM education for teachers and to be a major resource for professional development. Through this guidebook we aim to help early childhood educators, researchers and pre-service educators construct theoretical framework of STEM through a European perspective. Therefore, this handbook will be a valuable source for those who want to create more solid STEM education at kindergarten level by providing both a theoretical and a pedagogical framework for STEM. There are 15 chapters in the book. The content of the guidebook contains STEM definition, constructing positive STEM self -efficacy and identity, effective STEM implementation, assessment of STEM activities and strategies for parent involvement in STEM education. Each chapter included theoretical explanations of the STEM concepts as well as suggestions and tips to integrate these theoretical concepts into practice for educators.

Content

Preface

This guidebook is the first intellectual output of the Erasmus+ Project,"PARENSTEM: STEM Education for Preschoolers and Their Families" (2018-1-TR01-KA203-059568). This project involved the coordinator Kırıkkale University (Turkey) and partners; Science Technology Engineering Art Mathematics (STEAM) Association (Turkey), Kızılırmak Şehit Volkan Pilavcı Anaokulu (Turkey) The University of Southern Denmark ((Denmark), Martin Luther University (Germany), Ajuntament de Cerdanyola del Vallès (Spain), The Universitat Autònoma de Barcelona (UAB) (Spain), Sofia University St. Kliment Ohridski (Bulgaria) and The Martin-Luther-University Halle-Wittenberg (Germany) The aim of this European project is to increase family involvement in STEM education process of early childhood students specifically coming from low socio-economic status through increasing the capability of early childhood educators both on STEM education and on involving parents to this process.

In parallel with the aims of the project, this guidebook is prepared to be used as a resource to create a vision for European STEM education for early childhood educators particularly and for all teachers in general. It is believed to be one of the major resource for professional development for those who wants to integrate STEM education in their programs. Through this guidebook we aim to help early childhood educators, researchers and pre-service educators construct theoretical framework of STEM through a European perspective. Therefore, this handbook is believed t be a valuable source for those who want to create more solid STEM education at kindergarten level by providing both a theoretical and a pedagogical framework for STEM.

In this guidebook, there are fifteen chapters that are believed to be milestones of the STEM education in early childhood years. The content of the guidebook contains STEM definition, constructing positive STEM self -efficacy and identity, effective STEM implementation (providing equality, defining technology, effectively integrating science, technology, engineering and mathematic), assessment of children during STEM activities, ways to support STEM rich home environment, involving community resources into STEM education process and creating an environment which provides a good opportunity for parents to involve into STEM education. In each chapter, the reader could find theoretical explanations of the STEM concepts as well as suggestions and tips to integrate these theoretical concepts into practice for educators.

Chapter I

It is Never too Early to Start STEM Education

Şahin İdin and İsmail Dönmez

STEAM Education Research Association

Investigations show that early exposure to STEM has positive impacts across the entire spectrum of learning. For instance, early math knowledge not only predicts later math success but might also predict later reading achievement (Gonzales & Kuenzi, 2012). STEM education can be identified as it is an interdisciplinary approach covering the whole educational process from pre-school to higher education. STEM education can be identified as one of new approaches to be used in the education system, which also aims for students to be able to solve problems in their daily lives (İdin, 2018). The National Research Council of US (1996) defines STEM as an educational and teaching approach which integrates both the content and skills of science, technology, engineering, and math. İdin (2017) states that STEM is an integration of science, technology, engineering and math which includes between pre-school and higher education, and it provides learners with 21st century skills. Pre-school children are mentally and physically active. They bring wonder and curiosity to preschool experiences. K12 Learning Liftoff (2019), children benefit from learning STEM subjects which include Science, Technology, Engineering, and Math, because these disciplines play a fundamental role in setting the foundations for future learning. STEM educational activities invite them to explore the world around them using all their senses. STEM is a way of thinking about how teachers at all levels—and parents as well—should be helping pre-school children integrate knowledge across disciplines and encouraging them to think in a more connected and holistic way. For this reason, STEM education can be given to preschool students via STEM activities within both formal and informal contexts. Each STEM subject provides subject-specific attention to ensure that pre-school children build their foundational subject matter knowledge systematically. In addition, it emphasizes the creativity, beauty, and unique features of the discipline itself. Children's attitudes towards STEM are formed early, so pre-school children's earliest experiences with STEM subjects set the stage for their later success in STEM fields.

Within this context, teachers have responsibilities. The role of a teacher is to create a rich environment, when planning any STEM activity for pre-school children. Teachers also engage pre-school children in inquiry explorations by focusing their observations. It is known that 21st century skills are important, and today STEM is thought to have a significant role in students' futures for an advanced society. The Partnership for 21st Century Skills (2011) defines 21st century skills as "collaborating, communication, critical thinking, and creativity. The National Research Council (2010) states that 21st century skills are "nonroutine problem solving, self-development, systematic thinking, adaptability and complex communication skills. Besides these, innovation, employability, and efficient teamwork can also be given as 21st century skills. As 21st century skills stand out in professions, secondary schools instill 21st century skills in their students to prepare them for the 21st century. In fact, 21st century skills can also be built in the pre-school curricula/frame. It is thought that any child can solve any problems if he/she develops 21st century skills well. 21st century skills have a significant effect on STEM subjects. Idin (2018), If a person faces any problem in his daily life, he could solve those problems. This could be possible by himself or with a team. STEM education can achieve this with its entire content, such as activities, events, experiments, and so on. Some individuals in the community will be interested in STEM fields, both academically and professionally. All these efforts will help to prepare them for the 21st century. Within this context, it is recommended that students should be directed towards STEM career fields.

In order for STEM training to be meaningful, three basic elements should be gained. These are: entrepreneurship, employment, and creativity. OECD (2015), states that we should start at an early age with a wide definition of entrepreneurship embedded across the curriculum and relevant to all students, preferably in preschool since the field of entrepreneurial education is in a quite early stage of development. Individuals who receive STEM education provide these three features in solving a problem they face. To be able to ensure that preschool students have these features, STEM education should be given to preschool students. There can be seen some stereotypes in society within gender based role. For example, STEM based jobs are not suitable for girls. Girls have not talent for STEM and STEM is boring and not interesting for girls. To change both boys and girls attitude towards those mentioned stereotypes it is important to start STEM Education at preschool level. Individuals who have received STEM education gain 21st century skills, such as critical thinking, teamwork, creativity, entrepreneurship, innovation, communication, teamwork. It is thought that STEM Education allows children to develop their communication and problem-solving skills, when they are actively encouraged to talk and write about their ideas.

Additionally, they are expected to have a respectful, understanding, and democratic attitude toward people around them. Successful citizenship in the 21st century requires the interest and ideas of STEM and practices and areas.

These features can be gained at early age, so it is recommended that preschool STEM education include them.

The key recommendations are the following:

- Raise the profile and understanding of early childhood STEM education via advocacy.
- Renew pre-service STEM-related training and supports for early childhood teachers.
- Establish initiatives and resources which promote parents' involvement and engagement in their pre-school children's STEM education.
- Provide high-quality early STEM resources and implementation guidance available to practitioners for using in pre-school STEM education.

- Ensure that early pre-school learning and development objectives explicitly address the STEM subjects and align with K-12 objectives.
- Develop and support a research agenda that informs very effective resources and excellent practices in early childhood STEM education.
- Science centers might be great learning tools within STEM subjects. Pre-school children can be supported via STEM activities in science centers.
- Physicaeducational STEM activities can be planned for pre-school children.

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Chapter II

STEM Education Should Support and Encourage 21st Century Skills of Children and Sustainability and United National Goals

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Skills development begins in early childhood. Children in the early years are curious and excited learners. It is our responsibility as parents, educators, professors, and policymakers to create learning experiences and environments that tap into that natural curiosity and excitement. This includes not only supporting emerging skills in reading, math, science, and social studies, but also most importantly, the 21st century skills of critical thinking, collaboration, communication, creativity, technology literacy, and social-emotional development. Children need to begin to develop the early foundational skills that will help them reason, think creatively, analyze data, and work collaboratively in the future[1]. Because in the future they are expected to provide better solutions about the global challenges that society faces.

The main document which address the plan of action for future prosperity for people and planet is the 2030 Agenda for Sustainable Development adopted at the United Nations Sustainable Development Summit on September 25, 2015[2]. The Agenda consists of 17 distinct but interlocking Sustainable Development Goals (SDGs), which aim to "end poverty, protect the planet and ensure that all people enjoy peace and prosperity"– and they can be achieved only with the help of STEM[3]. For fulfilling UN ambitions of a sustainable future, we need to implement new educational approaches into practice.

Although there is no clear definition what STEM is, it is a new educational approach which looks at the child as the best resource that the humans have in order to achieve global sustainable development for future well-being. From providing energy and clean water, through improving healthcare, to fighting hunger, solutions to the world's most pressing problems lie in the hands of mechanical and chemical engineers, computer scientists and technologists – people with hearts set on making the world a better place and minds set on using STEM to do so[4].

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[1] 21st Century Learning for Early Childhood Guide
[2] United Nations Sustainable Development Summit.
[3] Lipscomb, E. (2018).
[4] Lipscomb, E. (2018).

Sustainable Development Goals[5]

1. No Poverty
2. Zero Hunger
3. Good Health and Well-Being
4. Quality Education
5. Gender Equality
6. Clean water & Sanitation
7. Affordable Clean Energy
8. Decent Work & Economic Growth
9. Industry, Innovation & Infrastructure
10. Reduced Inequalities
11. Sustainable cities & Communities
12. Responsible Consumption & Production
13. Climate Action
14. Life Under Water
15. Life On Land
16. Peace, Justice & Strong Institutions
17. Partnerships for the Goals

If children have their hearts set on making the world a better place, they should have their minds set on mastering STEM6. A good basic STEM education is vital for citizens to make informed, evidence-based decisions and fully participate in an increasingly technological world.

Trough STEM every single Sustainable Development goal can be addressed in the kindergarten. Even though these goals are too ambitious and require huge resources (time, human...), the fundamentals of solving problems could start at an early age where children learn to solve simple problems.7 For example, trying to reduce hunger by sharing food with other peers who don't have enough or plant seeds and look after them. To manage to do these things, kids should try to get to know how the food is produced, what healthy food is and what our role is in the process of preparation (SDG 2). We can only understand the real world through interdisciplinary approaches and helping the children to understand how disciplines are integrated and work together.

One billion people today live in poverty8, but as preschool teachers, we are important agents of this change. We already know that breaking the circle of poverty requires investment on the children from poor families. The best way to reduce poverty to zero can be through involving parents and their children in STEM activities as early as possible.9 And later to guaranteed that the child will actively participate in 21st skills developing activities with other peers.

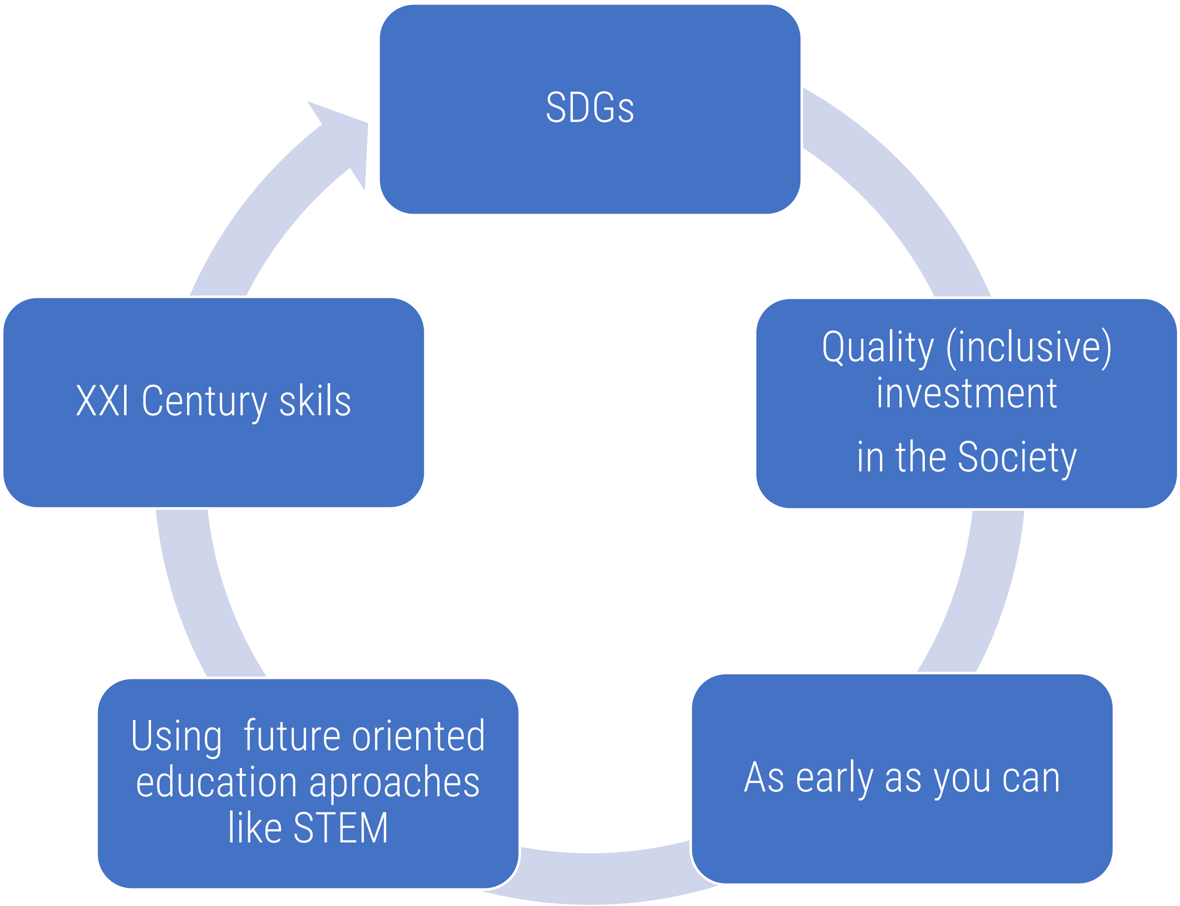
[5] United Nations. (2015).
[6] Lipscomb, E. (2018).
[7] Osman, A., Ladhani, S., Findlater, E & McKay, V. (2017).

[8] The World Bank: Understanding Poverty.
[9] United Nations – Numan Rights. (2018).

Collaboration through STEM makes children value themselves and others and that in itself promotes fairness and kindness. Play and interactions in early inclusive setting built the ability for sharing, self-regulate and sensitivity to others (SDG 1 and 4). STEM activities at this age shows diversity as a value, and helps everybody feel as part of a group, especially to girls and marginalized children to develop their potential in the future requires jobs. (SDG 5 and 10). Doing STEM activities allow children to learn about STEM careers in context and connect the skills they are using to the real world. STEM skills are also an ideal communication channel that enhances social engagement as well as sharing information and innovative ideas to overcome poverty and to promote peace and prosperity for all.

The communication is a key component of STEM education. By asking the right questions, we can help stimulate investigative thinking where children can identify objects, make comparisons, make predictions, test his/her ideas, and share what they have discovered with one another. Positive communication and problem-solving skills can be stimulated, by asking specific STEM approach questions, around problems like saving how to safe water and electricity, how to reduce the plastic pollution, how to prepare for emergency situation, how to reduce the garbage and keep the environment clean. (SDGs – 6, 7, 9, 10, 11, 13)10. STEM education is about preparing for what's next. Doing STEM, like design, build and test models, younger children are faced with personal, local issues, which help them gain both a deeper understanding of the global issues they care about and learn the engineering design process they can use to solve them.

[10] Osman, A., Ladhani, S., Findlater, E & McKay, V.



The SDGs need transformative way of thinking and living.[11] To be prepare for the future, we need to develop new strategies and action plans, how to transform or adapt out curriculum, our practices, the way that we teach and communicate with children. This is not an easy task, it requires a huge developmental jump in some communities – but all young children deserve a chance to develop creative thinking, problem-solving orientation, empathy to each other, communication and collaboration skills and equal chance to live in a better sustainable world.

The SDGs need transformative way of thinking and living.[12] To be prepare for the future, we need to develop new strategies and action plans, how to transform or adapt out curriculum, our practices, the way that we teach and communicate with children. This is not an easy task, it requires a huge developmental jump in some communities – but all young children deserve a chance to develop

[11] United Nations: The Sustainable Development Goals. Knowledge platform
[12] United Nations: The Sustainable Development Goals. Knowledge platform

creative thinking, problem-solving orientation, empathy to each other, communication and collaboration skills and equal chance to live in a better sustainable world.

The generation in their early years will have the opportunity to learn how to fight poverty, exclusion, war and any injustice - with the gentle guidance from the teacher. So that they may explore the world with wonder, play, ask questions and discover answers – that is the nature of STEM. The world more than ever needs critical thinkers, doers, and problem solvers. STEM education gives the child information to decide what he or she like to do, the ability to solve real problems in his/her community, to communicate and work with others that possess knowledge in field that is different than his/her own. At the same time world needs young people who understand science, who can adapt to the latest technology, and who can engineer new solutions to solve problems of all sizes. The investment in STEM early in life support the future generation to create the skills for wellness and well-being of the whole world!

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Chapter III

Development of Positive STEM Identity and STEM Self-efficacy in Early Childhood Years

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The growing disengagement in STEM starts in the early grades of elementary school. Although the STEM (Science, Technology, Engineering and Mathematics) subjects are exciting and connected to daily life, interest in STEM fields is declining in most of the European countries, but STEM fields are critical for European countries to sustain research and innovation-driven economies. STEM-related fields are careers in science, technology, engineering, and mathematics as well as medicine, biological engineering, material engineering, computer hardware engineering, biotechnology, polymer chemistry, genetics, and so on. These fields are reported to the required fields for countries to meet 21st century demands, to be able to compete with other growing, innovation-based economies. The glaring decline in students' interest in STEM fields, resulting in avoiding the pursuit of a career in STEM subjects have been reported in many studies (Potvin & Hasni, 2014).The results are alarming considering the shortage of efficient STEM-skilled professionals in Europe needed by 2025 (Dobson, 2014). Effective early years STEM education enhancing the development of interest, persistence, and competence in STEM is among the major efforts needed to provide qualified STEM professionals (Denissen, Zarrett, & Eccles, 2007). Therefore, being exposed to STEM through the early years of elementary education is vital for children to be able to develop interest in STEM and potential career aspirations (Mohr-Schroeder et al., 2014). STEM identity and STEM self-efficacy are among the key components to ensure ongoing interest and perseverance in STEM. The foundations of these two concepts are constructed through early childhood education experiences. Therefore, it is vital that early childhood education experiences help children construct positive STEM identity and STEM self -efficacy.

STEM Self-Identity

Self-Identity is a concept related to an individual's feeling of belonging to a certain societal group based on his/her interest and expertise. The self-identity concept is closely related to personal and societal factors. Based on these factors, children associate themselves with certain societal groups (e.g. certain job fields or tasks requiring special expertise. Based on this definition, STEM self-identity could be defined as sense of belonging which one feels towards to STEM-related communities (Aschbacher et al., 2010). Interest in STEM fields and association with role models in STEM areas are the factors which aid in the construction of positive STEM self-identity (Hazari et al., 2010). Having positive STEM identity is important because it has an impact on whether someone enrolls in STEM courses, uses and understands STEM ideas, and transfers this understanding to daily life or pursues a STEM career. Considering the importance of early years experiences with science in forming positive attitudes towards STEM subjects, shaping positive STEM identity in early childhood should be one of the main concerns of teachers.

Use of the following strategies would help early childhood teachers construct positive STEM identity among children:

- Use engineering activities nurturing exploration and observation of the world based on young children's interests
- Involve children in inquiry and design tasks including collaboration and sharing ideas
- Use problem-based, project-based strategies focusing on finding solutions to problems
- Use contextually relevant problems
- Help kids understand STEM careers correctly (e.g. what engineering is, what engineers do)
- Be alert to cultural stereotypes, such as presenting exemplary female role models in STEM fields

STEM Self-Efficacy

Self-efficacy has been defined as a person's sense of self regarding her/his capability of doing a task (Bandura, 1977). One's goals, persistence, efforts, learning, and success are closely related to self-efficacy (Ormrod, 2006). Four sources of knowledge have been proposed as affecting development of self-efficacy: enactive mastery experience, vicarious experience, verbal persuasion, and positive emotional tone. Mastery experience is undertaken where experimentation and successful behavior construct a strong sense of efficacy. It assumes the sense of success will improve with respect to completing a task. Therefore, the learning environments in which children engage in multiple tasks related to science, math, technology, and engineering, in which they have successful experiences doing so, would improve their sense of success related to these fields. Therefore, it is important to consider children's developmental level and design tasks in which they can succeed. Vicarious experience takes place when a person observes the success of peers serving as models, which might be in various forms. Verbal persuasion provides people the kind of feedback that makes them feel capable of doing a task. For children, especially at kindergarten level, their teachers are very significant for them, so it is very important for them to sense support and encouragement when they have doubts related to a task. For instance, teachers' statements such as "I know that might be a difficult idea to cope with, but I am sure you can do/understand this" could be beneficial for children to maintain their self-efficacy. Lastly, the emotional tone includes reducing the anxiety of students related to STEM tasks, such as encouraging them to attend fully to the task and a having positive attitude towards children's engagement with the task.

These four sources of knowledge have been attributed as key contributors to the development of self-efficacy beliefs (Bandura, 1977). If individuals feel capable of doing science and math, they will be more likely to maintain their interest and effort in STEM related tasks. Application of the self-efficacy theory (Bandura, 1977) in STEM self-efficacy could be defined as one's sense of capability related to STEM subjects. That is, if children believe that they are capable of succeeding in STEM subjects in which they feel confident, they will persevere with the complicated STEM tasks, put greater effort into the tasks, and show more resilience and better achievement. However, if they have low self-efficacy beliefs, they are more likely to avoid engaging in STEM tasks. Teachers could help children develop STEM self-efficacy by designing STEM activities in which they experience a source of self-efficacy beliefs, such as mastery experience, vicarious experience, verbal persuasion, and positive emotional tone:

- *STEM tasks with mastery experience:* hands-on engineering design activities, such as building rockets or robots.
- *STEM tasks with vicarious experience:* STEM activities with group work providing opportunities in which students can observe others' success in STEM fields, such as having female role-models in class to engage in activities with the students.
- *Verbal persuasion for STEM self-efficacy:* giving encouragement and feedback in a positive tone while students are engaging in STEM tasks (for instance, engage children fully in a task which reduces anxiety, provide extra explanations of tasks for those who have doubts related to doing the task, monitor success in each step of the task, and guide them during the task in which they need support).
    - Informing families about the importance of supporting their children in STEM fields (such as informing parents that their beliefs related to their children's success in STEM fields are closely related with children's success in STEM fields).
- *Emotional tone as a source of STEM self-efficacy:* reducing students' anxiety related to STEM tasks, such as encouraging them to attend fully to the task, having a positive and genuine attitude towards children's engagement with the task (using verbal encouragement, such as "Your design is great! How about considering these ideas? You did a great job! etc.).

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Chapter IV

STEM Education is More Than Just Doing Activities in Science, Math, Technology or Engineering

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The contemporary term STEM originated in the 1990s at the National Science Foundation (NSF) as an acronym for science, technology, engineering, and mathematics and has been used as a generic label for any event, policy, program, or practice that involves one or several of the STEM disciplines. For most, STEM means only science and mathematics, even though the products of technology and engineering have so greatly influenced everyday life. Some think that STEM is about engineering while others that STEM is a combination of two or three disciplines. However, we do not have a series of stratified earths, one of which is mathematical, another physical, another technological, etc. We live in a world where all sides are bound together; all studies grow out of relationships in our one great common world. Tackling global challenges like climate change, energy efficiency, and resource use call for interdisciplinary thinking and action. These challenges are clearly related to the STEM disciplines, as are competencies that citizens need in order to understand and address issues such as the 17 Sustainable Development Goals (United Nations, 2019). These goals, set by the United Nations General Assembly in 2015 for the year 2030, should be understood before addressing other disciplines such as economics and politics.

Advantage of using the 17 Sustainable Development Goals in STEM disciplines
• knowledge, attitudes, and skills for identifying questions and problems in life situations, explaining the natural and designed world, and drawing evidence-based conclusions about STEM-related issues; • understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design; • awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and • willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen (Bybee, 2013, 2018).

Advantage of using STEM literacy in STEM disciplines
Understanding the characteristic of STEM disciplines
Knowledge of the mathematical, natural and designed domains
Recognizing how STEM disciplines shapes our world
Acquiring STEM knowledge to identify STEM related issues
Values, meaningfulness and usefulness in relation to STEM domains

The focus on developing children's STEM literacy is an awareness of how and when they apply knowledge and practices from across STEM disciplines. The application of knowledge allows the children to develop even deeper understanding of STEM concepts and processes and how they are interrelated. For preschoolers, this entails that the children can be introduced to the scientific method, a systematic and logical approach used to answer a question or solve a problem. By asking the right questions, we can help stimulate investigations where students are identifying objects, making comparisons and predictions, testing ideas, and sharing discoveries, all while observing their natural environment. Children can also explore sizes, shapes, patterns, and quantities in the process. In this way, children can learn concepts from different disciplines in different contexts, all in ways that are naturally engaging to them. The challenge is appropriate to their age, grade, and developmental stage. As they explore options and gain an understanding of the problem, they must "reach out" to the respective STEM disciplines and apply knowledge and skills to the problem. We can only understand the real world through interdisciplinary approaches, and we need to educate children in how disciplines integrate and work together. The best way to foster STEM literacy is to encourage curiosity, to ask questions, to explore, and to play.

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Chapter V

Technology in Early Childhood STEM Education

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Technology is a comprehensive concept and people do not agree on a common definition of it. The word 'technology' is originate two Greek words techne and logia. Techne means art, craft and skill, and the logica means works, study, or body of knowledge (Spector, 2015). Saettler (1968) stated that in contrast to the common opinion, technology is not only the use of machines, but also the application of scientific knowledge for practical purposes. A broad definition of technology is anything that is human made that makes life easier (Stohlmann, Moore and Roehrig, 2012).

Technology is an essential component of any science, technology, engineering, and mathematics (STEM) activity. Bybee (2010) claims that a true STEM education should increase students' understanding of how things work and improve their use of technologies. The role of technology in integrated STEM education has emerged in two common categories in the related literature. Firstly, technology directly integrated and embedded into STEM activities. Secondly, technology used as a tool of facilitator to enrich STEM education (Akgun, 2013).

Technology in early childhood is widely misunderstood as using digital or electronic technology, such as computing and touch-screen tablets in a classroom (McClure et al., 2017; Sanders, 2009). This understanding about technology is distorting the intended meaning of the STEM education (Sanders, 2009). The focus of using technology (whether a printed book, a chalkboard, or a tablet) in STEM education should be on helping children gaining technology literacy or teaching them that technology is used to expand our knowledge beyond what our senses can tell us (McClure et al., 2017).

It is important to understand that technology is a tool – a means of more efficiently and effectively achieve the ultimate goal of improving child outcomes. Adapting technologies without thinking about their relationship with educational objectives will not results expected outcomes (Hernandez, Markovitz, Estrera, & Kelly, 2015). Successful integration of the technology into classroom could be achieved by using the technology strategically to achieve the academic goals and to encourage active learning among children and between children and teachers. Teachers should deeply engaged with the learning process when children use technology. They should scaffold difficult tasks and support learning by linking it to real-life experiences (Presser & Busey, 2016).

U.S. Department of Education has defined four guiding principles for use of technology with early learners. These principles are:

- Technology—when used appropriately—can be a tool for learning.
- Technology should be used to increase access to learning opportunities for all children.
- Technology may be used to strengthen relationships among parents, families, early educators, and young children.
- Technology is more effective for learning when adults and peers interact or co-view with young children (Lee, 2016, p.7).

Pasnik and Hupert, (2016) stated that technology can enhance early childhood STEM learning and teaching and it can be beneficial if it's used for:

- Providing models of real engagement for educators, parents, and children.
- Connecting educators to a STEM related community.
- Providing access to teacher training resources such as adaptable STEM activities.
- Accessing visual and auditory information that they may not be observable in the classroom.
- Promoting development of children's early science skills/practices.
- Engaging children in tasks that encourage children to share, collaborate and discuss like paired playing of digital games.
- Supporting the roles and responsibilities of parents.

Main Points of Appropriate Use of Technology in Early Childhood STEM Education

Technology should be considered as a tool for early childhood STEM education

Early Childhood STEM Working Group, (2017) states that "T" in STEM -technology- should be considered differently in early childhood STEM education. Technology should be considered an important tool that can support learning in the STEM discipline rather than a content area to be studied by young children. They recommends that using digital technologies with young children should start with learning how to use technology tools in the same way promoting book-handling skills in early literacy. The next step should be using technology as tools to explore the world and investigate about interesting things for children. Interaction with technology at this phase should focus on using technology for exploration, discovery, documentation, research, communication and collaboration. When children approach to school age, the next step should be learning about technology. In this stage, appropriate introductions to coding and computational thinking activities could be done with children.

Technology in STEM does not mean only high technologies.

"Technology in early childhood" is widely misunderstood as using digital or electronic technology, such as touch-screen tablets, in a classroom (McClure et al., 2017). However, technology can be an object, a system, or a process (Early Childhood STEM Working Group, 2017).

STEM education often requires numerous materials that can include construction tools (saws, measuring devices, hammers etc.), electronic materials (computers, design programs, robotics kits, calculators etc.) and other materials used in design (wood, styrofoam, glue, cardboard, paper etc.). Through the use of various materials, students can see that technology is not just electronics but can involve many different things (Stohlmann, Moore, & Roehrig, 2012).

For example, coding or computational thinking activities could be achieved by using different technologies. These activities can be conducted by using electronic technologies such as touch-screen tablets or robotics. However, coding activities could be achieved also by using paper and pencil. The aim should not be using high technology, it should be helping children gaining technology literacy.

Technology integration requires thoughtful planning

Digitals tools have some unique attributes can provide access to information that is otherwise hard to observe. For example, shadows shift according to sun position during a day could be observed by using digital camera and could be examined with fast-forwarding (Pasnik & Hupert, 2016). Using technological requires thoughtful integration. The first step in selecting an appropriate technology tool is to clarify the learning goal and ensure that the technology will address that goal and build on prior knowledge (Presser & Busey, 2016). Technology could make difference in young children's STEM learning but technology alone is not enough. Technology can never replace human interaction or quality teaching. Children, especially young ones, need caring and knowledgeable adults to help them navigate and learn about the world, and this includes the world of technology (Goldstein & Gropen, 2016; Pasnik & Hupert, 2016). Well-organized learning experiences with technology should be design and this experience should be within the children's zone of proximal development (Presser & Busey, 2016).

Encourage group work while using technology in the classroom

Related literature showed that device-to-child (one device per child) approach of using technology like touchscreen tablets is not the effective way of using technology in the classroom. Instead, these technologies are more effective when children use them in pairs or small groups

(Pasnik & Hupert, 2016). In addition to the content investigated, children have chance to learn to share, collaborate and discuss.

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Chapter VI

STEM Literacy is based on STEM Knowledge, Practices, Transversal Competences and Values

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Introducing STEM education in the early years is not an easy task. It requires rethinking the goal of Early Childhood STEM Education (ECSE) (OECD, 2012), that is, what outcome is pursued. The goal of ECSE must be the driving force shaping decisions on *what* ideas, practices and values of STEM education must be included.

The goal is STEM literacy. In the literature on STEM education, there have been various attempts to provide definitions of STEM literacy (Balka, 2011; Zollman, 2012). Based on these definitions, we propose that to be literate in STEM is:

To be able to identify and apply core ideas and the ways of thinking, doing, talking and feeling of Science, Engineering and Mathematics in a relevant integrated way, so that we can both understand, make decisions and/or act in front of complex problems and build creative solutions, using the necessary technologies in a collaborative way. (Couso, 2017)

When applied to early childhood education, this definition has certain implications that ECSE teachers should consider.

Content in STEM education is more than scientific, engineering or mathematical concepts.

One of the main problems faced when selecting, adapting or designing STEM activities for early childhood education is the lack of a clear vision and appropriate criteria regarding what content should be included. Today most STEM curricula refer to conceptual, procedural and epistemic knowledge. As a consequence, what it is important in an a STEM activity it is not the learning of concepts or ideas of the discipline (e.g. names of parts of a plant or the definition of a machine), but the practices used to construct them (e.g. detailed observation of real plants or testing of machinery) and the “rules of the game” applied in such practices (e.g. that observation, if scientific, must be systematic, or that engineering testing should be done under different conditions).

This extended view of STEM content that includes knowledge both of and about STEM does not aim to extend the generally overcrowded list of topics in most STEM curricula. On the contrary, to become literate in STEM, one needs to construct only a few core ideas (NRC, 2012). For instance, starting in early childhood education, there is consensus on the 10 scientific ideas necessary to be built during compulsory education (Harlen et al., 2010). An example is the core idea of the particle model of matter (Molecular-Kinetic Theory), which has the potential to explain the change of state or actual properties of a given material as well as its temperature or what happens when applying pressure. In an STEM activity for 6 years old children, the work on this core idea includes exploring the observable macroscopic properties of different materials, progressively experiencing qualitative properties (colour, stickiness, texture, etc.) and representing them in various forms (e.g. body movement, oral language, drawings).

The same applies to the processes and practices of STEM disciplines. It is not necessary for children to learn all the methods and techniques used in science, engineering or mathematics, but they should actively participate in the core practices of each of them. These core practices are the idiosyncratic ways of doing, thinking and talking in a discipline. For instance, scientific practices include asking researchable questions, planning and carrying out investigations, gathering and analysing data or constructing evidence-based explanations (NRC, 2012). These practices should become the core activities in which children are engaged when doing ECSE. An example is 5-year-olds involved in the scientific practice of using evidence to build explanations after doing purposeful observations of snails (Monteira & Jiménez-Aleixandre, 2016). In engineering, the practice of designing and constructing solutions can be promoted by, for instance, challenging children to build a catapult. In mathematics, children can develop the practice of solving numeracy problems by grouping themselves according to the number they portray (1, 2, 3 or 4).

Participation in STEM practices also includes the distinctive epistemic knowledge and value systems of each of the STEM disciplines. For instance, this includes the fact that scientific explanations have to be consistent with evidence; in engineering, the importance of choosing the optimal solution; or in mathematics, the need to verify the solution of problems or to value estimation when calculation is unattainable.

In summary, becoming literate in STEM means gaining the ability to construct core STEM ideas by participating in STEM practices in accordance with epistemic values. An example (Figure 1) would be the development of the STEM core idea of "classification of living and non-living things by observing and comparing (engaging in STEM practices) different objects that could be classified into living or non-living categories using available evidence (a STEM epistemic value).

Figure 1: Box with objects that trigger children's understanding of what is alive or not, including toys shaped like humans, fossils, rocks, leaves, wood, bones, a desert rose, minerals, water, a snail and sea shells, living insects, living worms, and seeds (CESIRE, 2019)

STEM education helps to develop transversal competences.

In addition to specific STEM competences, STEM literacy requires the development of a set of transversal competences. These competences, which are understood as a basic survival kit for citizens, include not only life skills such as autonomy or cross-cultural understanding, but also skills for thinking and continuous learning. As such, they refer to higher-order thinking skills, which are the top-level thinking strategies in which one can be engaged, such as argumentation. They also refer to the so-called "soft-skills", such as cooperation. The Partnership for 21st Century Skills (P21) proposes focusing on critical thinking, creativity, communication and collaboration as the most important skills to be learned in order to become a life-long learner.

Transversal competences have to be developed within the disciplines. This implies that educators do not need to design specific activities to develop creativity or critical thinking per se, but rather content-based activities, such as rich STEM exercises in which creativity and critical thinking are developed. This requires additional time and methodological resources for STEM education because the demand on children is higher (Pellegrino, Hilton, & Learning, 2012). To give an example, it does not require the same level effort to hear about the number of legs that different animals have as to observe the diversity of animals and arrive at the conclusion that some have six legs (i.e. insects), others four (i.e. mammals) and so on, or to use this knowledge to propose creative solutions to the open problem of "what animals entered Noah's boat if he sees 10 legs crossing".

STEM education is about values.

STEM activities reflect but also develop different sets of values in participants. STEM is usually associated with high-cost technologies (e.g.. commercial robots). These reinforce negative values such as irresponsible consumption, technocracy and elitism. However, STEM activities can be done with an environmentally friendly approach by using recycled materials and low cost technologies and sharing resources. It can also be done while either reinforcing gender stereotypes or including a gender equity perspective, for instance, in pursuing social impact by focusing on solving local problems. As such, positive values like sustainability, social justice and equity should be considered central to ECSE content.

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Chapter VII

The Importance of Being Aware of Potential Problems in Early Childhood STEM Education

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STEM reveals rich opportunities for children's development through the integration of knowledge from various fields and through the spillover of experience from the field of Science, Technology, Engineering and Mathematics. At the same time, some problems arise in the process of early STEM education. They could call into question the effectiveness of training and repel children from STEM from their early age.

1. Destruction of the unity of STEM

One of the problems is the destruction of the unity of STEM. Studies have shown that „some educators regard STEM as any of the individual STEM disciplines" (Moomaw, 2013, p. 1). This desrupts the overall picture that children receive of the world.

Children experience the world as a whole. Early childhood educational experiences should not force that whole into pieces. This would give children a better base for life, where the problems are not isolated and separated in individual areas, but in most cases they are complex. Knowing the interrelationships set in a phenomenon will prepare the child to find connections and relationships between things and to act multifunctionally.

2. Different interpretations of early STEM education

In some cases, early STEM education is associated with **distant and abstract topics for children**. Such an approach is not appropriate. STEM education should focus on materials, situations and experiences that are important and meaningful for young children (Moomaw, 2013).

Early STEM education does not require laboratories or large experiments. It is enough to follow the children's questions and to develop children's STEM conceptions based on life situations. At the same time, care must be taken not to repeat what children already know, because this would cause them to lose interest in STEM topics.

3. Teacher centered instruction is given priority

But the STEM idea is different, because "the teacher is more of a facilitator allowing students to be active learners making sense of the activities for themselves" (Anderson, 2002, p. VIII). Kindergarten should not become a school. This would distract children from the desire to make discoveries in STEM and become future researchers in the world.

When the themes and situations are related to the children's experience, to their life world, it is much easier for them to enter the task, they more skillfully discover the characteristics of a phenomenon, guided by their experiences and impressions of the world around them. Of great importance here is the teacher's ability to capture children's issues, to put them at the center of the study, and skillfully guide children to enrich their experience.

4. In some cases only worksheets and books are used to fill in and perform various math or science related tasks. In these cases,
5. it is believed that children will memorize new information and repeat what they have learned.

Parts of STEM are "understood to be learned most effectively by rote memorization, book-based, classroom settings" (McClure, 2017, p. 53). STEM has another role and provides other opportunities. "STEM education is most effective when a child is taught to think and act as a scientist, mathematician, inventor, or engineer" (Aaron & Valle, 2016, p. 3).

Putting the emphasis on memorizing "hollow knowledge" does not lead to understanding. Children cannot understand the phenomena and the existing relationships. STEM has another role and provides other opportunities. The main activities are focused on "curiosity and wonder, investigation / adventures, exploration / explorations, think time, dream time, hypothesis time (Bardige/Russel, 2014, p. 10). Inquiry should be a guiding force in STEM learning.

6. The assessment focuses only on the final product of the activity, without paying attention to the process.

This is seen as "hindrances to effective inquiry" (Jeanpierre, 2018, p. 155).

In STEM education, children should be discoverers, should think, analyze and clearly express their conceptions, step by step to discover the phenomena. The learning process is very important.

7. In many cases, emphasis is placed only on the fun side of STEM

without paying attention to the content side. This option also does not lead to efficiency in education as it does not provide enough opportunities to enrich the knowledge and the experience of the children.

STEM is a great opportunity to support children's development. “Adults model genuine, ongoing interest in the world, often asking questions about why and how. They help children define a problem they might solve, think about the goal, and encourage them to persist when design fail. They provoke, challenge, and extend children's curiosity, interest, and thinking. They expose children to memorable, sustained and relevant experiences, using carefully selected materials and phenomena that help children make sense of the world." (Early STEM..., 2017, p. 13)

8. The little time spent on STEM activities

This problem is highlighted in some studies (Aaron & Valle, 2016; Jeanpierre, 2018). The lack of sufficient time does not allow the content to be expanded, children to dive into the topic and conduct their own research through experiments and games. The time is also not enough to discuss and to answer children's questions.

9. The interpretation of the role of the teacher in the learning process.

On the one hand, emphasis is placed on teacher centered education, which is not very effective. Another extreme is that children do not need a teacher and need to explore the world on their own.

The teacher plays a significant role and builds the skeleton of STEM training. "This scaffold an experience, adults can provide assistance by giving, prompting, questioning, modeling, discussing, and telling. By observing what children are doing and then asking questions and working with them as they develop their own understanding of the world, adults can help them walk through increasingly complex ways of thinking." (National Center..., 2019) There must be a balance. „Scaffolding is a balance. If we don’t offer enough help, the child can struggle and become frustrated and give up. But if we offer too much help, the child is missing out on an opportunity to stretch his learning. And sometimes, it is best for a child to explore with no scaffolding at all. To find the “just right” spot, we have to pay attention to what the child is doing to decide how much support to offer.“ (National Center..., 2019)

10. Problems in training are often created by existing standards.

Sometimes early childhood educators are pressured to get children ready for school, ready to succeed in school, and ready to perform well on tests of academic skills (Katz, 2010). All of these goals and outcomes are often cited as the end product or outcomes of the curriculum "delivered" to young children. Lilian Katz (2010, p. 5) believes that "curriculum, cannot be delivered; it must be provided ".

Rather than "delivering" education, we are most likely **to help children by "providing" experiences** known to benefit young children (Katz 2010).

11. The attitude of society towards STEM can also be mentioned as a problem

Studies show that **many parents, even teachers, believe that STEM education is only suitable for gifted children** (Arnon & Hanuscin, 2018; McClure, 2017**) that it is more important for boys** who show greater talent than girls (McClure, 2017) **and that it is suitable for old children** (McClure, 2017). These adult attitudes about STEM can also be passed on to children.

These problems could affect the effectiveness of early STEM education. They can hinder the development of spontaneous interest that children develop towards these areas of knowledge and the realization of the necessary preparation of the children for life. These problems can be overcome by selecting appropriate teacher training activities for working with teachers and parents. This is one of the goals of the PARENTSTEM project.

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Chapter VIII

STEM Education is for Everyone and a Gender Equality Perspective has to be Included from the Early Years

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"The first years in human life are crucial for the development of essential competences, skills and learning dispositions that influence future education and employment prospects", says the invitation to the January 2019 European Union event, Tackling Inequalities in Early Years: Ensuring Harmonised Early Childhood Education and Care Systems. Following this statement, it cannot be underestimated how important early childhood experience is for the future of individuals, and how much inequality hinders the building of a satisfying career and the a society with equal opportunities for everyone.

In 2002 Meyers et al. and Magnuson et al. stated the importance of early childhood equality, as they are key requisites for a successful school career (Meyers et al., 2003, Magnuson et al., 2004). The authors reported long-term-studies which indicated the importance of early childhood education for mathematical and reading skills. Children who participated in kindergarten and early childhood programs had fewer school entrance problems. An even more interesting finding was that children from a disadvantaged background profited most from these programs.

More recently, EU policy showed a strong interest in an investment in children. The report on national policies in the EU and 7 other countries, "Investing in children: Breaking the cycle of disadvantage" (Frazer & Marlier, 2017), which followed the 2013 EU recommendations shows only small progress in bringing in a focus on children. The group behind the authors, the European Social Policy Network (ESPN), sees the major reason for slow development in fighting the risk of poverty and social exclusion (AROPE, 2019). They remark that in the last years the applications for funds to be invested in early childhood education and care did not rise significantly. This concerns wealth, but also education, gender, physical status and language abilities. Some of these aspects also concern race as a factor, which is not as severe in Europe as in other regions of the world; however, it may affect Roma and immigrants from Africa.

Another important reason for inequality is drawn from the correlation between household income and exclusion from good education. This is seen in many studies (e.g. EAPN, 2019). However, not only economic reasons are crucial; the lack of participation in educational opportunities derives also from a lack of family support for the children as well as the fact that the parents do not have experience with educational opportunities. This leads to a lack of knowledge about possible support mechanisms, a lack of support of young children at home, and a lack of experience in how to deal with problems which might occur in the daily life of children in childcare or pre-school institutions.

Another important topic is gender equality. The dominance of male role models in media (e.g. researchers, technicians, professors) has still not been completely overcome. The challenges faced in STEM fields themselves, like technical manipulation, argumentation on a more abstract, conceptual level, and dealing with material more than with human relations, is often more attractive for boys than for girls. Another fact is the dominance of women in childcare, as fathers are mostly absent in the first years. Fathers parenting is a demand but not very widespread. Furthermore, male pre-school teachers are rare, as they are in primary school education.

Early childhood education focuses – as any other level of education – the demand on integrating children into the group. This is difficult for many reasons, as children are individuals with their own personal background, history (even when it is comparably short), and family/cultural background. However, topics like these are not remarkable, and educators and childcare experts in early childhood education are used to overcoming these differences in their daily work. In the German city of Cologne, for example, the percentage of migrant children in all educational institutions is 50%. However, the participation of children from a migrant background in early childhood care or education is comparably low (see Figure 2). Only 20% of them are participating in these institutions, which play a crucial role in language and social integration. In East Germany, the percentage is higher, because in the former GDR childcare was well established. However, only 7% of the population there has a migration background.

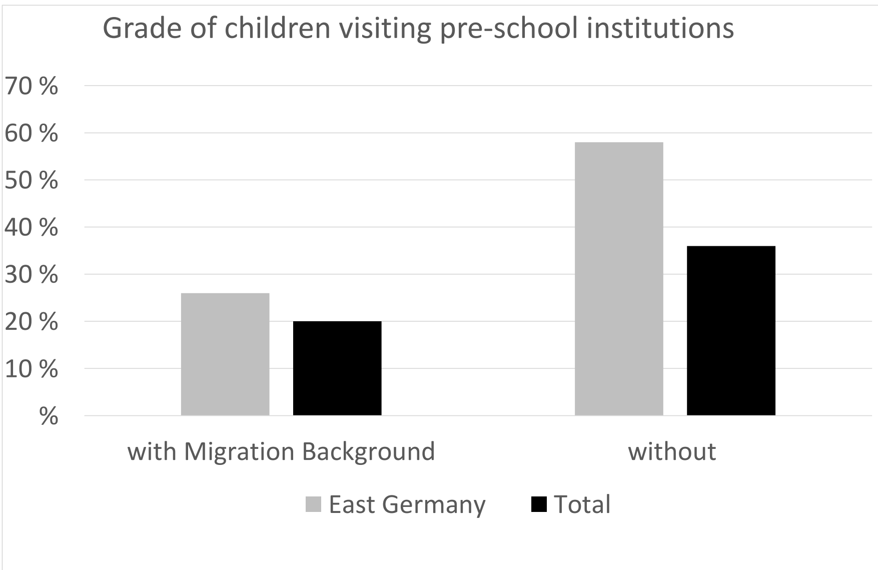

Figure 2: Rate (in percent) of children attending pre-school institutions (Kindergarten, pre-school, day-care) in Germany in 2017. Black bars show the percentage in East Germany, grey the percentage in the whole nation (Bertelsmann-Stiftung 2019).

This turns out to be problematic when these differences among children are a barrier to integrating all children and when these differences are due to a child's social, economic, or cultural background.

Reasons for disintegration are seen (Bertelsmann-Stiftung 2019):

- Values of the families
- Distance to the kindergarten
- Families' budget restrictions
- Religious concerns
- Lack of information
- Fear of alienation
- Disagreement and dissatisfaction with the quality of the education
- Disagreement with the sponsors of the kindergarten (e.g. if it is a church)
- The composition of the children's groups regarding languages and cultural backgrounds
- Lack of intercultural competencies of the staff

These facts are not only linked to the cultural background of migrant families; more important is the low educational status of the families (Lokhande, 2013). One option to minimize those barriers is the implementation of intercultural education for parents inside the pre-school institutions (Lokhande, 2014). This means that different cultures come together in social events, e.g. festivals throughout the year (summer break, Christmas, Ramadan, etc.). The festivals are celebrated as parties, inviting the other cultures to join in common meals, introducing cultural backgrounds and sharing common visions.

Having the above-mentioned statistical facts in mind, it is clear that reasonable ParentSTEM activities will search for alternative ways of teaching. First of all, it is necessary to be aware of all these restrictions and then to have a change in mindset on these aspects. Unequal economic and educational background will not be crucial to STEM educators, as every child can contribute in his or her own way. This must be accepted by educators.

These demands will be addressed by a set of activities. First of all, all programs developed by ParentSTEM will consider language challenges for non-native speakers. They will be illustrated and explained in simple language. Second, the involvement of parents will tackle the problem of their possible lack of experience. Third, the concerns of economic obstacles will be addressed by the use of simple materials like household equipment, reuse of household materials, and design of simple equipment, so-called low cost experiments (Poppe et al., 2010).

The gender equality topic will be addressed by focusing on three important strategies: 1. The focus of equal involvement of girls into research activities. Sometimes it might be helpful to separate boys and girls, so that girls´ tasks are not taken by boys. 2. The provision of female role models, when researchers or technicians are present. So, if the group visits technical companies, firefighting stations, or research institutions, guidance should be provided by women and not only by men. 3. The presence of fathers and male educators in the combined activities between children and parents.

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Chapter IX

STEM Activities should be Embedded in a Local Context

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These activities are for example in the neighbourhood of the children education institution. Is there a small forest to explore wilderness? Does a neighbour have a solar panel or a solar heating system? Is there a garden with local fruits and vegetables? Or an organic waste collection with rainworms, insects or other small creatures, which could be observed by lenses? Or is there a creek or a small pond which is easy to observed by the water data or the animals living close to it?

Effective STEM education

Effective STEM education is organized around the didactical topics of Inquiry Based Science Education (IBSE), context and relevance, and ownership. What does this mean?

The basis for an effective STEM education was laid by the paper: Science Education now, issued by the EU Directorate-General for Research, Science, Economy and Society already in 2007. Under the lead of the former French prime minister Rocard a group of experts recommended the IBSE method as the most rewarding method to teach Science. It explains and proves from many citations and observations the importance of this method, and justifies the change of Science classrooms to prepare children for a dramatically changed job world. They have to be the future decision makers, and these decisions have to involve scientifically and technically based issues, to which they should be prepared.

IBSE, Inquiry Based Science Education, starts with questions of the children's, and not with the curriculum fixing topics to every classroom at a certain time. These questions of course will not arise from topics, which are far away from the reality in which the children live. So they have to be with relevance for the children more than with relevance to the Sciences. And they have to be inside the context which is interesting for children.

It will be important in a second step try to find experimental ways to find answers to these questions. Of course also experts could be involved, however, the creating of evidence through scientific methods is more convincing. These methods will include investigation, lab work, research methods, observations (like microscopic work), art determination, etc.. Through the use of these scientific methods, data are created. These data are the own results of the children's work.

In a third step these data will be interpreted and finally discussed. This way of gaining data is an example for the way how scientists try to find solutions, and how they base their decisions on facts and not on opinions.

Beside this also the more practical, technical way of finding solutions is also possible. This way includes more try and error experiments, based on previous solutions for similar problems. This way includes workshops, in which the pupils can try to experiment with material, with hands-on activities, with tools and objects. Again: this leads to data, which are more experimental results, more observation, more experience than data from science experiments. And these data will then be used to formulate a solution.

Relevance and Context

STEM education will have to be linked to the everyday life of the learners. E.g. it is not important for pupils to discuss the price of petrol, even when they are brought by car or motorcycle to the kindergarten, because they did not drive cars or motorbikes. For children it is more important to deal with water, with living plants, with wood and with earth. Also, fire is a fascinating object.

And in addition to this, it is more adequate to work with household material than with lab-equipment. Sometimes it might foster the fasciation to visit a real lab, however, the work for children is better with everyday tools. Thus they can observe scientific facts in their everyday life and are able to link the “lab work” in the Kindergarten or pre-school with the household or garden at home.

Ownership

Nothing is learned, when it is not taken into the personal life. Thus, the experiments of STEM in early childhood should not only be relevant and linked to the context of children, but be also done by themselves. Only experiments with an individual or small-group hands-on activity are of importance for children, because they are actively involved. Listening or observing is possible, but should lead to individual hands-on work. And of course, the results should be able to be presented at the clip-board of the classroom or be able to transport home. This could be a photo, a self-drawn picture, a completed lab-book or a self-created tool.

Summary

The way STEM activities are described leads to basic insights into participation of everyone in a society, which is driven by Science and Technology. Pupils who know to raise questions, who know to be curious about getting data, who had learned to interpret and discus data in the solution process are prepared to be able to participate in social processes, which are around technical and scientific issues.

And in addition to this, they are prepared to emancipate from “given facts”. These so-called facts are often just opinions, traditions or ideologies. Once you learned to question them, you are not so easy to be influenced, manipulated or made anxious of prejudice. This emancipative power is immense, and it is one of the reasons, why sometimes the education system is kept in bad status, as emancipated children (and students) are not so easy to be ruled by state rulers.

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Chapter X

STEM Activities Should Be Planned and Implemented Between Teachers and the Community

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Advancing STEM from early childhood to tertiary education could be a long-term response to the myriad contemporary challenges we face. STEM is about an integrated curricular approach to studying the great challenges of our era like energy efficiency, resource use, environmental quality, and risks.

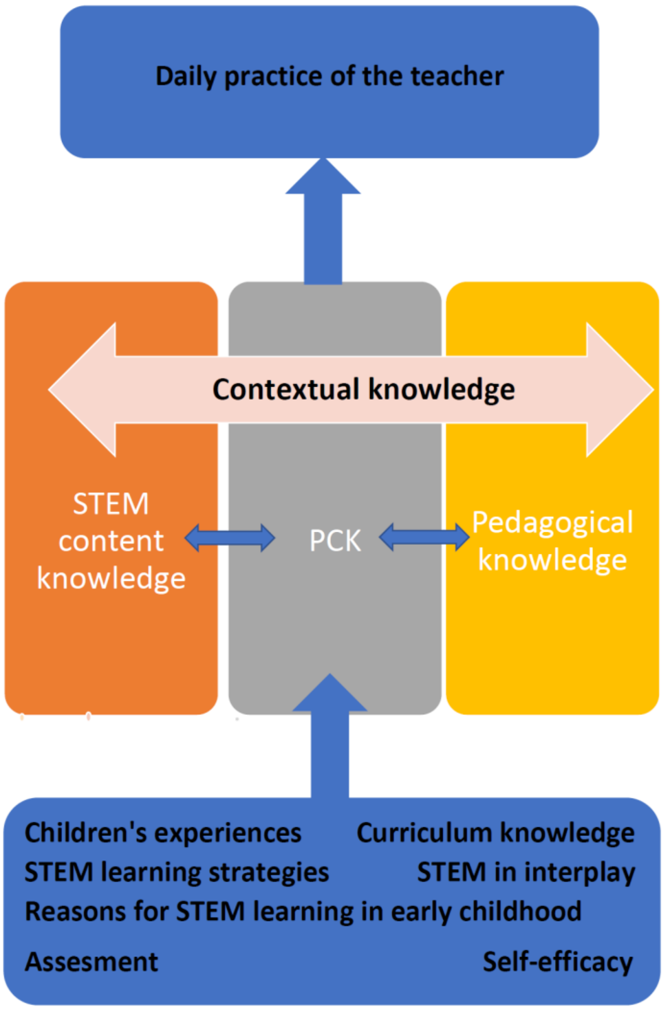
This calls for an approach to learning that emphasizes competency in addressing the situation, problem, or issue, and not exclusively knowledge of concepts and processes within the respective STEM disciplines. The STEM reform of early childhood learning should at a local level provide model STEM learning units and professional development and increase understanding and acceptance of STEM among key stakeholders like parents, teacher educators, policy makers, and administrators (Bybee, 2013, 2018). The STEM reform should create and support continuous learning opportunities for all kindergarten staff and promote collaboration among all staff and between staff and key stakeholders.

Critical to the success of an integrated STEM approach to early childhood learning are professional development and assuring that the complexity of the integrated STEM context is somewhat aligned with the early childhood teachers' knowledge of STEM. Therefore, teachers should have professional knowledge that relates positively with child outcomes. The concept of pedagogical content knowledge (Shulman, 1986) is a common contemporary point of reference for teacher qualifications and teacher education (Abell, 2007); a model for early childhood STEM teachers' pedagogical content knowledge is proposed and unfolded below with concrete examples.

The model describes various domains of knowledge that the competent teacher must have insight into in order to act appropriately in relation to teaching STEM. Overall, the model consists of three domains of knowledge that provide a framework for the early childhood teacher's daily practice in the kindergarten and cooperation with the community:

- Contextual knowledge
- Pedagogical knowledge
- STEM content knowledge

Contextual knowledge stands out because it will depend on the specific children and the specific institution's values. Knowledge of the individual child, relations between children, the close preschool context, and the local environment is a fundamental prerequisite for the other domains of knowledge to be brought into play in an appropriate manner. Knowledge of the close preschool context includes knowledge of subject areas, available material and apparatus, resources and preschool-based customs in relation to, for example, excursions, as well as the attitude toward professional development and cooperation with the community. Likewise, knowledge about children's cultures locally and globally, the education system and different social conditions from place to place is an essential part of contextual knowledge. Pedagogical knowledge refers to the teacher's professional and specialized knowledge in creating and facilitating effective learning environments for all children. STEM content knowledge is central to teaching STEM but is also knowledge that is central to "knowing" STEM. Subordinate to the three domains of knowledge, the model operates with six subdomains of teacher competences:



Children's experiences

- The teacher can involve and challenge children's experiences and everyday conceptions for starting up activities or as a starting point for STEM activities. This also includes the children's values.

Examples:

- Cars can be used as motivation and a starting point for activities that can develop concepts such as speed and friction.
- Living marine animals can be presented to students. In this way, the students can think about the marine environment and the physics of waves, water, etc.
- Paper airplanes: by making paper airplanes, the students can learn about buoyancy, speed, etc., and mathematics rules can be implemented to award scores for the paper airplanes' ability to fly.
- Tug-of-war competition: in this way, the students can have fun while working with physics and mathematics.
- Flags from different countries: here, the students can work with shapes on the flags.
- Water: a number of possible STEM subjects can be included, such as the chemistry of water, the importance of water in biology, waves (physics), etc.

Curriculum knowledge

- The teacher can implement specific curriculum themes into concrete STEM activities at all levels based on pedagogical reflection and the children's level of development.
- The teacher can evaluate and select learning materials and learning artifacts and apply them in multiple and alternative ways.

Example: The teacher plans and carries out concrete learning activities, e.g. making solar ovens out of pizza bins, with a curriculum theme about outdoor life as a starting point.

STEM learning strategies

- The teacher can reflexively and purposefully select and take as a starting point a specific learning strategy supporting the children's learning of STEM.

Example: The teacher plans and carries out an activity on soap bubbles, where the children set up hypotheses and carry out tests of the production of soap bubble water.

STEM in interplay

- The teacher can work in collaboration with colleagues and the surrounding community in planning learning activities involving multiple curriculum themes with a focus on STEM.
- The teacher can plan, organize, and carry out learning activities involving out-of-school environments and external persons.

Example: An activity about the theme of potatoes includes a visit to and activities in a neighboring retirement home.

Reasons for STEM learning in early childhood

- The teacher can work purposefully to increase the children's interest in STEM.
- The teacher can work purposefully to develop the children's ability, desire, and curiosity to work on inquiry-based STEM activities.

Example: The teacher plans and carries out frequent activities and events with a focus on STEM, e.g. a 'STEM Friday', where the 'Science Dog' visits the kindergarten every Friday and starts STEM activities.

Assessment

- The teacher can continuously and consistently evaluate the objectives and goals of the initiated STEM activities. This applies both to the children's learning process and the teacher's own work process.
- The teacher can continuously adjust activities and goals.
- The teacher is able to take previous science activities as a starting point and use experiences from previous STEM activities to create progression and improvement.
- The teacher can observe, identify, and document signs of learning in multiple ways.

Example: The teacher has planned an activity centered around the weather with a focus on the concepts of evaporation and condensation. It turns out that the concepts are too complex to the children's age or developmental stages. As a consequence, the teacher changes the concept terminology and uses the concepts steam, boil, and freeze.

Example: The teacher changes her/his way of documenting the children's learning from a focus on happy children to also including curious children.

Self-efficacy

- The teacher can take the lead in the planning of STEM learning activities, provide ideas, and perform actions.
- The teacher can justify choices based on professionalism and his/her own experiences.
- Example: The teacher learns about a STEM project or event, requests material, informs colleagues, comes up with suggestions for planning a learning activity, and takes the lead in the planning and implementation of the activity.

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Chapter XI

STEM Needs Active Participation of Teachers, Children and their Families in Dialogue

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Promoting STEM literacy in early childhood education should help children to develop an understanding of what we know and how we know it. The interaction between children, phenomena, and context is an essential element to achieve this objective, as seen in previous parts of the guidebook. However, there is a strong consensus in the literature that the mere interaction between children and their environment is not enough to facilitate the construction and refinement of children's ideas. Learning is considered a social practice because it occurs largely on a social plane (Vygotsky, 1978): interactions offer children the opportunity to develop their skills, imitating the actions of peers, teachers and/or parents, discussing the tasks that are carried out and making their own thought visible in a community… (Roschelle, Pea, Hoadley, Gordin, & Means, 2001). Thus, children cannot develop their full learning potential if they do not have the chance to interact with their peers, and especially with adults, when they are involved in STEM practices.

To take full advantage of children's learning, teachers and parents have to foster children's self-expression when they interact with the environment by:

- **Naming:** Children's verbalizations, labelling objects, materials, or situations with a name.
- **Describing:** Children characterizing their own actions or the qualities of an object or phenomenon.
- **Comparing:** Situations in which children can relate two (or more) materials or qualities (e.g. identify similarities and differences).
- **Classifying and sorting:** Grouping (objects, phenomena, etc.) according to similarities and differences among them (e.g. children are able to relate one element with a group of elements and not with another group). Arranging objects according to similarities or differences in an increasing/decreasing way (e.g. sorting 3 objects in which the medium object is at the same time larger than the small one and smaller than the large one).
- **Causality:** Establishing cause and effect relationships among changes.
- **Giving reasons:** Children give arguments based on previous items to justify their ideas in some way, that is, those cases in which the child simply gives an explanation about the question or the object.

There is strong evidence that the capacity of children to engage in some of the previous practices significantly increases in the company and interaction of adults (Pedreira Álvarez, 2016), which reinforces the relevance of interaction with adults in early childhood STEM education. To promote children's expression, teachers need to manage conversations to promote authentic dialogue, ask good questions, and interpret children's words or actions to understand how they think (Pedreira Álvarez, 2016).

Three privileged opportunities to promote children's knowledge by making their ideas explicit in STEM education

In the context of STEM education, there are three privileged opportunities to foster children's learning by promoting dialogue: exploring children's previous ideas, promoting the evolution and refinement of their ideas, and helping them structure their ideas.

Retrieving and exploring children's previous ideas

The initial moments of the activity are used to present a topic of study (e.g. a problematic situation, a particular phenomenon triggering children's curiosity, etc.). These initial moments represent a unique opportunity for teachers and parents to make explicit children's initial ideas or experiences about the presented situation (e.g. *What do you remember about…? When have you seen…? What do you think it will happen when…?*). Children's previous ideas or experiences will condition how they will further interact with the presented situation, so it is important for the teacher to know them at the beginning in order to provide subsequent appropriate feedback and guide children in their learning path. In other words, retrieving children's previous ideas activates their previous knowledge and facilitates connections with the new ideas formed in subsequent activities.

Depending on the children's age, the exploration of children's previous ideas using language may present a challenge for teachers. Communication between the teacher and the children should also consider different forms, such as the use of body language (actions, gestures, looks, and sounds). In addition, depending on the design of the activity (i.e. in free learning and play environments) retrieving children's previous ideas at the beginning may be difficult. It is important to spend some time before children start to interact with the materials to ask them what they think they will find, what previous experiences they have, etc. By doing this exercise, we are providing the lenses with which we would like children to interpret the subsequent experiences.

Promoting the evolution and refinement of children's ideas

To facilitate the construction and refinement of children's ideas from their experience with a different phenomenon and/or context, teachers need to know not only the targeted STEM ideas which can be constructed from children's interactions with the chosen situations or objects but also foresee other possible different ideas or conflicts which may appear during the activity. This previous planning is useful to prepare additional resources which can be used, if needed. However, it also opens a broad scenario of multiple possibilities, which makes it impossible to set in advance one only way to promote the evolution of children's ideas in an activity. In conclusion, the adult needs to be aware and identify the opportunities to interact and provide feedback to children to help them refine their ideas. For this purpose, three main strategies can be useful, as described by Pedreira Álvarez (2016) and Garrido Espeja (2016): contrasting children's ideas, providing new evidence that can point to contradictions and suggesting new possible actions or interpretations.

Contrasting children's ideas

Teachers use other children's ideas to provoke children's reconsideration of their own own ideas and positioning towards it (e.g. *S/he said that this ball will fall faster; what do you think?*).

Contrasting ideas can be carried out in an open way, where all children's different points of view are equally considered and there is no attempt to change children's views (e.g. Brainstorming), but also they can be directed, that is, emphasizing which children's ideas better help to reach the learning goals (e.g. *OK, let's focus on what Carles is saying…*) (Scott, Mortimer, & Aguiar, 2005). Since open discussions can be useful in the first stages of learning sequences, as the activity goes on, children need to structure their ideas in a consensual and shared final model (Couso & Garrido, 2016), so more closed dialogues are needed.

Providing new evidence that can point to contradictions

Teachers can help children to find new evidence in the phenomenon or problem of study which can stimulate children's contradictions with their previous ideas (e.g. *Have you noticed that… Yes, but if I do this, I get another result…*). Another example is to alternate the presentation of the elements or materials already classified in separate containers with the presentation of mixed elements or materials or to introduce discordant elements in a previously made series, as described in Pedreira Álvarez (2016).

Suggesting new possible actions, or interpretations

Sometimes, it is not enough to pose questions to children if teachers want to change their ideas, but new information needs to be introduced. Introducing new possible actions or interpretations does not mean an imposition of new ideas but suggests new ways to look to help children take a step forward. The suggestion of new possibilities can be done directly (e.g. *Didn't you consider doing this…?*) or indirectly (e.g. *Let's look at this book to see if we can get more inspiration*).

Helping children structure their own ideas

After children's experience with the phenomenon, it is helpful to devote a final part of the lesson to sharing what they have learnt from it (e.g. What did you see when…? What have we learnt?) in order to reach a consensus towards these constructed ideas (e.g. So now we can say that…). Ideally, these final agreed-upon ideas would be very close to the desired STEM key ideas set by the teacher, at the beginning. Moreover, structuring children's ideas should help answer their initial questions and compare their initial STEM ideas with later ones (Monteira & Jiménez-Aleixandre, 2016).

Structuring children's ideas can be done orally in a circle, where teachers can highlight the questions and ideas constructed in the activity, but also as individual work, asking children to represent the ideas from the activity with pictures and annotations, for example (Pedreira Álvarez, 2016).

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Chapter XII

Supporting Home Environments for STEM

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> If attitudes are formed already at early stages of life, and if they indeed have significant influence on the child's future development, educators ought to build environments in which students will enjoy science and have positive experiences.
>
> (Eshach & Fried, 2005)

As several authors have reflected (Osborne & Dillon, 2008; Sanmartí & Marchán, 2015) it is necessary to have a didactic model that could offer a closer and more exciting approach to the sciences from the very early ages and that, at the same time, could contribute to children's learning processes. In her book Principles and Big Ideas of Science Education Wynne Harlen (2010) reminds readers that schools should promote and keep open the curiosity of the "world learners" that children are, and should promote the joy involved in making scientific discoveries. In fact, just by looking at the faces of children, it is possible to recognize the interest and wonder that, for them, is the free exploration of reality.

To achieve the goal that children experience science in a joyful way does not require big expenditure of money or high-tech equipment because the natural phenomena surrounding them already fascinates them and invites them to observe and explore.

How can the STEAM perspective be promoted within family settings?

The immediate family environment, in itself, can be also a rich context of STEAM experiences in which the whole family can engage. Many possibilities can be considered, such as:

Exploring the environment
The forest, the beach, the meadows or the animals are stimulating contexts in (and about) which it is possible to find many fascinating things and which can be experienced with joy. The best science space experienced as a free-choice site is, without doubt, nature, which offers valuable

materials for exploration and discovery. Some suggestions are: allow children to pick up some different materials from the natural area that you visit to do collections; ask children to gather some rocks and compare the similarities, differences, weight, endurance; bring some plastic bags and ask children to collect different types of natural samples for later observations: leaves, types of soil, etc. In fact, mountains and forests are also a good opportunity for quiet observation and comparison using the different senses: can you sense this smell while closing your eyes? Can we touch the wet soil after the rain? What do you feel? Does the soil colour your hands if it is wet? Do you think that we can collect some things here to paint on paper when we are back home? Can we try to paint using this plant? Or this rock? Or this flower? Or maybe we can paint when transforming these materials?

Share experiences in everyday situations

Typical adult activities can be shared with children. Washing up dishes can lead us to question if we can make a plate float or sink, or if we can make bigger bubbles, or if warm and cold water have the same effect; also, collaborating in cooking recipes promotes the possibility for observing what changes occur with each new ingredient and even allows for discovering the effect that a temperature increase has upon the dough; assemble or disassemble devices or other objects, take care of plants, etc.

Take advantage of natural activities for children

Children really enjoy making balls with sand or earth. We can ask the children open questions such as: do you think any type of earth allows you to make a big/hard ball? Can you try with these other types of sand/soil? Was the amount of water important to make the ball? Can you try now with different/more/less amounts of water? What will happen to the ball over time, after one hour/day/week? Or another example: children often play with paper airplanes. Adult can ask: does size matter to make it fly? Does shape matter? Does the type of paper matter? It is easy to change the game into a variable control experiment with adult help. After a family meal, boys and girls usually collect all sorts of liquid or solid leftovers and mix them. What if we propose dying water different colours with natural materials (without using dyes nor paint)? Can we create all colours? Can we make gradations of the same colour? What happens to the mixture after a while?

Take advantage of children's curiosity and questions

Not so much to provide answers to them but rather to open new possibilities for intervention around the phenomenon to approach it in different ways, thus allowing children to better understand it. For example, use questions such as: how is it possible that...? What do you think if...? How about we try and see if...?

Such an approach should not involve solving the problems for the children or making them memorise different sorts of information (nor providing them with all the possible ready-made answers). It should rather involve accompanying them along this journey of discovery of the world, through mediation, facilitating materials, and promoting open dialogue between adults, children, and reality.

How to create a free-choice science space for children

Due to our expertise in creating science spaces designed for children, we propose the children's free choice space Lab 0_6: Discovery, Research and Documentation Centre for Science Education in Early Childhood as an example to provide inspiration to educators and parents on how to design these kinds of science environments que stimulating proposals/experiments for children where they can do science in a free-choice environment with some alternative types of actions and materials available for them to explore, experiment, make mistakes, and get interested in new phenomena and causal interactions.

The Lab 0_6 is a free-choice space, which means that children can choose, following their own criteria, where they want to go, with whom they want to go, and how long they want to stay in each place. The only restriction is that they cannot do anything which could hurt others or themselves or spoil the materials. The children enter into a space full of attractive materials with which they can freely decide what to do. As a result, they experience the space, the materials, and proposals in a playful way. The fact that children experience their enquiries playfully is interesting because it is through play that they naturally relate to their world. The adults in charge, however, are the persons endowed with the responsibility of ensuring that this play has a learning outcome rather than explaining and naming things for children.

Source: Lab 0-6

By developing similar spaces, educators and parents can promote children's autonomy by offering them new opportunities for learning through natural materials and through carefully chosen selected tools that they can handle. In this way, children are able to explore new properties and causal interactions. It is important, however, to allow children to have time to investigate and to choose tools to try new things and even make mistakes when trying new actions.

Criteria for selecting the proposals/play material

To make sure that learning value of the proposals/materials is reached, the following criteria are used to elaborate the different proposals. We suggest taking into account similar criteria (or some of them) when working within family settings to promote children's inquiry processes:

- Although it seems obvious, the educators in the space have to make sure that all the proposals in the Lab 0_6 should be related to science in general, and thus, should work as STEAM proposals. Translating this into a family environment, we would suggest that it is important that parents (or the family members involved) have, at least, some basic notions about what the children could discover or explore (or manipulate) but in a way of not making such objectives too easy or telling the children how to act because this would limit the children's autonomous initiative.

- All the proposals are created from, and as a result of, specifically observing children from 0 to 6 years of age, rather than being mere adaptations made by science experts for youth and adults and then adapted for children.
- The proposals are presented in a way that they should not require (or should only require very few) previous explanations by the adults. This is because if they require many explanations, this would only add difficulties to the children's autonomous actions and their need of a length of time before using the proposals and materials. The point of departure of the proposals is the children's capacity to give sense to what they can see by themselves and that they have enough time to think, try, and observe (and make mistakes to try again and again) to discover new possibilities.
- All the proposals have a clear and well-defined learning intention, yet they are also open enough to allow children new initiatives, thus offering new, unexpected things to happen. It is, thus, recommended to provide children with open-ended materials to allow them to engage autonomously in discovering the properties and causal effects with these materials without the constant guidance of adults.

Analysis of a specific example can aid in better understanding the criteria above:

Source: Lab 0-6

When engaged with a specific science proposal constituted by some slopes, a supporting structure, and small cars, such as the one shown in the image, no child needs an explanation of how to use them. In fact, the proposal is a response to a common children's game, that of allowing an object to fall down an inclined slope. This doesn't mean that they can only use it in the ways adults have intended, but it is obvious that there is no need to wait for an adult's explanation to use it.

On the right side of the tower that supports the ramps, there are three of these ramps of exactly the same size, which can be positioned at 3 different heights. It is clear that the adult's intention is that, while the children play, they can also become aware that the inclination of the ramp is a relevant factor in the speed at which the object descends from an inclined plane. On the other side of the supporting structure, the 3 slopes, although being equal in size, have 3 different textured surfaces. The adult's intention is to make children become aware (through play) that different forms of friction affect the speed of the object descending from the ramp.

The example with the car activity shows that when organizing children's play with carefully selected material (neutral, taking into account variables such as size, shape, form, etc. that would avoid distractions) and allowing children time for play, this can lead them to raise new observations, new interactions, new causal factors, or new surprising situations and engage them in informal inquiry while playing.

Furthermore, adults should not be obsessed with the idea that the children ought to end up repeating the concept that acar goes faster on a more inclined slope. This is because providing direct experience with this phenomenon is in itself sufficient. The tendency of adults is to explain, to solve, and to transfer information, and this must be changed to listening, giving time, and encouraging the children's initiative.

The study of movement that this proposal suggests is clearly related to science inquiries. To add to this a way of measuring the distance that the cars reach (for example, by marking the distances with lines of different colours) would also address mathematics. If we introduce programmed robots and test how the inclination of the slopes affects the distance that the robots travel when moving upwards on the slope, then we would engage the children in technological activities. It is clearly a STEAM proposal.

What moves scientists and researchers in general is passion. Doing science with children must also be exciting for adults. Only passion can ignite passion.

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Chapter XIII

Parent Involvement in Early Childhood Education STEM Education

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Parents' involvement in children's education is one of the hot topics in education research since it is consistently found to be positively related with children's higher academic success (Patrikakou, 1997; Reynolds & Clements, 2005; Seefeldt, Denton, Galper, & Younoszai, 1998), better cognitive competence, better problem-solving skills, and school attendance and negatively related with behavioural problems in schools (Melhuish et al., 2001). Moreover, parent involvement has been found to be the most important contributor for academic socialization in the primary and secondary school years (Fan & Chen, 2001; Feinstein & Symons, 1999). Higher and positive parent involvement is needed since in the early years, children spend most of their time in the home and at school. Today, it is clearly known that for healthy child development these two major environments need to have a strong partnership (Davies-Kean & Eccles, 2005). Research has also supported this claim. According to Bus, Van Ijzendoom, and Pellegrini (1995) parent involvement in children's reading activities in early childhood is the most important determinant of language and academic socialization. A similar effect was also observed in the areas of math (Berkowitz et al., 2015; Sheldon & Epstein, 2005) and science (Fleer & Rillero, 2008; George & Kaplan, 1998; Smith & Hausafus, 1998; Talton & Simpson, 1986). It is also known that this influence is long-lasting (Baker & Scher, 2002; Mullis, Mullis, Comille, Ritchson, & Sullender, 2004). For example, Feinstein and Symons (1999) found that parental interest in their child's education in early years was the single most powerful predictor of achievement at age sixteen. In the light of theory and research results, the importance of parents' involvement in children's' education and academic success is accepted without question. STEM is another ares that is positively influenced by parents' higher involvement beginning from early childhood years. The underlying reason for this is the fact that parents are highly influential on their children's STEM self-efficacy and STEM interests. The following section presents the underlying reasons for this. Technology is an essential component of any science, technology, engineering, and mathematics (STEM) activity. Bybee (2010) claims that a true STEM education should increase students' understanding of how things work and improve their use of technologies. The role of technology in integrated STEM education has emerged in two common categories in the related literature. Firstly, technology directly integrated and embedded into STEM activities. Secondly, technology used as a tool of facilitator to enrich STEM education (Akgun, 2013).

Parent involvement enhances children's stem self-efficacy.

Today we know that self-efficacy, i.e. the belief that I can do this, develops in early years, since in those critical years an individual encounters dozens of obstacles and must overcome them. In the development of self-efficacy family has a vital role. This is because the family environment is the first environment where the child experiences many successes and failures, and how family members comment on this failure or success is gradually embedded in ones self-evaluation and self-belief system (Hoskovcova, 2013).

There are four important factors influencing self-efficacy on a task: (1) prior experiences of mastering tasks, (2) watching others mastering tasks, (3) messages or "persuasion" from others, and (4) emotions related to stress and discomfort. Parents have an influence on almost all these factors. With the exception of the last factor, all other factors can be shaped by adults surrounding the children. According to one study, in families where parents accentuate the importance and the value of STEM areas and bolster children's STEM experiences and efforts, children develop higher STEM self-efficacy (Nugent et al., 2015) On the contrary, when parents have some misbeliefs about STEM, those misbeliefs will be possibly transferred to their own children in early years (Mcclure et al, 2017). These can be beliefs like: STEM is for older children; formal schooling is the only way to teach about STEM; or boys are better at STEM than girls. Previous research revealed that self-efficacy can be enhanced when parents and teachers collaboratively emphasize the importance and value of STEM skills (Bandura, Barbaranelli, Caprara, & Postorelli, 2001; Zeldin & Pajares, 2000).

According to the report prepared by McClure et al. (2017, p.5), despite parents' wish to support their children in STEM areas, they "experience anxiety, low self-confidence, and gendered assumptions about STEM topics, which can transfer to their children and students.". In the report, it was mentioned that when STEM is presented to parents as developmentally appropriate, playful learning opportunities such as "block play, gardening and exploring puzzles", parents' and children's curiosity and wonder will be increased (p. 5).

Parent involvement encourages and supports children's stem interest.

Every child functions as a little scientist from birth; he/she wonders why and how things happen as they do and is highly motivated to find answers. That is, they have an intrinsic interest to understand the world around them. Namely, each child is born with an intrinsic interest to learn each aspect of STEM. The main issue here is how this interest is guided by adults that the child interacts with. Is it encouraged through providing opportunities that feed this interest or is it discouraged via negative messages? According to Nugent et al. (2015), even for middle-school aged children, parents and teachers are the strongest contributors for their STEM interests. Therefore, an effective partnership between the school and parents and an attentively planned parent involvement program might encourage parents to support children's intrinsic interests in STEM in the early years.

Research studies have consistently confirmed that parents are in a pivotal position and have an important role to generate interest in STEM. When the education system provides opportunities for parents to share their children's science learning in and outside of the home, parents and children benefit from this process, which increases both the level of their interest in STEM and the joy they experience during STEM activities.

STEM self-efficacy and interest are in mutual relationship, and parent involvement influence both positively.

Some researchers claim that self-efficacy is one of the main factors increasing one's interest in a topic (Fouad & Smith, 1996; Lent et al., 1994), but it has been also claimed that having an interest in a topic encourages individuals to interact more with the task, which results in higher task-related self-efficacy (Nauta, Kahn, Angell, & Cantarelli, 2002; Tracey, 2002). As indicated, parent involvement influences both positively. Using this positive impact from the beginning of life in the early years and in early childhood education will have power to increase the number of individuals interested, motivated, and feeling confident in STEM. Preschools should be aware of this power and guide parents effectively. In the following section, ways of involving parents in the general education process and particularly in STEM education are presented.

Parent involvement has different types and not restricted to parent teacher communication and meeting or parents' in-class participation.

From early childhood education to high school education, parent involvement is one of the most important and valuable issues for a quality education. It is possible to find different definitions for parent involvement in the literature. Initially, parent involvement was defined as activities which are school-based such as participating in parent-teacher meetings, field-trips organized by the school, and in-class activities at the children's school (Mattingly et al., 2002; Stevenson & Baker, 1987). However, today it is accepted that parents' involvement in children's education refers not only to school-based involvement; rather, it consists of parents' participation in home-based and out-of-school activities as well as effective school-family communication and parents' participation in school-related decision making processes.

Among very different definitions (Epstein, 2001; Hoover-Dempsey, Walker, & Sandler, 2005; Swap, 1993), the model proposed by Joyce Epstein (2001), which presents six different parent involvement types, is the most common definition used in the literature. Six involvement types for parents are: (1) parenting, (2) communicating, (3) volunteering, (4) learning at home, (5) decision-making, (6) collaborating with the community. In the next section, the definitions of these different parent involvement types and examples of how to use these parent involvement types during STEM education are given.

Six Types of Parent Involvement

Level 1-Parenting:

This is the first level of parent involvement, which refers to parents' efforts to provide a supportive environment for their children's' development.

Level 2-Communicating:

At this second level, parents communicate with their child's teacher and school about the child's educational progress and school programs.

Level 3- Volunteering:

At this level, parents are expected to be involved as volunteers in activities suggested by teachers or schools.

Level 4- Learning at home:

At this level, parents are expected to participate their children's academic learning at home.

Level 5- Decision-making:

At this level, a well-established partnership between the school and parents is required for success.

Level 6- Collaborating with the community:

At this level, the teacher and school try to link the community resources and parents with each other.

Examples of how to use the six parent involvement types during STEM education:

Level 1-Parenting:

- Providing information and suggestions for home conditions that support STEM learning
- Providing workshops, videos, or phone messages on home-based STEM learning
- Providing STEM-learning activities for parents (STEM courses, parent STEM-education programmes)

Level 2-Communicating:

- Providing program policies regarding STEM learning and teaching
- Providing information on the child's interests, ability, or improvement in STEM areas
- Using bulletins, information sheets, or school board to enlarge parents' awareness of the importance of STEM and the importance of their involvement in STEM learning

Level 3- Volunteering:

- Asking parents to come to the class and participate STEM activities
- Collecting information on parents' STEM strengths and involving those strengths in the STEM teaching process
- Inviting parents to help the teacher for STEM-related field trips

Level 4- Learning at home:

- Providing information for parents about skills in early STEM learning
- Providing information on ways to support STEM learning at home through daily activities
- Providing step-by-step information on how to engage in specifically structured STEM activities
- Sending science kits home which require shared parent-child effort

Level 5- Decision-making:

- Providing opportunities for parents to be involved in determining school-based STEM policies
- Encouraging parents to establish a parent STEM organization which will function as a PTA

Level 6- Collaborating with the community:

- Providing information to families about community activities on STEM
- Strengthening the link between parents and NGOs that work for children's STEM learning
- Providing information on how to use neighborhood facilities such as museums, science fairs, and science centers to support children's STEM engagement.

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Chapter XIV

Assessment of Children

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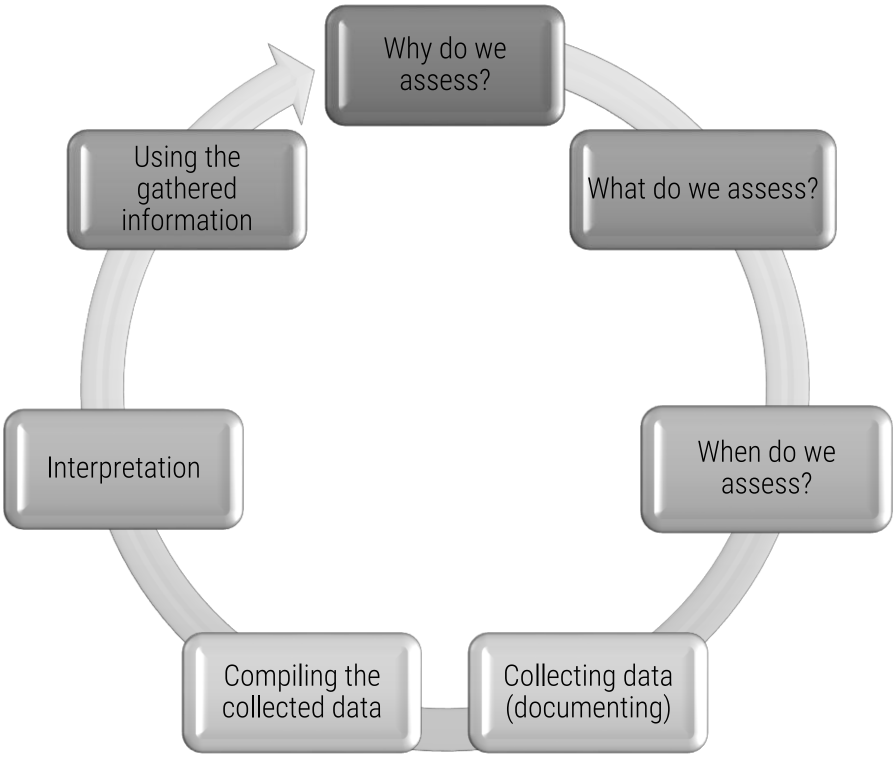
In this part of the guidebook, issues such as what assessment in early childhood education is and what kind of assessment tools can be used will be covered. This reflection was prepared under five main topics: What is assessment in early childhood education? principles of assessment in early childhood education, types of assessment procedures, interpretation of the data obtained from assessment, and working with families through the assessment process.

What is assessment in early childhood education?

Assessment in early childhood education is an important component for educating young children in a reliable, healthy, and high-quality environment (Snow, 2008). There are many definitions of assessment, but, essentially, all of these definitions address the need to collect necessary information on children's development and learning and to decide on their educational needs. Assessment plays an important role in supporting children's development and learning through early childhood education. With the help of assessment, we can understand children's interests and skills and discover their strengths and weaknesses, and by this way, we can design the most effective educational program for them (Nah & Kwak, 2011; Wortham, 2008; McAfee & Leong, 2007).

The cycle shown below represents the purpose of assessment, including why, what, and how we assess. Using this cycle helps us to determine the child's individual development, progress, and changes in a certain time period.



Reference: McAfee and Leong (2012), p.30

Principles of assessment in early childhood education

When assessing children, teachers should act in accordance with their intended purpose and consider some important points. These points can be listed as follows:

- Developmentally appropriate assessment methods should be chosen,
- As a process, assessment should be done continuously,
- Assessment process should be culturally appropriate to the environment in which the child lives,
- The data gathered through assessment should be valid and reliable,
- Assessment should give information about children's needs and interests,
- Data should be obtained through multiple assessment tools,
- Gathered data should be used for the benefit of children,

The assessment process should include both the child and his/her family (Snow, 2011;Wortham, 2008)

Types of assessment methods

Early childhood teachers should use multiple methods to gather information about children (McAfee & Leong, 2012). In this way, teachers will obtain comprehensive knowledge about different developmental areas and can make strong interpretations.

Observation

Observation is the most valid and natural way to collect information about children's development and learning in early childhood education. Informal observation and systematic observation are two main types of observation. During informal observation, teachers observe group or individual behaviors without any plans; on the other hand, systematic observation is planned, purposeful, and has specific goals (Wortham, 2008). There are some important points for conducting a high-quality and meaningful observation. These are:

- The observer should be objective,
- The purpose and focus of the observation should be determined,
- The observer should focus on both verbal and non-verbal behaviors,
- The focus of the observations should not be only on the children's products, but also on the development and learning process,
- While observation, information about the children, environment, and time should also be recorded with the observed situation.
- While observation, behaviors should be recorded rather than comments, which should be made after the observation,
- If the data obtained from the observations will be used to make important decisions, similar observations should be repeated,
- Observations should be recorded with different recording tools depending on the purpose (McAfee & Leong, 2012).

Because it is a direct and current way to collect data about children's development, early childhood educators should use multiple methods to gather information about children (McAfee & Leong, 2007).

Observation Recording Tools

Descriptive Recording: These are recordings noted as a story while observing children's development and learning levels in their learning environment. Scribbles are records that are written immediately in a shortened way. When the observation is written in a more detailed way, as a paragraph, and represents *what happened, when, and where* (Wortham, 2008), this is called an anecdotal record. Like anecdotal records, a running record is a more detailed narrative of children's behavior and includes *the sequence of events* and everything that occurred at a specific time period (Wortham, 2008). Another tool, event sampling, is used to determine *how often* a specific event or behavior occurs in a particular setting (Buldu, 2010).

Calculations needed recording tools:

Checklists: This is an observation tool that uses pre-determined learning and developmental targets (McAfee & Leong, 2007; Wortham, 2008). Using determined performance criteria, a checklist includes a system that has two options about targeted criteria (such as yes/no, can do/can't do,

✓/x, etc.). After recording is finished, average points are calculated, and the teacher can interpret the findings.

Rating Scale: This is used to record the degree of development and learning. It differs from checklist in terms of describing the performance level while a checklist is used to determine only the presence of performance criteria (Wortham, 2008).

Participation Chart: It is used to collect data about children's choices, interests, and participation matters. It provides knowledge about the number of children's participation to the class activities (McAfee & Leong, 2007).

Frequency Count: It is the observation tool that requires counting how many times a behavior occurred in a time period (McAfee & Leong, 2007).

Rubric: This observation tool is very similar to a rating scale in terms of having criteria; however, rubrics have qualitative indicators to determine children's developmental progress or learning level (Wortham, 2008).

Portfolio

As child-centered assessment method, a portfolio is used to develop the big picture of the activities that the students participated in during a specific period of time (like one semester or one year). While creating a portfolio, children's active participation is expected in order to document their development and learning in a regular and purposeful way in compiling the needed information (McAfee & Leong, 2007; Wortham, 2008).

The purposes for preparing a portfolio are to represent the development process of the child, to provide information for teaching, to communicate with the family, and to ensure the situations where intervention is required. For this reason, each child's portfolio should be prepared individually, and each child's file should contain individual examples of children's works (AÇEV, 2015).

A portfolio can include:

- Work products (e.g. art activities)
- Worksheets (e.g. science, mathematics, language learning)
- Observation notes
- Children's dialogue
- Examples of developmental evaluation scales
- Recommendations for families
- Interviews
- Photos, audio and video recordings
- Developmental tests
- Teacher reviews

Children should have active roles in their portfolio assessment. For instance, the products that will be put in their portfolio should be selected with their decisions. By this way, children take responsibility for their learning progress, which helps to increase their self-confidence (AÇEV, 2015).

Interpretation of the data obtained from assessment

It is important for teachers to know about what the data collected from children means and how to use it for their development and learning. At the end of the assessment process, the gathered information and the interpretations of the teachers are brought together to plan the next step of teaching process.

Cooperating with families through the assessment process

Children spend more time with their families than they spend at school. So, involving parents to the assessment process and informing them about their children’s development and learning level will help teachers to increase the effectiveness of the program. For instance, portfolios and bulletins are effective tools for this process. With the help of portfolio sharing days with the participation of families, teachers can provide the opportunity for children to share their activities and experiences with their families. In this way, teachers and families can examine and discuss about concrete examples of children's products instead of conducting abstract discussions about the children’s development. Also, with the help of bulletins, enriched photos, and information which reflects children’s development and learning processes should be shared with families to support their children at home.

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Chapter XV

Assessment of the STEM Education Process

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Assessment in early childhood education (ECE) plays an important role in supporting positive outcomes for children by informing what is taught and how. Using different methods and tools, educators assess, reflect on, and improve their pedagogical practice.

Teachers can use two types of assessment of the process: informal and formal. Assessments, both formal and informal, are used to plan programs and activities that allow children to develop their interests in a child-initiated context. Informal assessments are based on unstructured observations and self-assessments that are done in an ongoing situation. For example, when teachers see that the current materials in use are too difficult for the children, they decide to change some of the materials, allowing for easier manipulation. *Formal assessment* is usually used to review the broader learning process and involves recording observations for further analysis and reflection as well as creating a record over time. It enables teachers to identify changes in children's interests and capabilities and consider longer-term plans and strategies to support them. Formal assessment requires teachers to have a methodology with predefined goals. The methodology of the assessment does not need to be complicated or lengthy. However, it is important that it is well-designed and appropriate for the program and participants and returns culturally and contextually valid and useful information.

Today, there is an increasing expectation of STEM programs to provide evidence of replication or scalability. STEM develops a set of thinking, reasoning, teamwork, investigative, and creative skills that children can use in all areas of their lives.[13] The success of these efforts depends on many factors, including children's' equitable access to challenging learning opportunities and instructional materials, teachers' capacity to use those opportunities and materials well, and policies and structures that support effective educational practices. In turn, making informed decisions about improvements to education in STEM requires research and data about the content and quality of the curriculum, teachers' content knowledge, and the use of instructional practices that have been shown to improve outcomes. Therefore, the assessment of the STEM learning process is a multifaceted component related to the effectiveness of STEM training. Evaluation can focus on various factors depending on the purposes of the assessment.

[13] Jolly, A.(2014).

The assessment of the STEM educational process is dependent on the correct measurement of indicators in key factors in the educational process. In this context, several key factors and indicators for evaluating the STEM educational process will be presented in the next part of the text.

The teacher as an important factor in the STEM educational process. The experiences that a child has in his/her earliest years shape his/her development, and teachers play an important role in creating those experiences. The teacher's role is to be on the sidelines offering support when needed to help children develop new skills and facilitating interplay between children and the environment.[14]

- *Indicator - training in STEM.* Teacher professional development has a statistically significant impact on student skills and knowledge.[15] It is important that teachers have proper training in STEM in order to facilitate STEM activities. It is not necessary in some cases for the teacher to know how to develop STEM cultural and age-appropriate curriculum on her/his own, but she/he certainly needs to know how to develop a good, functional plan for STEM activities. Teachers should plan to cover all domains of development in their daily or weekly educational programs and assessments.[16]
- *Indicator - the teacher uses STEM language when communicating with children.* When communicating with children, the questions the teacher uses in the learning process are significant. In their *STEM Family Activities Workbook*, Fredericks and Kravette developed several categories of questions that the adult could use in STEM activities: attention-focusing questions ("Have you seen…" and "Did you notice…"); measuring and counting questions ("How many?" "How long?" and "How often?"); comparison questions ("Is it longer, stronger, heavier, more…?"); action questions ("What happens if…"); problem-solving questions ("Can you find a way to…"). These questions are appropriate when children's curiosity is going strong and their science understanding begins to make real progress.[17]
- *Indicator – the teacher respects diversity and promotes equality, equity, and inclusion.* The attitudes of the teacher are strongly related to the children's achievements. When planning activities, the teacher should always keep in mind ways to promote equality, equity, and inclusion. For example, whenever the teacher announces a new activity which requires teamwork, separation by factors that support exclusion, e.g., by gender, socio-economic status, native language, level of education, needs for support, are inappropriate for organizing the teams.
- *Indicator - the teacher prepares the necessary materials while planning the activities.* The successful learning process for children's transdisciplinary STEM skills requires the teacher to prepare for each activity. This includes goal outlining, materials preparation, space preparation, and specific usage of terms.
- *Indicator - the teacher follows the rhythm and pace of the child.* The teacher allows the child to determine the direction and pace of the STEM activity. This is an important part of the

[14] Boston Children's Museum. (2013).
[15] Rosicka, C. (2016)
[16] Kori Bardige and Melissa Russel (2014)
[17] Fredericks, B. & Kravette, J. (2014)

process that provides the child with time for reflection, formulation of new hypotheses, and willingness to experiment.

- *Indicator – the teacher provides regular, high-quality feedback to learners so they understand their progress in STEM learning.* Constant, effective feedback is a factor that guides children in how they move through the process. Studies have shown that when feedback is predominately negative, it can discourage student effort and achievement[18]. This does not mean that feedback is giving the child praise all the time but addressing new moments in his/her participation in STEM. The effective feedback is educative in nature and keeps a child "on target" for achievement.

Learning as a factor associated with the STEM educational process.

Quality STEM learning experiences place students in environments that help them to better understand and personally consider STEM careers.

- *Indicator - STEM activities are related to an existing problem that children might face outside of the school environment.* Nugent, Barker, Grandgenett, and Adamchuk (2010) and Barker and Ansorge (2007) emphasise the importance of hands-on, real-world, problem-based learning that develops more than domain-specific skills and knowledge.[19]
- *Indicator - each child is actively involved in the STEM activity.* When a student develops a knowledge and skill base around an activity, the context of that activity is essential to the learning process (Putnam and Borko 2000).
- *Indicator – activities include implementation of the engineering design process. The engineering design process* is a flexible process that takes students from identifying a problem—or a designed challenge—to creating and developing a solution[20].

Curriculum as a factor associated with the STEM educational process.

The Collections Curriculum encourages children to be curious, to wonder, think, play, question, and connect with the world around them so they will become innovators able to make great contributions to society.[21]

- *Indicator - STEM activities are appropriate for the age and experiences of the children.* Developmental theories show that at the concrete age based on the existing experience of the child, new milestones could be achieved with proper interaction with the environment. So, the best STEM education requires good knowledge of developmental theories and, moreover, deeper knowledge of the child's zone of proximal development based on his/her experience.

[18] Hattie & Timperley, 2007, Dinham
[19] Rosicka, C. (2016)
[20] Anne Jolly (2014).
[21] Kori Bardige and Melissa Russel (2014).

- *Indicator - STEM activities are systematically linked, and each subsequent result adds to the child's experience.* The system of STEM predicted skills supports effective acquisition of the necessary skills in children by unfolding their knowledge and interests while giving them a sense of confidence and familiarity with the activity.

Environment as a factor associated with the STEM educational process.

The environment should be carefully crafted to serve as inspiration for children's explorations. Teachers should use their environment as inspiration for designing their own investigations. Educators often describe the environment as being the "third teacher," and this should the case when using this curriculum as well.[22]

- *Indicator – safety.* Ensuring safe environmental conditions, like having easy access to a sink, gloves, first aid kit, and other supplies depending on the activities is crucial.
- *Indicator – providing conditions for STEM in-class and outdoor activities.* STEM skills are built not only in the classroom. Therefore, it is important that children have the opportunity to work on their STEM tasks in any environment where they spend most of their time.
- *Indicator – adequate use of the environment in STEM activities.* It is important for children and their families to have the opportunity to use their newly learned skills, which is easily done in the maximum natural environment.

Society as a factor associated with the STEM educational process.

When evaluating the STEM process of education, it is necessary to include indicators related to the extent of the partnership if there are conditions for parental participation in the STEM process. Additionally, the teacher can guide the parents at home in promoting STEM skills.

- *Indicator - active participation of significant adults in the STEM training process.* Families are an integral part of any early childhood program, and throughout the investigations there are intentional opportunities for families to be involved by sharing their knowledge, favorite books, or experiments . The degree of involvement of the child's families is directly related to the effectiveness of the early childhood educational process. If parents share what the child's interests are, this will help teachers to include the child's interests in the program, giving opportunities for the child to develop his/her ideas. This can happen through various channels: e-mail communication, phone, home visits, notebooks, and more.

[22] Teresa Strong-Wilson and Julia Ellis

When designing the STEM assessment process, it is most important to:

- Identify which indicators are important to evaluate and why.
- Determine with what frequency and for how long will it be assessed;
- Develop resources – time, human and financial.

In conclusion, assessment of the STEM education process is a multifaceted, complex topic. Every assessment requires careful development of key characteristics to be assessed, prioritizing the goals in developing an assessment design, and step by step operationalization of the assessment.

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