ER4STEM FRAMEWORK: FINAL VERSION

[Deliverable 1.4]

Julian Mauricio Angel-Fernandez

ER4STEM - EDUCATIONAL ROBOTICS FOR STEM

The ER4STEM project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 665972

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V0.3	12.01.2018	Update of the document's structure base on the draft definition	Julian M. Angel-Fernandez
V0.4	23.01.2018	Literature review on changing and sustaining attitudes on STEM	Georg Jäggle and Julian M. Angel-Fernandez
V0.41	10.02.2018	Brief explanation of ER4STEM pedagogical principles	Sofia Nikitopoulou
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V0.6.5	18.09.2018	Corrections on how ER4STEM pedagogical principles were created	Carina Girvan and Nikoleta Yiannoutsou
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CONTRIBUTORS

Name	Section affected	Date of 1st contribution
Ivaylo Gueorguiev **Pavel Varbanov** **George Sharkov**	Structure of the document and ER4STEM Processes description and update	01.10.2017
Julian M. Angel-Fernandez	All	12.01.2018
Georg Jäggle	Changing and sustaining attitudes in STEM, and literature review of communication	23.01.2018
Chronis Kynigos	Description of constructionism, Introduction, ER4STEM pedagogical principles and ER4STEM activity plan template.	22.02.2018
Annalise Ducca	Brief description of the Repository	12.06.2018
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Christina Todorova **Pavel Varbanov** **Ivaylo Gueorguiev** **George Sharkov**	Analysis of European Strategies	14.09.2018
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1 EXECUTIVE SUMMARY

1.1 ROLE/PURPOSE/OBJECTIVE OF THE DELIVERABLE

This deliverable reports on the final version of the ER4STEM framework, which is the result of three-years of improvement and iteration based on the continuous contribution of WP 2, WP3, WP4, WP 5 and WP6. Consequently, this document could be considered as an organizer and a window to the work done throughout the ER4STEM project's implementation period. The framework aims to make explicit the connection between pedagogical strategies, robotics and 21st century skills providing processes and tools to guide stakeholders along the critical use of robotics in education. Moreover, it situates the educational use of robotics in constructionist learning activities for children both inside and outside of school in which, they:

- Collaborate within and between teams
- Creatively engage with challenges in STEM domains
- Engage in critical thinking through reflection
- Have opportunities to learn how to recover from failure
- Gain a sense of achievement

These activities are taking place in shared spaces with mediating artefacts (aka robots), teachers and children are able to challenge existing classroom norms and attitudes towards learning (in STEM and in general), in order to develop and maintain young people's interest in STEM subjects and careers.

To achieve this, the ER4STEM framework provides four components that are the result of the work done throughout the project:

- **ER4STEM Glossary,** (ER4STEM Glossary)
- **Tools**: **ER4STEM web-repository** (WP 5) (ER4STEM Repository), **ER4STEM activity plan template** and **activity blocks** (WP 4) (ER4STEM Activity Plan Template), and **ER4STEM generic curriculum** (WP 2**)** **(**ER4STEM Generic Curriculum**)**
- **ER4STEM pedagogical principles** (ER4STEM Pedagogical Principles)
- **Processes** for the delivery of Educational Robotics Educational Robotics Workshops (WP 2 – D2.3) and Conferences (WP 3 – D 3.3) for young learners (ER4STEM Processes).

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1.2 RELATIONSHIP TO OTHER ER4STEM DELIVERABLES

This deliverable is the conclusion of the work presented in D1.2 and D1.3, which were based on the literature review reported in D1.1, and on the results and suggestions reported in D6.3, D6.4 and D6.5. D6.3 provided ten suggestions that were embraced in the framework and included as ER4STEM pedagogical principles. These suggestions or principles were then evaluated and reported in the subsequent deliverables (D6.3 and D6.4). In addition, this deliverable links to D2.4, D3.4, D4.3, D4.4 and D5.4, which provide detailed information about the educational robotics workshops and conferences delivery processes, the activity plan template, the activity blocks, and the ER4STEM repository on educational robotics that are briefly introduced in this deliverable.

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1.3 STRUCTURE OF THE DOCUMENT

This document is structured as follows: Chapter 2 introduces the ER4STEM framework, explaining facets of educational practices based on robotics and the framework's components. Chapter 3 presents the ten ER4STEM pedagogical principles with good practices and ideas based on an extensive literature review. Chapter 4 briefly introduces the ER4STEM activity plan template and the ER4STEM activity blocks. Chapter 5 introduces the ER4STEM generic curriculum. Chapter 6 explains the macro-process created to serve as a foundation for other processes created in ER4STEM. In addition, it introduces the workshops and conferences process. Then, Chapters 7 and **Fehler! Verweisquelle konnte nicht gefunden werden.** present the ER4STEM repository and the ER4STEM glossary. Finally, Chapter 9 provides conclusions of the work done in WP 1.

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2 INTRODUCTION

The domain of robotics is a multi-disciplinary and highly innovative field encompassing engineering, design as well as social sciences, such as psychology. As a consequence, it does not only cover mechanical, electronic and computer engineering, as might it be commonly perceived, but it also involves other fields as mathematics, physics, biology, art and philosophy (e.g. studying existential aspects of building intelligent robots) (Reported in D1.3) [1]. Therefore, robotics has been suggested as a field of powerful potential in education [2] and with high expectancy to impact teaching from kindergarten to university [3]. However, its real impact has not been formally determined [4] neither guidelines have been provided to designers of workshops and lessons to combine different features, crucial for the success of any activity in an educational settings. Moreover, recognized weaknesses of the current educational robotics approaches could hinder the impact of robotics in education (Reported in D1.1) [5]:

- Research in educational robotics lacks detailed and structured description of activities and their pedagogical design, which are of importance to their scalability and assessment. There is a need for an analytical and critical description of educational robotics activities to become more explicit and elaborate about pedagogical design, and to have activities that can be shared and interlinked.
- Research questions are focused on increasing interest in science through the use of robots and learner experience, but a lot of this research is vague or unclear. The analysis and tests, carried out as part of the research available have different aims: some of them are focused on understanding whether engagement with robotics can increase knowledge of certain subjects, whilst others focus their attention on the development of 21st Century Skills.
- Whilst they are not always stated, the pedagogical theories that appear to underpin the learning experiences are social constructivism and constructionism. However, how these theories are used to inform the design of the learning experiences is not well documented.
- Lego Mindstorms is a dominating educational robotics platform both as hardware and as software. However, there are other platforms with similar features and lower price that allow people to achieve similar desired learning outcomes.
- Although there is a wide range of workshops using robots with and without curricula, there is a need for a process that guides teachers, workshop organizers and other stakeholders in the creation or adaptation of activities that are pedagogically informed.
- There are many different successful robot competitions worldwide, but these mostly address young people already interested in STEM and use the concept of competition for motivation. There is a need to have diverse learning contexts like robot art exhibitions or conferences to address more young learners with diverse fields of interest.
- Many existing educational resources regarding robotics are based on the technology they use. There is a need for a user- and activity-centric repository.

Despite the listed weaknesses, researchers' current approaches do not manage to unify all the components present in ER. For example, the project TERECoP [6] presented a constructivist methodology for teacher training in the use of robotics in education. Several training sessions were available across Europe, but nevertheless, this approach focused on the face-to-face training of teachers and it is linked to the robotic platform Lego Mindstorms: a clear structure of a framework is not provided. Others have come forth with frameworks to establish precise procedures that have to be followed in order to create and implement an educational activity with robotics. This is the case of the Roberta initiative [7], which established specific criteria for the activities that were implemented under

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the "Roberta" brand and more importantly – criteria for the teachers, carrying out Roberta educational robotics activities. Although these approaches are beneficial in the long term, they still require further materials and guidelines to increase the use of robotics in a critical way that take into consideration the benefits of the technology and pedagogical methodologies. For more information about existing frameworks in educational robotics, refer to Appendix 1: Literature Review on Existing Educational Robotics Frameworks.

Although researchers have still not managed to unify all components present in ER, the cost of robotic platforms decreases and the need of more initiatives to promote STEM education increases (For more information refer to the European strategies review done by the ER4STEM team Appendix 8: REVIEW OF CURRENT STRATEGIES ON NATIONAL AND EUROPEAN LEVEL THAT ENCOURAGE STEM EDUCATION AMONG THE YOUNGER POPULATION) [8], which further raises the use of robotics in education. However the current approaches, as commented above, have not fully conciliated the use of pedagogical methodologies and robots, which might lead to misusing, or not fully unfolding the potential of robotics as a tool for education and therefore jeopardize the learning experience [9]. Therefore, the ER4STEM framework has been created to make explicit the connection between pedagogical strategies, robotics and 21st century skills. Its development was cyclical and started during the first project year. The development of the ER4STEM framework has been informed by WP 2, WP 3, WP 4, WP 5 and especially by WP 6, which provided useful information about the strengths and weaknesses identified during the evaluation of the educational robotics activities carried out as part of the ER4STEM project.

2.1 FACETS OF EDUCATIONAL PRACTICES BASED ON ROBOTICS

Diverse facets are involved in the design and implementation of any educational activity involving robots as mediating artefacts. By considering these facets, designers can perform a risk analysis in order to have a clear idea about possible additional requirements that should be addressed before implementing any activity. These aspects are 1) **robotic platform, 2) equipment and space, 3) educational objectives, 4) pedagogical approach** and 5) **context. Equipment and spaces,** and **robotic platform** are considered as different facets because robots play an important role in the design of the activity and it can condition the space and equipment required to implement the activity. In addition, these facets are reflected in the **activity plan template** [10] (More information could be found in ER4STEM Activity Plan Template).

The **Robotic platform** is a facet that should be considered in order to determine the equipment (i.e. hardware and software), the characteristics of the space, skills and concepts that can be taught during the activity. For example, let us consider the Sphero SPRK+ [11] and Thymio II [12]. SPRK is a robotic ball developed by Sphero and has gyroscope and accelerometer sensors. It is programmed through diverse applications that could be downloaded and installed on smartphones and tablets, but could also be programmed via Chrome's extension. The programming is done via Bluetooth, which is available on all smartphones and tablets but not on all Laptops or desktops. On the other hand, Thymio II is a robotic platform with a variety of sensors (e.g. accelerometer and distance sensors). It is programmed via USB cable or through a USB stick for remote programming, which restricts its use to devices with USB ports. Although these two platforms could be used to teach programming, their physical characteristics determine to some extend the topics that could be taught through them. For instance, SPRK could be used to teach the concepts of rotation, friction and angles. On the other hand, Thymio II could be used to display the use of a proximity sensor (i.e. infrared proximity sensors) and let

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participants draw. These subtle differences influence the activity on many levels and could serve different learning outcomes.

Equipment and spaces facet refers to physical spaces (e.g. classrooms and computer rooms) and the equipment (e.g. computers, laptops and tablets) available in the institution or organization, where the activity will take place. Continuing with the previous example, Thymio II requires access to a computers' USB, while SPRK requires Bluetooth modules, which could require having Bluetooth USB or tablets. These two different devices would require specific spaces, in which different approaches could be followed. For instance, Thymio II would require the use of Laptops or Desktops, which will reduce the distribution of participants in the room, while SPRK would require the use of tablets, which will allow for better flexibility in the arrangement of the room.

The educational objectives facet is related to the main concepts that are going to be covered during each session. Depending on the designer of the activity, it helps to align the activity to **specific curricula** or design an activity with concrete **learning objectives**, that could be measured or assessed. They are also going to be influenced by the platform. Moreover, this facet is highly influenced by the **pedagogical methodology** facet, which is related to stakeholders' teaching approach (e.g. discovery learning or collaborative learning).

The last facet is **context**, which influences all the previous facets and gives important information about the profile of the participants (e.g. students), the characteristics of the organization (i.e. school, museum) which hosts the activity, and the country. This information could significantly affect other facets. In addition, it gives valuable information to understand where an activity was designed, so it would allow for the adaptation to other contexts.

To have a clear idea how these facets link to each other, it is possible to think that **robotic platform**, **educational objectives, equipment and spaces**, **pedagogical methodologies** and **Context** located on the edge of a pyramid, such as it is depicted in Figure 1. The rationale behind it is that every person who wants to design or adapt a new activity with robots needs to take into consideration these facets, as they directly influence the success of their activity.

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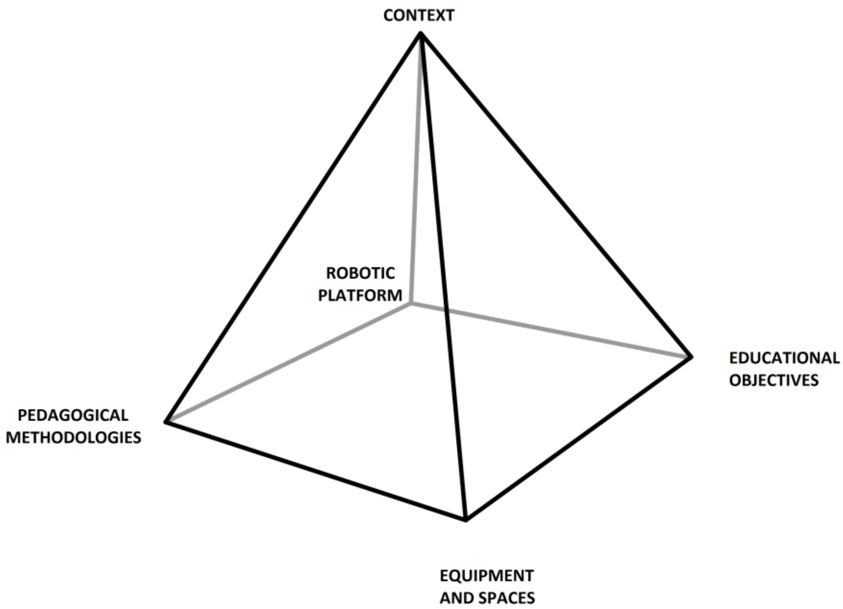

Figure 1 Relationship model of the facets, comprising an educational robotics activity

2.2 DEFINITION OF THE ER4STEM FRAMEWORK

ER4STEM's framework is the outcome of the analysis of stakeholder requirements and needs [5], existing frameworks in ER and in other technologies (Reported in D1.3) [1], ER4STEM's aims, suggestions and insights provided by the evaluation (Reported in D6.3, D6.4 and D6.5). One of the main conclusions of the evaluation of ER4STEM's educational robotics activities is that workshops and schools' lessons must be treated in a similar manner with regards to place (e.g. school or external organization) and situation (e.g. formal or informal) of an ER activity they must achieve equal outcomes. Therefore, any activity should have clear learning outcomes and evidence of learning. This approach has two main benefits. First, the activities designed and implemented as workshops can be easily adapted as schools' lessons because educational robotics practitioners and teachers can connect them to specific topics within formal curricula. Secondly, evidence of learning lets people to verify if the activity achieved the expected results or not, which will helps measure the impact of an ER activity [4], which would generate arguments towards the use of ER in formal settings. Therefore, all educational activities carried out under ER4STEM, and also in ER activities outside the ER4STEM project, should carry the following characteristics:

- Clear learning outcomes and evidence of learning, which could be formal (e.g. assessment) or informal (e.g. write to a friend about what you have done today).
- Apply of one or more pedagogical methodologies during the activity and its design, and refine the pedagogical approach after the implementation of an activity.
- Description of the activity using the activity plan template created within the ER4STEM project (Reported in D4.3) [10] (More information could be found in the ER4STEM Activity Plan Template). This will help other stakeholders to gain a clear idea of all aspects of the

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activity taken into account throughout its design and the assumptions (e.g. participants' knowledge or attitudes towards technology) done by the designer.

Therefore, ER4STEM framework makes explicit the connection between **pedagogical methodologies**, knowledge in **robotics** and **21st century skills** through **processes**, **pedagogical principles** and **tools** that will let any stakeholder, identified in D 1.1 [5], to design or adapt, implement and evaluate **educational robotic activities**. To achieve this, the ER4STEM framework provides four components that are the result of the work done in ER4STEM. First, ER4STEM glossary (ER4STEM Glossary), which provides specific description of each term used in ER4STEM. Second, **tools** created specifically to be used in ER. This tools are an **ER4STEM web-repository** (WP 5) (ER4STEM Repository), **ER4STEM activity plan template** and **activity blocks** (WP 4) (ER4STEM Activity Plan Template), and **ER4STEM generic curriculum** (WP 2**)**. The last tool mentioned, the activity blocks, are pieces of activities that has been proven useful to foster specific skills and could be connected with other blocks to create a pedagogical activity. Third, **ER4STEM pedagogical principles** (Chapter ER4STEM) were suggested from WP6 -D 6.3) [13] as a conclusion of the analysis of the evaluation done on the workshops and conferences implemented during the first year of ER4STEM (Reported in D2.1) [14], literature review on educational robotics (WP 1 -D1.1) [5], current industry needs and project objectives (Project Proposal). This analysis was refined after the second year analysis (Reported in D6.4) [15]. These principles are (WP 6 - D6.3) [13] creativity, collaboration, communication, critical thinking, evidence of learning, mixed gender teams, multiple entry points, changing and sustaining attitudes to STEM, and differentiation. Four, **processes** for Educational Robotics Workshops (WP 2 – D2.4) and Conferences (WP 3 – D 3.4) for young people (ER4STEM Processes). Figure 2 shows these four components and the relationship between them.

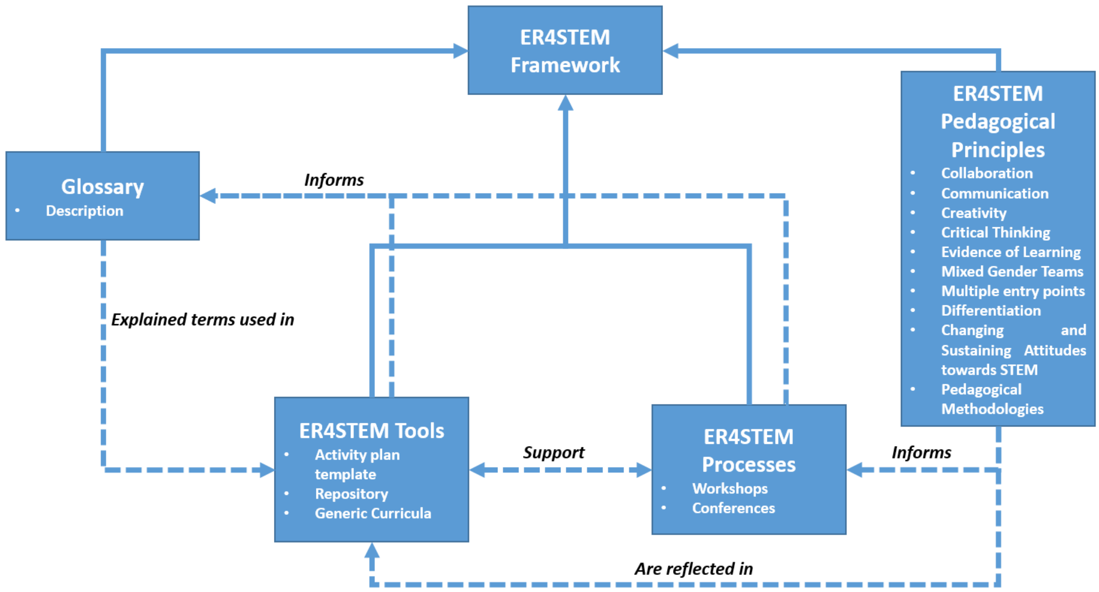

Figure 2 Graphical representation of the elements that compound the ER4STEM framework

The dashed lines within Figure 2 Graphical representation of the elements that compound the ER4STEM framework represent the connections between elements that constitute the framework. The bold lines represent the elements that constitute the framework.

Consequently, the ER4STEM framework situates the educational use of robotics in constructionist learning activities for children both inside and outside of school in which, they:

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- Collaborate within and between teams
- Creatively engage with challenges in STEM domains
- Engage in critical thinking through reflection
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These activities are taking place in shared spaces with mediating artefacts (aka robots), teachers and children are able to challenge existing classroom norms and attitudes towards learning (in STEM and in general), in order to develop and maintain young people's interest in STEM subjects and careers.

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3 ER4STEM PEDAGOGICAL PRINCIPLES

ER4STEM pedagogical principles came as a suggestion from WP6 (Reported in D6.3) [13] as part of the conclusions of the analysis of the evaluation done on the workshops and conferences implemented in the first year of ER4STEM (Reported in D2.1) [14], literature review on educational robotics (Reported in D 1.1) [5], current industry needs and project objectives. From the **literature review on educational robotics**, several weaknesses on how work in ER is documented were found. First, there is no clear evidence how pedagogical theories were considered during the design of the activity. Second, activities reported in many cases are not systematically or well described, which limits their scalability. Finally, some of the studies lack rigorous and systematic analysis of the data, which would make it become anecdotal.

The **analysis of the industry needs** reveals that there is a common agreement that STEM is critical for the future economic growth. However, there are different views on whether the supply of STEM-skilled labour will be sufficient or not in the near future. According to Business Europe, the lack of STEM-skilled labour will be one of the main obstacles to the economic growth in the coming years [16].

Last but not least, the **project objectives** are four. First, provide multiple entry-points to ER and STEAM. Second, empower children to solve real world problem and address all young children. Third, provide a continuous STEM schedule. Fourth, develop an open and conceptual framework. As a result, the ER4STEM pedagogical principles identified are (D6.3) [8]:

1. **Collaboration**: Students must be able to work effectively and respectfully with others. More specifically to a) contribute constructively to project teams b) be helpful and make necessary compromises to accomplish a common goal c) assume shared responsibility and value the individual contributions when working in a team d) use collaborative technologies to connect and work with others (i.e. peers, experts or community members etc.) globally.
2. **Critical thinking**: More specifically to be able to a) use various types of reasoning depending on the situation b) analyse and evaluate major alternative points of views c) synthesize and make connections between information and arguments d) Interpret information and draw conclusions based on the best analysis e) reflect critically on learning experiences and processes.
3. **Communication**: Students must be able to communicate with others effectively. This includes the ability to a) articulate thoughts and ideas effectively using oral, written or nonverbal communication skills b) communicate complex ideas clearly and effectively c) publish or present content that customizes the message and medium for their intended audience d) utilize multiple media and technologies in order to communicate and know how to judge their effectiveness e) communicate effectively in diverse environments.
4. **Creativity**: By “creativity skill” we mean the ability to think creatively, which includes: a) constructing and generating new and useful ideas b) using a variety of techniques to create these ideas c) coming up with innovative, unique or imaginative solutions to problems d) implementing the creative ideas in tangible artefacts.
5. **Pedagogical methodologies**: ER4STEM has adopted constructionism as a foundational approach to designing workshops and robotic solutions and in the development of an integrated framework for inclusive learning and engagement with STEM. Key features of constructionism are its epistemology for learning portraying knowledge and meaning making as fallible and its focus on learning while engaged in bricolage with digital artefacts.

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6. **Mixed-gender teams**: Develop approaches to the orchestration of teamwork, with particular consideration of mixed-gender groups.
7. **Differentiation**: within student productions, teaching methods and the sequence and description of activities, prompt activity designers to consider differentiation, providing examples of how this can be achieved in relation to sample objectives.
8. **Multiple entry points**: highlight alternative entry points by including this aspect in the student learning process with examples; similarly include suggestions and examples within the first phase of the sequence and description of activities
9. **Evidence of learning**: evidence of learning: include examples of achievable and measureable objectives; provide examples of how student productions (artefacts of learning) and reflections (as a form of student production) can demonstrate achievement in a range of objectives, including domain, technical and 21st Century skills.
10. **Changing attitudes towards STEM**: identify points for discussions about the work of scientists (including who scientists are), experiences of STEM subjects and robotics in relation to STE(A)M subjects and career

Next subsections presents good practices and ideas for the use of these pedagogical principles based on a literature review. Good practices identified during the evaluation process done in WP 6 are reflected in ER4STEM Activity Blocks (Section 4.1).

3.1 COLLABORATION

Collaboration is in many cases misused and confused with cooperation. Korzar [16] uses the following example to illustrate the differences between the two. She says that cooperation is like an assembly line, in which the problem is divided in small parts and each part is assigned to each group member. However, there is not much interaction between members and in some cases, one person could do most of the work. On the other hand, collaboration involves [21] communication, coordination, mutual support, balance of members contribution, and cohesion between all team members. Therefore, collaboration includes cooperation but not the other way around. Moreover, it is possible to observe the following:

- Creating groups would not imply that group-members would collaborate within them [17] [18] [19].
- If a group is not created properly, it could jeopardize the expected outcome [17] or the learning process [19].
- Kennedy and Nilson identified four phases for the correct creation of a team [20]:
  - Forming occurs when members meet and it is socialized the activities that are going to be carried out during the time the project is together. Therefore, it is important to discuss within all team members the expectations, roles, responsibilities, and establish ground rules.
  - Storming is characterized by individual assertiveness, hidden agendas, conflict and discomfort. This phase is of vital importance for the performance of team in subsequent phases. It is important to involve all members in the communication and start creating the membership into the team.
  - Norming occurs when all teammates work to solve existing conflicts that have surge and start working on the project’s objectives.
  - Performing phase is recognized due to the close attachment within team members and the constructive mechanism to resolve conflicts and ideas.

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- Behaviours that increase team cohesion are [21] [22]: talk about the task, motivate trust within members, share time formally and informally with team members, create effective communication channels, and generate an environment where team members feel that they are heard.
- Collaboration involves [23] communication, coordination, mutual support, balance of members contribution, and cohesion within members.
- There is a difference between team and group. Beebe and Masterson [21] defined group as three or more people working together with a shared purpose and a sense of belonging. On the other hand, they defined team as a coordinated group with a high structure, which embraces a clear specification of roles, expectations, and organization.
- It is not always necessary to work in a team to achieve a goal. Peter Scholtes et. all [24] suggest that a team is required when:
    - The task is so complex, that the effort of one person is not enough,
    - Creativity is needed, the path to come with a solution is unclear
    - An efficient use of resources is required
    - High commitment is desirable
    - Cooperation is essential to come with a solution, members have a stake in the outcome
    - The task or process involved is cross-functional
    - No individual has enough knowledge to solve the problem.
- Despite most beliefs, conflict in teams is something that must not be avoided or feared [22].

3.2 COMMUNICATION

Communication skills can be understood as children's capacity to transmit ideas and information received in class through technological mediums [25]. Communication takes place when a sender expresses an emotion or a feeling, creates an idea, or senses the need to communicate a goal. The communication process is triggered when the sender makes a conscious or an unconscious decision to share the message with another person—the receiver. This could happen in three different ways: ***verbal, non-verbal*** (e.g. body language and appearance) and ***written***.

Barriers to good communications are always present. For instance, the language itself can be a barrier—unclear wording, slang, jargon, the tone. Another barrier is the failure of the sender to realize that their body language might contradict the spoken message. The channel used to convey the message might be wrong. For instance, you would not use the telephone to relay a lot of statistical information; you would need to write that message on paper. Poor listening skills can constitute a barrier also.

- ***Verbal communication*** is divided into two parts *speaking* and *listening*. *Speaking* is focus on the process of communicating the idea to listener(s). *Listening* is as important as speaking because without this skill the communication between people is not going to be fluent. For example, a passive listener is attentive but does nothing to assist the speaker to create fluid communication. On the other hand, active listeners sit or stand alertly, maintain eye contact with the speaker, concentrate on the speaker's words, make verbal responses, and summarize parts of what has been said when clarity is needed.
- ***Non-verbal communication*** comes particularly from the face, eyes, gaze, body, clothing, gestures and touch. For example, turning your back to others in a group conversation could be interpreted as detachment from the conversation.

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- ***Written communication*** is the process to convey a message through written symbols. Its effectiveness depends on the correct choice of words, organization, coherence and spelling.

Each one of the types of communication has a vast number of skills involved, which in many cases do not overlap with each other. For example, someone who is good at verbal communication could be not as good at written communication. Consequently, addressing all types of communication at once could be difficult. Therefore recognizing the type of communication that is going to be addressed could help to have better results.

3.3 CREATIVITY

Creativity is one of the skills that is much discussed but not consistently explained. An important aspect to foster creativity is avoiding telling children that they are not creative just because what they are doing does not seem as something innovative. Regarding this, researchers have come up with different types of creativity, for example Kaufman and Beghetto proposed four types of creativity [26]: little-c, big-c, mini-c and pro-c. Little-c is the creative that involves novelty beyond individuals. Pro-c could be positioned between little-c and big-c, and it stands for the embedded ideas that are considered of significant value within their field but their contribution has not been recognized as big-c. Little-c, which occurs when individuals come across ideas that are new for them and for others but without a significant relevance to their field; and big-c, which occurs when individuals come up with ideas that revolutionize their fields.

Other important points to bear in mind when it comes to creativity are:

- The creation of environments, that promotes creativity, is also possible by:
  - Defining clear goals in the activity [27]
  - Balancing knowledge and challenge [28] [27]
  - Creation of a climate where students are not concerned that they may fail [28] [27] [29] [30]
  - Not creating competitions or providing rewards after finishing the activity [28]
  - Motivating students to be creative [31]
- Elements proposed by Nelson to foster creativity in robotics [32]:
  - Ability to visualize solutions, for example sketching or building prototypes of robots.
  - Thorough knowledge base in the domain, for example building on previous robotic projects
  - Ability to decompose and manipulate partial solutions
  - Ability to take informed risks, which include tasks with no right or wrong answers
  - Flexibility to try alternative techniques
  - Creativity-friendly environment
  - Practice
- Failure must not be punished [29] [28]
- Use of diverse tools to motivate creativity [29], such us brainstorming, story boarding, lotus blossom, checklists, morphological analysis, and excursion techniques.

3.4 CRITICAL THINKING

Researchers have identified as a main problem of teaching critical thinking is schools and universities that curricula are focus on subject, leaving small space to teach generalizable skills [33]. Pithers and Soden [33] suggest the following ideas to teach critical thinking in a classroom:

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- Make students think about the process of thought more explicitly, making them reflect upon their thinking.
- Make students think about the strengths and weaknesses of their way of thinking.
- Teachers could make connections between their subjects and other topics.
- Teachers should aim to challenge current student ideas. For example, teachers could ask students to generate hypothesis, interpret data or information, or help them understand the judgmental process.

Moreover, Walker and Finney [34] in their study concluded that self-awareness through reflection has helped students to improve their critical thinking. In addition, Raht [35] recognized eight behaviours to be corrected by students that could hinder their critical thinking:

- Acting without thinking - impulsiveness
- Needing of help at each step – overly dependent
- Using goal-incompatible strategies – do not perceive cause-effect relationships
- Having difficulty with comprehension – miss meaning
- Are convinced of the rightness of their belief – dogmatism
- Operating within narrow rule sets – rigidity/inflexibility
- Are fearful – not confident
- Condemn good thinking as a waste of time – anti intellectual

Also, Sternberg [36] identified fallacies of the stakeholders (e.g. teachers, parents and students) that inhibit critical thinking:

- Believing that teachers and professors do not have anything to learn from students
- Assuming that critical thinking is solely the lecturer's job.
- Believing that there is a correct programme for the delivery of critical thinking. It depends on the programme goals, content, context or culture.
- Assuming that the choice of a critical thinking programme is based on a number of binary choices
- Thinking that the right answer is important.
- Notion of mastery-learning.

3.5 EVIDENCE OF LEARNING

Any educational activity, even while a research is being done, must include a proof of learning from the participants. This evidence informs teachers, organizers and researchers on what participants are learning and how well they are learning [37]. This will let teachers take timely measures to achieve expected results.

Researchers have created some suggestions on how to use assessment techniques. For example, Angelo and Cross provide the following suggestions when assessment techniques are going to be used [37]:

- "*Don't try any technique that doesn't appeal to your intuition and your experienced judgement as a teacher*"
- "*Don't make self-assessment into a self-inflicted chore or burden.*"
- "*Do choose techniques that will benefit both you and your students.*"
- "*Don't ask your students to use any technique you haven't previously tried yourself.*"

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- "*Do remember that administering an assessment technique and analysing the feedback will probably take twice as long as you estimate*"

Examples of mechanism with pros and cons could be found in the guidelines created by Angelo and Cross called "**Classroom assessment techniques**" [37] .

In order to obtain evidence of learning, it is required to have a clear set of learning objectives before the activity is implemented. This will help on the selection of the best technique. A simple way to write a learning objective is to consider the following three parts [9]:

1. An action verb phrase, which describes what the learner will be doing during the activity.
2. The connection phrase that connects the action with the next part
3. Accomplishment/achievement phrase, which describes why the learner is engaged in the action.

For example: Participants will measure and report the values obtained from the sensors of a robot to gain a better understanding on how they work. Another possibility is the use of taxonomies such us the Bloom's taxonomy.

There are several assessment techniques that could be used. For example, Angelo and Cross [37] offered in their handbook 30 techniques with examples, pros and cons of each technique. They have divided the handbook in three sections: (1) techniques for assessing academic skills and intellectual development; (2) Techniques for assessing student's self-awareness as learners and self-assessments of learning skills; and (3) techniques for assessing student reactions to teachers and teaching methods, course materials, activities, and assignments.

Once the data has been collected, it has to be analysed. At this point the idea is to look for patterns in the data that could help to better understand the situation and if the desired learning outcomes were achieved or not. Penn State suggests the following questions during the analysis of the data [38]:

- Are the answers what you were expecting? If now why it happen?
- Any suspicions were confirmed? How you can use it in the next lesson?
- What is the most common answer? How common it is?

There could be cases where the number of students is overwhelming, which might make it difficult to go through all the data. Therefore, two solutions are possible. (1) Instead of having an answer per person, it is possible to create groups to do the activity. This is especially good when it is used to determine if participants are really learning the expected topics. (2) Random selection of the answers.

3.6 MIXED GENDER TEAMS

Gender differences between males and females must be considered to achieve the expected results of pedagogical activities. Therefore, educators must determine the best group composition to achieve the learning outcomes [39]. It is important to highlight that results of studies done in mixed-gender teams are contradictory but there are certain tendencies [40] [39], so they could be used as a baseline to group teams accordingly. Despite the discrepancies, Holmes-Lonergan [40] recommends to create mix-gender groups at early ages because children can learn how to adapt to different types of collaboration.

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It is important to remember that there is difference between men and women in the way that they communicate, influence others and solve conflicts [41]. Similarly, boys and girls between 4 to 7 years old have differences when a conflicts arises:

- Girls tend to avoid conflict by offering compromises or changing the topic [40] [42] [43].
- Girls use moderate verbal persuasion more often than boys, while boys used more often threats or physical force [44] [45].
- Boys are more likely to provide direct commands and less to provide rationales for their assertions [45] [46].

The following are considerations that could be helpful when creating groups:

- Children between 3 and 4 years old (pre-schoolers) also engage in collaborative work [39].
- Pre-school girls in same-gender groups are more likely to agree with others than boys [40].
- Pre-school children solve problems depending on the gender of their partner [40].
- Pre-school girls are more likely to dominate the computer than boys [39] [47].
- Boys between 6 to 12 years old (elementary students) are more likely to dominate the computer than girls [39] [48].
- Gender does not affect the social interaction in an activity but the age is an important factor [39]. Elementary students collaborate more when there is just one computer and big groups, than when there is one computer per student. On the other hand, this difference is not observed with pre-schoolers.
- Same gender groups are preferable when [39]: 1) group activities involve novel tasks and software, which encourage collaborative behaviours in boys. 2) students are already familiar with the software, which encourages collaborative behaviour in girls.

3.7 MULTIPLE ENTRY POINTS

Howard Garddner in his chapter "*Multiple approaches to understanding*" [49] presents six entry points that could be aligned with specific type of intelligences:

- *Narrative:* address children who enjoy learning through stories.
- *Quantitative or numerical:* focus on children who are interested in numbers, patterns, operations, etc.
- *Foundational or existential:* appeals to children who are attracted to fundamental kinds of questions about a topic.
- *Aesthetic:* focus on children who are interested in art.
- *Hands-on:* speaks to children who find it easy to learn a specific topic through activities where they can create, build or manipulate objects.
- *Social:* focus on children who learn better in a group setting, where they have the opportunity to present and discuss their ideas.

3.8 DIFFERENTIATION

Differentiation is a modified instruction [50] that aims to create a space where students' skills, interest and learning profile to improve their learning. In other words, differentiation is not a strategy but a way of teaching that considers students' differences [51]. Therefore, there is no single method to create a differentiated classroom [52] and each teacher should approach it depending on their school's culture,

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curricula, students and teacher's knowledge. Although at first glance differentiation could be seen as a way to complicate teachers' life [53] due to the extra effort, which is required to generate different content, differentiation does not require to create individual plan for each student. Differentiation also does not require keeping students in groups based on certain data collected once nor does it require teaching only lower-level students and letting the higher-level students teach themselves [54].

Teachers could differentiate in four different aspects [55]:

- Content: is the information provided to students [52] [53]. Some examples are providing different material to each student or putting text materials on tape [55].
- Process: is related the way students learns [52] [53]. Some examples are the use of tiered activities or providing interest centres [55].
- Products: are artefacts that are created in any activity [52] [53]. Some possibilities are letting students to choose the way that they are going to show their learning or encouraging students to create their own products as long as they are align with the learning objectives [55].
- Learning environment: is the way the classroom works and feels. Some ideas are letting students to understand that some need to move around to learn, while others do better sitting quietly [55].

Some strategies for differentiation are [53]:

- Know, Understand, and Do.
- Tiered Instruction.
- Menus.
- Cubing.
- Tic-Tac-Toe.
- Socratic Seminar.
- Layered Curriculum ®.
- Use of technology.

3.9 CHANGING AND SUSTAINING ATTITUDES TO STEM

An important factor to change and sustain attitudes in STEM is to increase students' self-efficacy during more practical lessons and a good relationship between teacher and students [56]. So it is required to implement teaching methods, which foster learning through making and give students a feeling of success, which will contribute to increase their self-efficacy.

3.10 PEDAGOGICAL METHODOLOGIES

There is an agreement among educational researchers that robotics is a perfect tool to design activities based on constructivism, which is a methodology that advocates on learning through interacting with the world and it's the one encouraged in ER4STEM.

The most widespread pedagogical methodologies in educational robotics are [57]:

- Discovery learning: An inquiry-based and constructivist approach to learning. Learner draws on their existing knowledge and applies it to a new situation or a problem. In the process the learner identifies the limits of their existing knowledge and discover new knowledge by manipulating objects and sharing ideas.

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- Collaborative learning: is based on collaboration between students and emphasizes the skill of how to collaborate.
- Problem solving: consists of using generic or ad hoc methods, in an orderly manner, for finding solutions to problems.
- Project-based learning: is a teaching method that provides students with real complex problems that they have to solve.
- Competition-based learning: A constructivist approach to learning in which competition is used as stimulus for the maximization of the intended learning outcomes specified in a given course or curriculum, while team members participate in a project in a controlled environment.

All of them follow the ideas of constructionism.

Constructionism

Constructionism has developed in the past 50 years as both a learning theory and a framework for action and pedagogical design [58] [59]. It approaches learning as meaning making in a constructivist frame [60] [61] but extends individualistic approaches to learning to include collaborative, socio-constructionist learning environments [59]. Key features of constructionism are its epistemology for learning portraying knowledge and meaning making as fallible [62] and its focus on learning while engaged in bricolage with digital artefacts [2]. Constructions – being sand castles or theories about the universe (ibid) – as public entities to be shared and discussed, integrate elements of art that relate not only to the end product (i.e., the construction) but also to the process: the art of learning how to learn [63]. While constructionism has not excluded tangible or robotic artefacts, the emphasis on digital artefacts originated due to their affordances of malleability, computer feedback, interconnected representations [64] recently including dynamic manipulation [65].

One of the approaches used in ER4STEM and that was the award winning is the '*Half baked Robot*'. This approach, based on the theoretical framework of 'boundary crossing' [66], includes a robotic artefact that is designed in a way that promotes the modification, the interference of the student to its core construction and the continuous evolution of its initial form. In other words, a robot ready to be expanded, evolved and transform to something new. This approach is based on the design approach of "half-baked microworlds" [67] a term used to describe digital media designed in a way that their users would want to build on them, change them or de-compose parts of them in order to construct an artifact for themselves. In many cases they function as boundary objects because they facilitate the communication between researchers, technicians, teachers and students as they are involved in changing them.

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4 ER4STEM ACTIVITY PLAN TEMPLATE

The ER4STEM activity plan template provides a generic design instrument that identifies critical elements of teaching and learning with robotics based in theory and practice and is expected to contribute to the description of effective learning and teaching with robotics. Thus, this template is in essence, an abstraction of what we have identified as essential and transferrable elements of learning with robotics. Our aim is to find a balance between a) a level of abstraction that it will make the template adaptable to different settings and b) a level of detail that will demonstrate the influence of a specific pedagogical approach. It will address the particularities of robotics and it will augment the affordances of the specific robotic kit used in each activity plan. The main pedagogical idea underlying the template is that it addresses robotics as a multidisciplinary constructionist activity (i.e. drawing from the pedagogical theory of constructionism Papert,1980) with an inherent social dimension which includes sharing ideas and learning from others. Further information about ER4STEM activity plan template can be found in WP4 – D4.2 [68] and D4.3 [69].

4.1 ER4STEM ACTIVITY BLOCKS

The ER4STEM activity blocks were designed as a response to the recommendations resulting from the first (WP 6 - D6.3) [13], and the second year evaluation of the project (WP 6 – D6.4) [15]. They are a new construct focusing mainly on the practical aspect (i.e. the how to in the classroom) of the **activity plan**. ER4STEM activity blocks are adjustable short activities (that can last from 10 minutes to 1 or 2 hours) a combination of which constitutes the "*how to*" in the classroom section of the activity plan. They are smaller units in comparison to the activity plans and they belong to the third level of the activity plan hierarchy: (i.e Activity plan template (1st level), Activity Plan (2nd Level) Activity Block (3rd level). An activity plan, and specifically the section "*how to*" consists of 3- 7 or more activities or activity blocks. In several cases, the activity blocks are accompanied by relevant worksheets that are designed to facilitate the implementation of the activity.

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5 ER4STEM GENERIC CURRICULUM

The ER4STEM Generic Curriculum on educational robotics is a structured tool providing processes, templates and guidelines to navigate, better understand and implement the educational robotics activities created under the ER4STEM project. The ER4STEM Generic Curriculum employs the ER4STEM Framework, the ER4STEM Activity Plans and builds on the evaluation results obtained throughout the project implementation, as well as from teacher interviews, to create set of tools and processes to guide researchers, educators and other relevant stakeholders to carry out a sequence of educational robotics workshops in order to achieve predefined learning outcomes.

The ER4STEM Generic Curriculum consists the following Key elements:

- **ER4STEM Generic Curriculum Map** - it highlights the progression between sets of activity plans, structured around use cases proposed by teachers. The curriculum map is the contextual visualization of educational robotics learning opportunities, as organized content into a set of use cases and contexts, revolving around desired learning outcomes.
- **Generic Curriculum Paths Template** – this is a tool which facilitates different stakeholders to design Generic Curriculum Paths for different robotics toolkits, containing various educational robotics Activity Plans and addressing various STEM domains. It has a simple structure serving as the backbone for the formulation of the use cases, or the logic, behind a Generic Curriculum Paths.
- **Generic Curriculum Paths Aggregation –** an element of the ER4STEM Generic Curriculum that provides an overview of the core values of the Generic Curriculum Paths. It aggregates the 21st century skills and targeted values, as well as the core subject-objectives of the Activity Plans, comprising a Generic Curriculum Path. It further gives an overview of the technologies, programming languages, total duration and targeted STEM domains to help an educator assess the applicability of a Generic Curriculum Path to their unique use case
- **Generic Curriculum Process** – it provides a clear picture on the key steps that need to be planned and executed for the implementation of educational robotics workshops.

Those elements are described in detail WP 2 - 2.4 ER4STEM Curriculum and are further organized as interactive content within a dedicated menu of the ER4STEM Repository on educational robotics.

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6 ER4STEM PROCESSES

A macro-process was created based on the research cycle methodology and the professional teaching and learning cycle [70]. The main aim was to conceive a suitable structure that could be used to define educational robotic processes that are aligned with the ER4STEM framework's objectives. The final macro-process is depicted in Figure 3. This macro-process is comprises four main macro-phases: **design or adaptation** of an activity, **implementation** in real settings, activity's **evaluation or assessment**, and **improvement** of the activity. The first macro-phase is divided into two possible steps, which represents the possibility to design an activity from scratch or adapt one from other existing activities. The second macro-phase is implementation, which mainly focuses on considerations involving the settings and the context in which the activity is going to take place. The third macro-phase provides instruments and procedures for evaluating the implementation. The fourth and last macro-phase focuses on possible improvements of the activity plan based on information derived from the implementation in real settings, on reflections from teachers, students, designers or any other relevant stakeholder. Once the activity has been improved, the cycle start over with the adaptation of the activity for future groups.

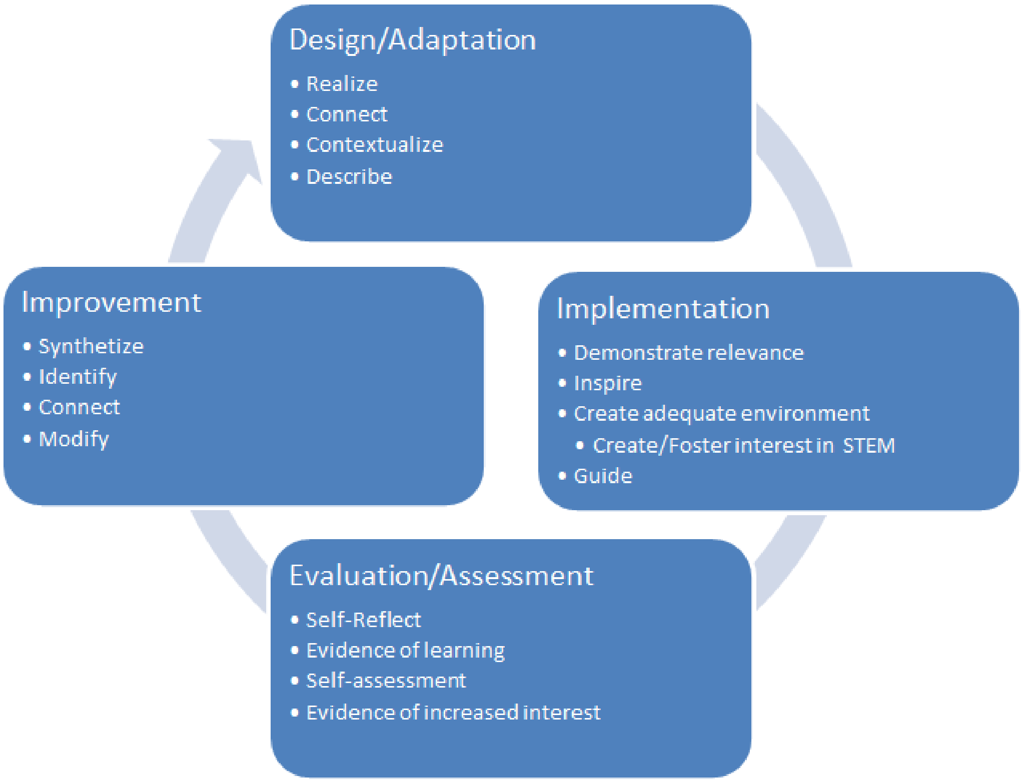

Figure 3 Framework's macro process definition

The ER4STEM framework provides two processes that have been created in WP2 and WP3 respectively. These two process have been refined through the analysis and suggestions provided from WP6. The next sub-section provides some additional considerations before using any of the process presented here. Then ER4STEM educational robotics workshops delivery process (Reported in D2.4) and finally ER4STEM conferences process (Reported in D3.4) are presented.

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6.1 SOME CONSIDERATIONS

Regarding the type of process that is going to be used, it is advisable to first reflect on the facets introduced in Chapter 2 and depicted in Figure 1. The following are questions for each one of the facets that could be helpful to answer before planning an educational robotics activity:

- ▪ Are the participants male, female or both?
- ▪ How old are the participants?
- ▪ What is the maximum number of participants that you are able to manage?
- ▪ What is the cultural background of the participants?
- • Is expected to have participants with disabilities?

The questions marked with ▪ bullet are present in the activity plan. The same notation is going to be used henceforth for questions related to other aspects of educational robotics activities organization. Once the context's questions have been answered, it is open to the designer to decide with which factor start with. The following are the questions for each facet:

Educational objectives:

- ▪ What is the domain of the activity? (e.g. Mathematics)
- ▪ What is the skill or skills that are going to be covered in the activity?
- ▪ Is any previous knowledge required?
- ▪ How are you going to assess the participants' progress?

Robotic Platform:

- Which are the robotic platforms available within your institution?
- Are you able to buy new robotic platforms?
- What is required to use the robotic platform? (e.g. batteries)
- How many robotic platforms do you have?
- What can you teach with each of the robotic platforms enlisted?
- What are the roles that could be portrayed by the robotic platform? (e.g. tool, tutor or peer)
- Does the robotic platform need to be assembled? How many times could it be assembled? In how many different ways could the robotic platform be assembled?
- How many robotic platforms are fully operational?
- How many spare parts are available?
- What is the recommended age group for the robotic platform(s)?
- How is the robotic platform programmed?

Equipment and space:

- What is the equipment that is available in your institution?
- How many of items of this equipment per type are there in your institution?
- What is the procedure to have access to this equipment?
- How many computers rooms are available in your institution?
- How many people use these computer rooms?
- How many people could fit in the computer room?
- Are there laptops/tables available?

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- For how many uninterrupted hours you could have access to the computer rooms or necessary equipment?
- How can you access to the computer rooms or laptops?
- Can you modify the room's organization?
- Where is the activity going to be carried out?

Pedagogical approach:

- What is going to be your role in the activity?
- What are the materials (e.g. Handouts or forms) that you are going to give to the students?
- What is going to be the process followed by the students?
- How are you going to manage students' difficulties during the activity?
  What is the social orchestration/s you are going to implement? (Working in groups? Working individually? Switching between different modes?)
- If the participants are going to work in groups, what are the criteria for group formation?
  Are you expecting interaction between the participants?
- How are you going to manage the different learning pace of the participants?

Once all the facets have been considered, it is necessary to determine if there is any inconsistency among these facets. For example, the use of collaborative approach could require modifying the distribution of the tables in the room. However, not all computer rooms allow the redistribution of tables. This could bring stakeholders to rethink the approach to the activity: changing the pedagogical approach or looking for a different space. Table 1 presents small example of questions and a template that could be used to look for incongruences or risks. The table includes a column for comments, which lets stakeholders add possible solutions or risks. These comments would allow for a better understanding on the decisions made during the design, which could sometimes be forgotten with time or help others understand the rationale behind any particular decision.

Table 1 Example of questions that could be used to determine incongruences.

Equipment and Space – Context		
Question	**Yes/No**	**Comments**
Is the equipment (e.g. platform and computers) sufficient for participants?		
Can you make sure that the equipment (e.g. robotic platform and computers) will be available for the duration of the activity?		
Equipment and Space – Pedagogical Approach		
Question	**Yes/No**	**Comments**
Can you re-organize the space to facilitate your pedagogical approach (e.g. group work? Interaction during construction etc)?		
Do you consider that all the available equipment could be used in the desired methodology?		
Equipment and Space – Robotic Platform		
Question	**Yes/No**	**Comments**
Does the robotic platform require specific software to be installed?		
If the answer to the last question was yes, can you install the program or is already installed?		

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Do you have all the necessary components to program the robot? (e.g. USB cables)		
If your answer to the last question was no, do you have budget to buy the additional components?		
Robotic Platform – Educational Objectives		
Question	**Yes/No**	**Comments**
Can the platform Support all the aspects of the activity you have in mind?		
Does the specific platform support the stated objectives?		
Robotic Platform – Context		
Question	**Yes/No**	**Comments**
Can you book the robots for the amount of hours that you are going to use them?		
Is the platform safe for the participants?		
Do you have enough robotic platforms for all the groups?		
If you have to buy materials, do you have enough budget to purchase them?		
The robotic platform shape is not considered as vulgar or offensive by the institution, country or community.		
Is the robotic platform advisable for the participants' age?		

6.2 EDUCATIONAL ROBOTICS WORKSHOPS

The generic educational robotics workshops delivery process was designed as part of the activities carried out under WP 2 of the ER4STEM project and is reported in Chapter 5 of D2.4 ER4STEM Curriculum. Within the third project year, the Educational Robotics Workshops delivery process evolved into the Generic Curriculum Process. The Generic Curriculum process describes the key steps of the implementation of sequences of educational robotics workshops, structured around common use cases proposed by teachers, in order to achieve their desired learning outcomes.

The scope of the Generic Curriuclum process is limited to the adaptation and delivery of the workshops and does not cover educational robotics workshops pedagogical design, which is a subject of WP4 or the educational robotics workshops evaluation, which is a subject of WP6. The process presented is concerned with the steps around the implementation of sequences of educational robotics workshops.

The aims of this process are to provide a clear picture to researchers and teachers on the key steps that were planned and executed within the ER4STEM project for the implementation of educational robotics workshops. From a research perspective, the process complements the evaluation data received from the workshops with detailed information on how this data was generated.

Throughout the course of the ER4STEM project, the overall process, its phases, description and criteria were continuously improved and updated based on the experience gained and the feedback received from relevant stakeholders and educational robotics workshops beneficiaries (students, teachers, school representatives and school management).

The process for the implementation of educational robotics workshops contains four phases, namely Initiation, Preparation, Execution, and Closure that are visually represented within the process scheme

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as horizontal lines. The “Preparation” and “Delivery” steps are presented in more details as sub-processes.

The final version, presented in D2.4, incorporates changes and improvements made throughout the ER4STEM implementation period and serves as an updated and final version of the Generic Process.

Although the updates do not change the process’s structure, they reflect on three very important issues 1) the need for closer cooperation with teachers/tutors for the workshops and educational materials’ organization and preparation 2) the alignment of the content of educational robotics activities to curricula of other disciplines, included but not limited to science, technology, engineering and mathematics domains and 3) the need for continuous improvement of the workshops, by sharing experience, data, Activity Plans and other relevant information with stakeholders .

6.3 CONFERENCES

The European Conference on Educational Robotics (ECER) is an international scientific robotics conference for students, commonly aged 15-19 years. The ECER provides an opportunity for them to prepare and present their artefacts and ideas to each other and to professional research scientists. The basic idea is to provide a chance for the students to show what they have been empowered to achieve. The ECER is a yearly event, which was organized in the frame of the project ER4STEM (WP 3) in the years 2016 (Reported in D3.1) [71], 2017 (Reported in D3.2) [72] and 2018 (Reported in D3.3) [73].

The developed ER4STEM conference process is derived from the ECER organization within WP3. The purpose is to provide a process on how to organize a student conference. The conference process provides a sequence of activities that should be performed by conference organizers prior to the actual event. It is divided into 4 phases:

1. The initiation phase is concerned with finding a host of the conference and defining the main topic(s).
2. The preparation phase encompasses planning the activities and required resources for the conference. Besides, during this phase an awareness campaign should be carried out for reaching out to possible contributors and participants.
3. The execution phase incorporates the detailed organization prior to the conference as well as its actual implementation.
4. Finally, the closure phase is concerned with the evaluation of results and impact.

The detailed conference process is described in deliverable D3.4 [74]. Despite being intended for conferences with a technical topic like educational robotics, the described organization process can also generally be viewed as guideline for any student conference.

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7 ER4STEM REPOSITORY

The ER4STEM repository is a platform designed to create a community to promote the critical and adequate use of robotics in education. It lets teachers, practitioners and people interested in educational robotics to get inspiration from existing activities and allowing them to share their own activities. The activities (also referred to as Activity Plans) are visualised in an interactive and intuitive way thanks to the adaptation of the activity plan template. When a stakeholder is building their activity plan online, tips are given together with activity blocks suggestions. This lets the designer of the activities to use or get inspired by proved and tested activities. The repository offers a graphical interface to easily identify activities that use specific programming languages, cover certain domains of knowledge or are linked with precise subjects.

The ER4STEM Repository can be accessed from https://repository.er4stem.com and further information is also available in WP 5 - D5.4.

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8 ER4STEM GLOSSARY

The ER4STEM glossary has been created to provide a tool to any person who is using the ER4STEM framework to get a better understanding of the main terms use in it. Table 2 presents words and their meaning in the frame of ER4STEM.

Table 2 ER4STEM Glossary

Word	Definition
Activity Template	A structure for describing educational activity plans including the main aspects that need to be addressed when designing a robotics activity, it is based on the theory of constructionism and on the special characteristics of robotics as educational technology. The activity plan template can be used to generate different examples of activities addressing formal and non-formal settings and different types of kits used.
Artifact	Physical or virtual object, usually the result of something.
Collaborative Learning	Learning based on collaboration between students and emphasizes also the skill on how to to collaborate
Competition Based Learning	A constructivist approach to learning in which competition is used as stimulus for the maximization of the intended learning outcomes specified in a given course or curriculum, while team members participate in a project under controlled environment.
Constructionism	Learning theory based on constructivism: The main idea is that students learn more efficiently when they engage in individually or collaboratively constructing, sharing and modding something meaningful for them be it a sand castle or a robot
Constructivism	Learning theory addressing learning as an active process where learning takes place through interaction of the learner with the environment
ER4STEM Generic Curriculum	In ER4STEM, we assume the definition of a curriculum being everything that goes in the learners' live such as planned and not planned interaction of pupils with educational objectives, instructional content, materials and resources used and materials and resources not used the sequence of courses, objective, standards and interpersonal relationships (Adams and Adams, 2003). The Generic Curriculum in ER4STEM is a mediating artifact between the ER4STEM Framework (WP1) and the implementation of ERWs (WP2), integrating products developed in WP4, in alignment with the evaluation results from the workshops (WP6). The ER4STEM Generic Curriculum on educational robotics is a structured methodology and a tool to navigate through educational robotics activities (as both educational approach and content), developed and applied by all partners.
ER4STEM Generic Curriculum Architecture	The ER4STEM Generic Curriculum Architecture represents the structure of all elements comprising the ER4STEM Generic Curriculum on educational robotics. The ER4STEM Generic Curriculum Architecture organizes the Generic Curriculum elements in three levels - macro, meso and micro levels, all of which are further broken down into context, content and process levels.
ER4STEM Generic Curriculum Map	The curriculum map is the contextual visualization of educational robotics learning opportunities, as organized content into a set of use cases and contexts, revolving around desired learning outcomes.

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	It is a part of the context layer of the generic educational robotics curriculum under the ER4STEM project.
ER4STEM Generic Curriculum Path	A tool introduced under the ER4STEM project to address desired learning outcomes through a set of use cases. A Generic Curriculum Path consists of a set of educational robotics workshops or single activities within the workshops activity plans, which are suitable for a given context, students, specific objectives and prior knowledge. A Generic Curriculum Path is designed to be further modified by the educator to fit their specific learning context.
ER4STEM Generic Curriculum Path Template	As is the Activity Plan Template, the Generic Curriculum Path Template is a design tool of a generic nature. The Generic Curriculum Path Template facilitates different stakeholders to design Generic Curriculum Paths for different robotics toolkits, containing various educational robotics Activity Plans and addressing various STEM domains. This template provides a simple structure serving as the backbone for the formulation of the use cases, or the logic, behind a Generic Curriculum Paths and is the common element between a set of Activity Plans.
ER4STEM Generic Curriculum Paths Aggregation	A table, providing an overview of the core values of every each one of the 6 currently identified Generic Curriculum Paths. It aggregates the 21st century skills and targeted values, as well as the core subject-objectives of the Activity Plans, comprising a Generic Curriculum Path. It further gives an overview of the technologies, programming languages, total duration and targeted STEM domains to help an educator assess the applicability of a Generic Curriculum Path to their unique use case.
ER4STEM Generic Process	A Generic Process in ER4STEM is a high-level process informing researchers and teachers on the key steps for the implementation of educational robotics workshops or conferences.
Digital Artifact	A digital object constructed by users of a piece of software (a video can be such an artefact, a digital story etc)
Discovery Learning	An inquiry-based and constructivist approach to learning. The learner draws on their existing knowledge and applies it to a new situation or problem and in the process identify the limits of their existing knowledge and discover new knowledge by manipulating objects and sharing ideas
Domain	An area of interest or an area over which a person has control.
Educational Activity Plan	A description of the main aspects a teacher or an instructor needs to consider in order to plan his/her teaching (may include objectives, resources, prerequisites etc)
Educational Artifact	An object cteated by students during a course of instruction. To be considered as an artifact needs to be lasting, durable, public, and materially present.
Educational Robotics Activity	An activity that makes use of robotics in an educational setting.
Educational Robotics	A collection of activities, instructional programs, physical platforms, educational resources and pedagogical approaches related to the usage of robotics for educational purposes.
Facilitator	A facilitator is a commonly defined as a substantively neutral person who manages the group process in order to help groups achieve identified goals or purposes.
Formal Learning Activities	Activities, which are normally delivered by trained teachers and pedagogues in a systematic intentional way within a school, higher education or university as part of the academic curricula, as defined by the OECD.

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Non-formal Learning Activities	Learning activities, which include trainings, workshops and courses, provided by non-trained educators without a formal curriculum, as defined by the OECD.
Learner Centered Design	Learner centered design focuses on creating software for heterogeneous groups of learners who need scaffolding as they learn while completing constructivist activities.
Learning Objectives/Outcomes	A set of objectives set out in a lesson plan or in an activity plan which aim to be achieved during the implementation of the lesson, the activity and/or a course. Can be long term, short term with different foci (pedagogical, cognitive, technological etc)
Mentor	Someone who supports a learner. They do not provide direct instruction but act as a guide or advisor.
Peer	A person who has equal standing/ knowledge/ skills with another or others, as in rank, class, or age
Problem Solving	This includes a) to solve different kind of problems in both conventional and innovative ways b)to devise effective solutions to real-world problems c) to identify and ask significant questions that clarify various points of views and lead to better solutions
Project Based Learning	Project Based Learning is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge.
Robot	A robot is a machine which operates semi- or fully autonomously to perform services useful to humans or the production of goods. IFR (International Federation of Robotics) subdivides service robots performing for the well-being of humans and equipment and Industrial Robots which are automatically controlled, reprogrammable, multi-purpose manipulator with three or more axes for use industrial automation applications and manufacturing.
Robotics	Robotics is a branch of mechanical engineering, electronic engineering and computer science that studies the creation and improvement of robots.
Skills	An ability and capacity acquired through deliberate, systematic, and sustained effort to smoothly and adaptively carryout complex activities or job functions involving ideas (cognitive skills), things (technical skills), and/or people (interpersonal skills).
21st Century Skills	Also known as 'soft-skills'. Skills that have been identified as being required for success in 21st century society and workplaces by educators, business leaders, academics, and governmental agencies. Important 21st Century skills are creativity, critical thinking, communication and collaboration.
Student-centred Learning	The concept of the student's choice in their education; others see it as the being about the student doing more than the lecturer (active versus passive learning); while others have a much broader definition which includes both of these concepts but, in addition, describes the shift in the power relationship between the student and the teacher
Teaching Methods	Different models and approaches used by the teacher to teach a subject/topic
Digital fluency	It refers to the technological knowledge of the students. Thus, it includes the ability to understand the fundamental concepts of technology operations and to know how to use digital technology

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	and media as tools to research, organize, evaluate and communicate information.
Workbook	A student's book containing instruction and exercises relating to a particular subject.
Kit	A set of articles or implements used for a specific purpose.
Arduino	Arduino is an open-source prototype platform, which lets users to program and control diverse of devices through the use of easy micro-controller programing approach.
Textual Programming	It is any programming language that uses text, usually in English, to describe the sequence of commands.
Visual/Graphical Programming	It is a programming language where users create the program through the graphical manipulation of elements.
Societal Issues	They are problems that influences individuals' life.
Life skills	A set of basic skills acquired through learning and/or direct life experience that enable individuals and groups to effectively handle issues and problems commonly encountered in daily life. They include creativity, problem-solving, decision-making, the ability to communicate and collaborate
Hedgehog Controller	A controller with several ports
Finch	The Finch robot by BirdBrain Technologies is a small educational robot manufactured under license from Carnegie Mellon University. It is programmable in over a dozen programming languages to include children of different age groups and has a variety of sensors to allow for the creation of interractive programs.
SLurtle Robots	A programmable robot in a virtual world
Thymio II	It is a robotic platform with several sensors that could be programmed using ASEBA study.
Lego Mindstorms	Lego Mindstorms is a hardware software platform produced by Lego for the development of programmable robots based on Lego building blocks.
ER4STEM Framework	ER4STEM framework makes explicit the connection between pedagogical methodologies, knowledge in robotics and 21st century skills through processes, pedagogical principles and tools that will let any stakeholder to design or adapt, implement and evaluate educational robotic activities.
Resilience	The ability to recover from failure and/or overcome problems.
Activity Blocks	Adjustable short activities (that can last from 10 minutes to 1 or 2 hours) a combination of which constitutes the “how to” in the classroom section of the activity plan. They are smaller units in comparison to activity plans and they belong to the third level of the activity plan hierarchy: (i.e Activity template (1st level), Activity Plan (2nd Level) Activity Block (3rd level). An activity plan, and specifically the section “how to” consists of 3- 7 or more activities or activity blocks. In several cases, the activity blocks are accompanied by relevant worksheets that are designed to facilitate the implementation of the activity.
Post-Activity Template	The post activity template is expected to be filled after the implementation of a robotic workshop as a reflection of the implementation process. It includes sections for reporting infrmation related to unexpected and interesting/critical events,, the way that tutors facilitated these iinteresting events or mitigated some critical or unexpected ones. It also asks teachers/tutors to describe what they believed that their students learned and provide evidence of

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	this learning using verbal descriptions, pictures or any other information they think is relevant

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9 CONCLUSION / OUTLOOK

This deliverable reported the final version of ER4STEM framework. The framework was created with the contribution of WP2, WP3, WP4, WP5 and WP6, and all project partners, who provided suggestions, ideas and best practices to develop a practical framework, to be applied by relevant stakeholders for the creative and critical use of educational robotics. WP6 provided a valuable contribution to the framework providing suggestions and results from each year workshops. Especially as the result of the first year analysis, WP6 provided ten suggestions that later were introduced in the framework as ER4STEM pedagogical principles. Consequently, the framework could be seen as an organizer and a window to the work and results achieved in ER4STEM.

Also, during the development of the framework a review of the current strategies on national and European level that encourages STEM education was done [8]. The main conclusions of this review are presented in the following sections, which are expected to contribute to the development of educational robotics.

9.1 CONCLUSIONS OF STRATEGY REVIEW FOR ER4STEM

Only four from twelve strategies and strategic initiatives in total, from two countries (Austria and Greece) mention educational robotics as educational tools to keep children motivated to learn STEM. Within **Schule 4.0. – jetzt wird's digital**, educational robotics appears in the strategy two times with relation to child-friendly programming environments, robotics and creative digital design. Namely, part of the strategy is the organization of competitions. One of those competitions, the "computer creative wettbewerb" ("computer creative competition") is about projects handed in by school students that are then rated by a jury. It is stated that projects regarding various topics can be handed in with robotics being one of these topics. Furthermore, the strategy names the establishment of Education Innovation Studios at the University Colleges of Teacher Education throughout Austria, which are meant for increasing teacher competences regarding child-appropriate programming environments, robotics (e.g. LEGO WeDo) and creative, digital designing. Another strategy, again from Austria, that considers educational robotics is **Talenteförderung in Niederösterreich** for fostering young talents specifically regarding STEM topics. Robotics was chosen as core domain as it represents a multi-disciplinary field. Two modules are offered: 1) Robot programming for 12 to 14 year-olds and 2) Robot construction for 14 to 16 year-olds. **ESERO**, a European strategic initiative, currently being implemented in Greece, envisages *robotics and automation workshops for primary and secondary school teachers*. During the workshops, participants are guided through activities that can be performed in the classroom, such as creating robots using LEGO WeDo or Arduino platform, and using them to perform a 'mission to Mars' with specific discovery objectives. Last but not least, the Greek Ministry of Education and Religious Affairs' strategic initiatives aim at involving a large number of teachers and students with new technologies, science and robotics. However, no specific initiatives were mentioned within the strategy review.

As per ER4STEM's results, robotics allows ALL learners to engage with the four areas of STEM education through the design, creation and programming of tangible artefacts to create personally meaningful objects and address real-world societal needs. This is why we believe educational robotics and the ER4STEM Project could provide valuable tools and artifacts to support the strategies that already envisage robotics as part of their activities and initiative and further provide arguments for the inclusion of educational robotics as a tool to explore STEM concepts. As many of the reviewed strategies encompass not only the development of technical skills but also of soft skills that are of importance for

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professional life, multidisciplinary domains such as robotics, could provide support to achieving the objectives and core goals of the strategies related to STEM.

Furthermore, following the industry needs analysis, conducted under WP6 of the project (D.6.5 Evaluation and Analysis of 3rd Project Year), identifies most required skills by the employers are active learning, critical thinking, problem solving and interpersonal skills, as shown within Figure 1 below:

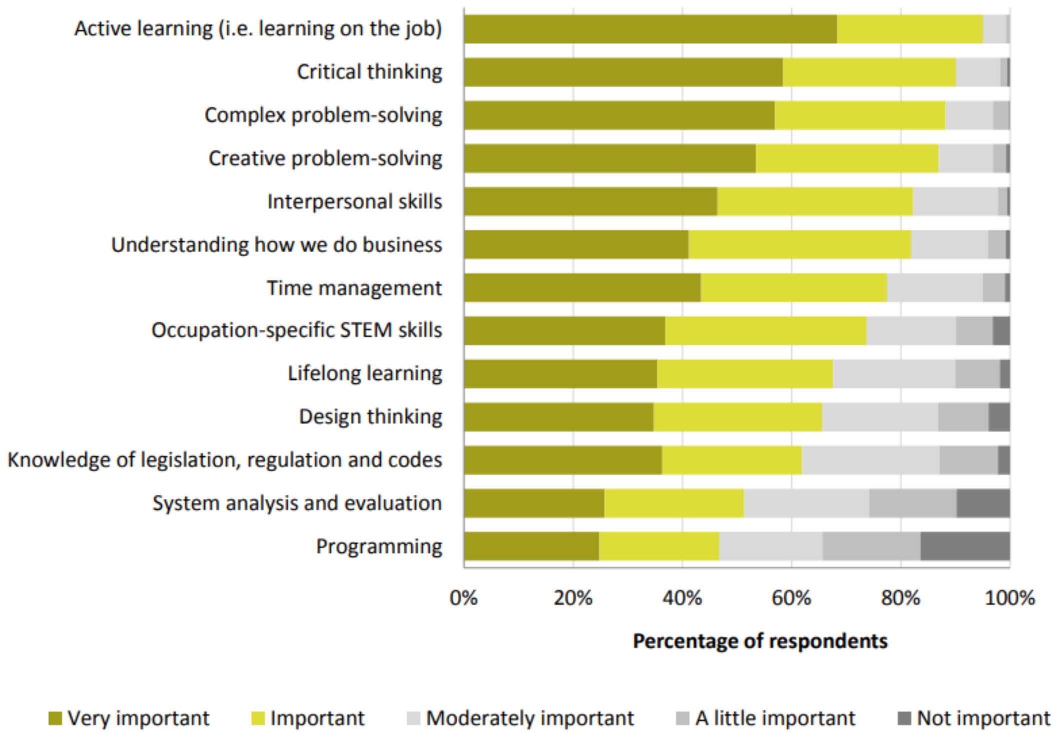

Figure 1 The skills that employers need from STEM graduates (D.6.5 Evaluation and Analysis of 3rd Project Year)

The strategies reviewed all aim to increase student's interest in STEM and reflect on the needs of the industry, which corresponds closely to ER4STEM's objective to turn curious young children into young adults passionate about science and technology with a hands-on use case: robotics. In the case of ER4STEM, the domain of robotics was chosen because it represents a multidisciplinary and highly innovative field encompassing physics, mathematics, informatics and even industrial design as well as social sciences. Our evaluation results further show that approaching STEM from a creative side creates multiple entry points to engage children from different backgrounds, with different interests and motivations.

This makes a compelling case for the integration of educational robotics as part of the strategic initiatives on a European and national level to increase interest in STEM education and careers.

9.2 POLICY RECOMMENDATIONS FROM THE STRATEGIES REVIEW

Based on the analysis of the 12 strategies and strategic initiatives reviewed and considering the results from the ER4STEM project, we can conclude that educational robotics could serve as an effective instrument for teaching STEM disciplines in schools and informal educational settings. Moreover,

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educational robotics effectively addresses the needs for developing 21st century skills. The educational robotics activities were well accepted by both girls and boys from a range of backgrounds.

The potential provided by educational robotics could be more fully exploited within national and European strategies through:

- becoming part of the strategic educational activities in STEM related strategies on both European, national and regional levels;
- being promoted as an innovative way to engage and motivate students in STEM-related disciplines in schools;
- initiating and funding educational robotics initiatives for non-formal educational organizations, which could result in raising young learners' interest in STEM and support the development of soft skills and 21st century skills;
- being a highly multidisciplinary vehicle for learning - encompassing all STEM disciplines and requiring a plethora of soft skills, which could serve as a great instrument for the cultivation of 21st century skills to meet the needs of industry. Further research on educational robotics is needed in order to gain further perspective on this potential;
- qualification programs for teachers which provide opportunities to develop both pedagogic and technical knowledge, so they are supported in the introduction and integration of educational robotics in the schools;
- practical guidelines and validation/certification mechanism to assure the effective, efficient and informed use of educational robotics for STEM;
- inclusion of evaluation mechanisms for the educational initiatives and activities, carried under the strategies, as well as mechanisms and toolkits for the ethical sharing of results. Those mechanisms will provide the necessary feedback loop for evaluation of the results and effective strategic planning.

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10 GLOSSARY / ABBREVIATIONS

EC	European Commission
ER4STEM	Educational Robotics for STEM
REA	Research Executive Agency
STEM	Science, Technology, Engineering, and Mathematics
WP	Work Package
ER	Educational Robotics
USB	Universal Serial Bus
ECER	European Conference on Educational Robotics
AL	AcrossLimits
CU	Cardiff University
TU Wien	Vienna University of Technology
UoA	University of Athens
ESI	European Software Institute

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11 APPENDIX 1: LITERATURE REVIEW ON EXISTING EDUCATIONAL ROBOTICS FRAMEWORK

11.1 EDUCATION TECHNOLOGY ADVANCEMENT OF ROBOTICS LEARNING FOR YOUTHS (EARLY) [75]

The objective of the framework is to prevent robotics being a one off activity towards the goal of a single competition, but instead to enable children to continually advance through different phases of robotics education from pre-school through to university. It furthermore aims to help in the creation of technology-rich resources for educational robotics. The framework is implemented onto robotics competitions – ensuring competitions progress through increasing difficulty/stages of learning depending on the student's ability and stage of education.

Framework Overview

It is structure in the following way:

- The EARLY framework is based on the PACT framework (People, Activities, Contexts, Technologies) introduced by Carroll (2002) with regards to Human-Computer Interactions
- EARLY has adapted the PACT framework and instead uses PEA (Participants, Environment and Arena such as it is depicted in Figure 4) as its physical constructs for implementation of the framework:
    - *Participants*: who they are and how they interact
    - *Environment*: composed of computer, material, robot and software
    - *Arena*: E.g. the challenge in a competition, any problem-based learning situation, etc.

Examples of its use by authors:

- In the article, the authors provide a case study of the EARLY framework's use in terms of a competition. The authors have referenced the article in other publications.

Examples of its use by others:

- The article is cited >10 times, once in a systematic review and otherwise as a brief reference to the need for long-term educational robotics rather than one-off competitions. Otherwise, the framework appears largely unused.

Critiques from others:

- None found.

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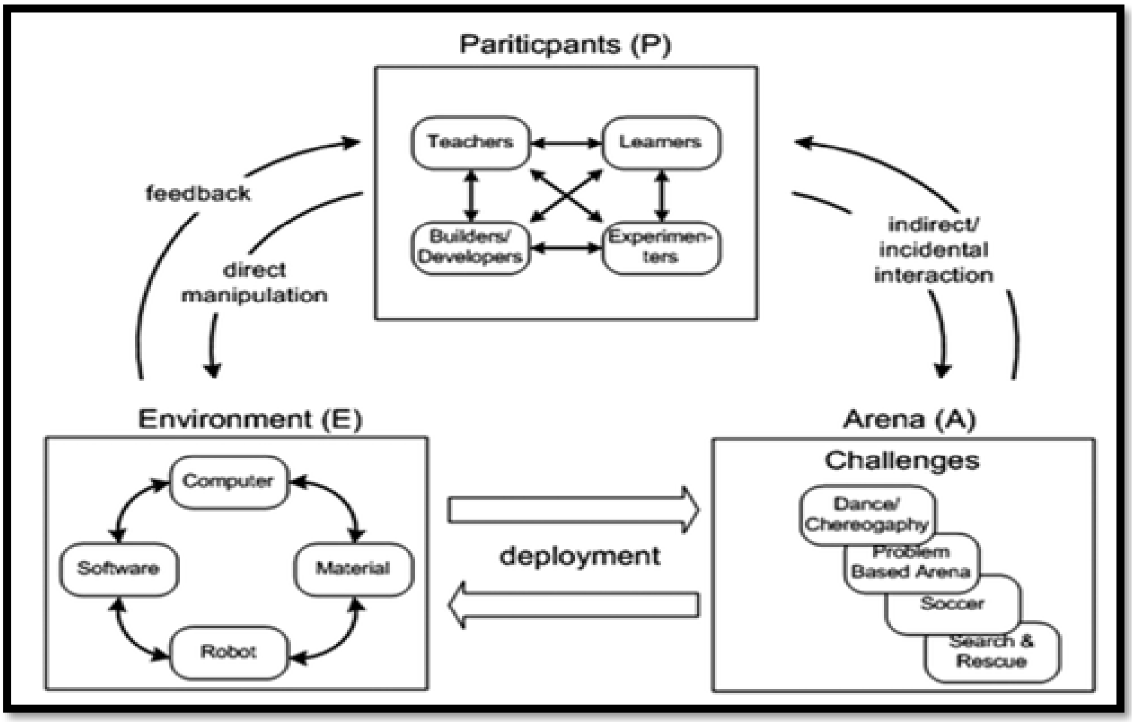

Figure 4 Visual representation of the EARLY Framework [75]

11.2 THE PRINCIPLES OF EDUCATIONAL ROBOTICS APPLICATIONS (ERA) [76]

The framework is a set of 10 principles that underlie successfully employing educational robotics, which is in line with constructionism. The framework:

- Explains how robots help students learn and the benefits of educational robots to teachers.
- Offers a checklist for those who want to design educational robots or develop activities that use educational robots.
- Helps justify the investment by schools in robotic technology.
- Suggests underlying cognitive and developmental processes.
- Provides researchers with a set of claims to evaluate.

The authors have made the principles themselves abstract in an attempt to ensure the framework is "future-proof" and not dependent on robot-type.

Framework Overview

It is structure in the following way:

- The principles form a holistic set, in which individual principles can interact with and relate to each other.
- Each principle is fully explained in the paper (approx. 1 page per principle) which is extensively linked to literature. For the purpose of this review, the principles are briefly summarised in Table 3.

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Table 3 Summary of the ERA Principles

Heading	Principle	Description
Technology	Intelligence	Robots can have a range of limited functions (behaviours) which can improve student learning
	Interaction	Allows an active learning process
	Embodiment	Students benefit by interacting with **physical** (as opposed to virtual) robots
Students	Engagement	Educational robotics can create positive learning attitudes – capturing students' attention and forming a relationship with the robot
	Sustainable Learning	Robotics enables learning of long-term cognitive, social, emotional and personal skills (soft or 21st century skills)
	Personalisation	Robotics can create a flexible learning experience which suits the individual needs of a student
Teacher	Pedagogy	Robotics can be related to pedagogical theories
	Curriculum and Assessment	Educational robotics can be used in traditional curriculum areas
	Equity	Provides an equal chance for students regardless of age, gender, race etc.
	Practical	Robotics must be carefully implemented (both systemically in practically in classrooms) in order to make its greatest positive contribution to education

Examples of its use by authors:

- The authors have later published research which further investigates the principles and applies them, for example:
  - Applying principles in an online research community called e-Robot [77].
  - Enhancing the performance of minority students [78].
  - Relating the ERA principles to computational thinking [79].
  - Relating it to other teaching frameworks such as "TACTICS" [80].
  - A fuller explanation of the Pedagogy principle [81].

Examples of its use by others:

- The article is cited by 14 other authors, for example referencing specific principles within the framework [82],or referencing the relationship of a specific robot within the framework [83].

Critiques from others:

- None found

11.3 OUTCOME OF THE TERECOP (TEACHER EDUCATION IN ROBOTICS-ENHANCED CONSTRUCTIVIST PEDAGOGICAL METHODS) PROGRAMME [84] [6]

The framework explores the role of constructivist pedagogy in a) educational robotics in a school setting and b) training teachers to use robots in education. Although the author refers to a framework multiple times during the paper, there is no clear structured framework.

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Framework Overview

It is structure in the following way:

- The paper explains its framework in terms of how to implement the pedagogy behind educational robotics in teacher training, whilst training teachers in educational robotics. The framework explores:
    - White-box technologies allowing creative thinking in learners
    - The importance of encouraging students (teachers being training) not just to build robots but to experiment and explore their ideas
    - Posing robotics activities as research projects
    - The role of students (teachers being trained) – working in groups, experimenting, reaching conclusions
    - The role of trainers – not having intellectual authority but acting as an "organiser, coordinator and facilitator"
- The paper illustrates best practice for teacher training through two case-studies (integrating robotics in training courses for future teachers, and integrating robotics in further training for in-service science teachers).

Examples of its use by authors:

- The author cites the paper in two later works – one exploring the general state of educational robotics [3] and the other exploring the implementation of robotics in physics lessons [85].

Examples of its use by others:

- The paper is cited over thirty times by other authors. It is generally referenced for its pedagogical emphasis, as a 'correct way' to implement educational robotics in ensuring the teachers are comfortable – focussing less of the hardware itself.

Critiques from others:

- None found

11.4 EDUCATIONAL ROBOTICS IN EARLY CHILDHOOD EDUCATION [86]

The framework is a tool for early childhood educators to use to design and teach educational robotics and programming. This tool is in the form of a conceptual model, made of 7 distinct phases, which has been developed following a series of methodological and pedagogical approaches. The model is aimed at enabling the implementation of early childhood robotics at a classroom level rather than at a systemic level.

Framework Overview

It is structure in the following way:

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- The model is shown in Figure 5. The paper does not especially explain the model after presenting the seven stages, instead continuing onto explaining the authors' methodological and pedagogical approaches for designing the model. The model and approaches were implemented using the Beebot robot.

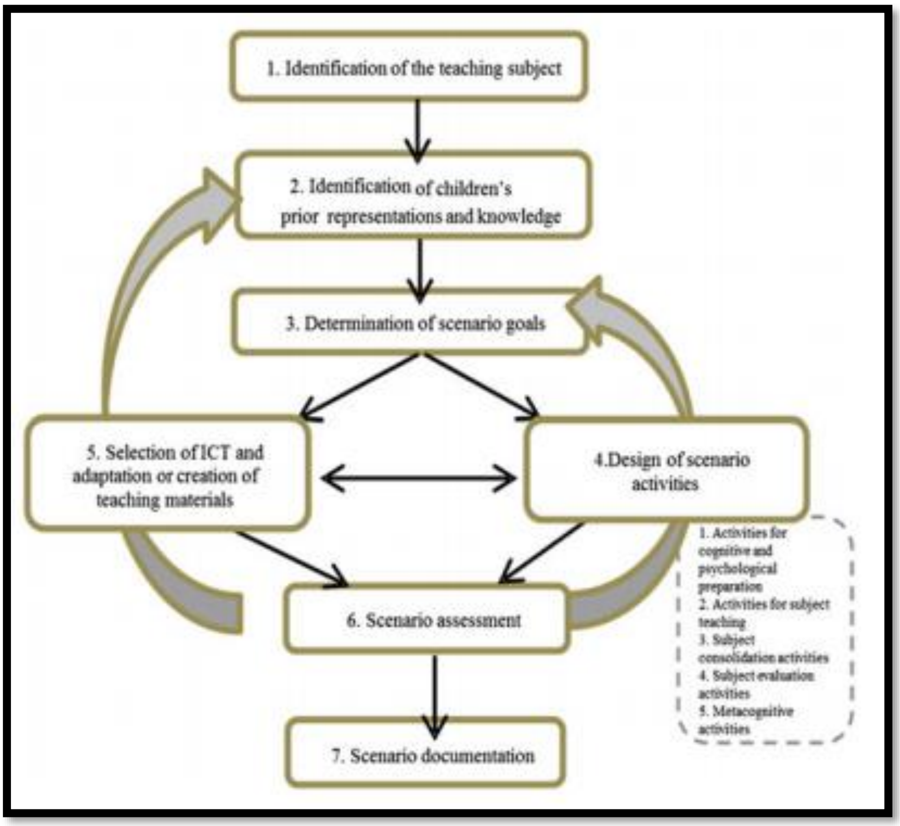

Figure 5 Seven phase model for designing educational scenarios for robotics in early childhood education [86]

- These (early childhood education) approaches are:
  - Methodological:
    - *"(a) the organisation of the educational scenario"* (designing structure and content)
    - *"(b) the introduction and the integration of didactic transposition of programming and informatics concepts"* (authors recognised that other literature did not integrate programming and informatics concepts)
    - *"(c) the development of instructional design"* (used to teach programming and informatics to increase the cognitive difficulty)
    - *"(d) the integration of inherent teaching strategies in pedagogical and informatics design"* (integrate, for example, problem-solving, cognitive conflict and inquiry)
    - *"(e) the use of explicitly stated teaching contracts"* (specific to each activity)
    - *"(f) the development of research protocols (instruments gathering data) for each individual."* (in order to evaluate)
  - Pedagogical:
    - *"(a) the development of a pseudo-language"* (graphical representations on cards support tailoring robotics to early childhood)

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    - *"(b) the development of additional teaching materials"* (describes resources)
    - *"(c) the initiation/organisation of an appropriate learning context"* (based on children's prior knowledge)
    - *"(d) the appropriate adaptation for implementation by in-service teachers in typical classrooms settings, taking the role of facilitators and co-researchers."* (enabling teachers to run the lessons)
- The paper also gives: an overview of programmable toys available for early childhood; a literature review of early childhood robotics; and an empirical investigation of the framework from the implementation of Beebot activities through a European project with 46 educators and 864 children.

Examples of its use by authors:

- In the paper itself, in the closing section outlaying the investigation. It is found that their approach was effective in enabling teachers with no prior experience with robotics or programming to teach using the Beebot.
- Author Komis has cited the framework in their work on broader frameworks regarding technology in education and ICT [87].
- The framework is cited in a later robotics framework [88].

Examples of its use by others:

- Cited 8 times by other authors.
- E.g. Burbaite *et al.* [89] briefly cite in relation to computational thinking and computer science
- E.g. in Jung and Won [90] systematic review of trends in robotics in education research, the paper is cited to define what the authors are referring to as robotics education.

Critiques from others:

- None found

11.5 FRAMEWORK OF EDUCATIONAL SCENARIOS AS A BASIS FOR PLANNING AND ORGANISING EDUCATIONAL ROBOTICS ACTIVITIES [88]

The framework is based on scenario-based approach for designing educational robotics activity aiming to support co-creative problem solving in K12 formal education context. Authors divide educational robotic activities in two categories and they will focus on the second category. The first category is non-integrated extracurricular activities, which are not aimed to evaluate participants' learning performance and it does not have a well-defined learning objectives. Nevertheless, participants are able to learn about topics. The second category is activities integrated in the classroom, which are activities that provide a detail procedure that leave not space for creativity.

Framework Overview

It is structure in the following way:

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- Scenario-based activities provide:
    - Instruction for the teachers.
    - Theoretical framework for each problem addressed.
    - Material required for the implementation.
    - Activity sheets for students.
    - Possibly other materials.
- Five activities are recognized:
    - *Preparatory activities*: are activities that aims to prepare learners for the activity and they do not include the use of the robot.
    - *Activities for initial knowledge construction*: are activities that the teacher guides participants to manipulate robots through peer-group interaction.
    - *Activities for the knowledge construction and consolidation:* are activities where participants have more responsibility to design, manipulate and engage with peers.
    - *Evaluation activities:* are those to measure learners' improvement.
    - *Metacognitive actives*: are those that though the use of robotics could help participants to better understand and control their cognitive process. E.g. problem solving.
- Taxonomy of ER activity according to the learners' engagement in the knowledge building process
    - Passive exposure to robotics – without manipulation
    - Discussion or debate about robotics – without manipulation
    - Individual or collaborative step-by-step robotics – procedural
    - Engineering oriented robotics – individual or collective
    - Co-creative robotics project oriented to solve realistic and challenging.
- Examples of the first three activities:
    - Preparatory activities: lecture-based introduction to robotics and classroom debate about robotics.
    - Activities for initial knowledge construction: individual guided activity (procedural) and collaborative guided activity (procedural)
    - Activities for the knowledge construction and consolidation: Individual or collaborative engineering problem and co-creative project-oriented robotic challenges.
- Critiques from others:
    - None found

11.6 THE ROBERTA INITIATIVE [7]

The Roberta initiative specifies several characteristics that teachers and activities must have to be considered as Roberta teacher and activity, respectively. These characteristics could be cluster in four main areas: activity and teacher characteristics, design ideas, and quality criteria. The design ideas for an activity are: selection of interesting topics, provide examples, allow rapid achievements, and strength participants' self-confidence. Once the activity is created, it has to fulfill the following requirements: last from 2 to more than 40 hours, be suitable for mixed groups, be connected to real problems, and be certified by the initiative. The people responsible to implement Roberta's activities should: be certified by the initiative, promote communication, creativity, independent work, gender awareness and gender-sensitive, and developing participants own ideas. Finally Roberta quality criteria are: the maximum number of participants per activity is 12, teacher-training takes at least 12 hours,

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participants work in teams of two and each team has its own computer and robotic construction kit, and teacher-training will be evaluated by the participants at the end of the course.

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12 APPENDIX 3: LITERATURE REVIEW ON CREATIVITY

Creativity is an abstract concept that everyone uses but when they are asked to define its meaning they struggle to come with a precise and clear definition. More important, most people link creativity with artistic creations, neglecting its presences in other fields. Nevertheless, creativity has been acknowledged as an important factor of competiveness in modern organizations [30] [29]. Despite its importance, there is not a unify definition of creativity [91] [28] and it could vary depending on the field and researcher. Nevertheless, there are common characteristics among definitions, which could slightly differ on terminology. Therefore, researchers tend to define creativity as the ability to come with ideas or products that are *novel* and *useful* [91]. It is important to notice that the interpretation of novel and useful is going to be given by the social context [31].

As a consequence, Fischer et al. [92] have determined require elements in creativity, they are: (1) originality or novelty,(2) expression, (3) social evaluation and (4) social appreciation within a community. Originality means people having unique ideas (mostly in the realm of psychological creativity) or applying existing ideas to new contexts. These ideas or new applications are of little use if they are only internalized; they need to be expressed and externalized so that social evaluation can take place where in other people (with different backgrounds and perspectives) can understand, reflect upon and improve them. Last, social appreciation refers to the effects of social rewards, credits and acknowledgements by others (e.g. reward structures such as in a gift economy and a market economy) that motivate (or thwart) further creative activities." This dissection of elements makes explicit the role of social environment in the appraisal of an idea, product or application as creative.

Until this point, the definition of creativity and its elements assume that creative ideas and products have similar relevance, which could tend to undervalue individual creativity. For example, kids could come with an idea or product that for them is creative but for the society is something that has been already in use. Therefore researches have described two types of creativity [31]: little-c, which occurs when individuals comes ideas that are new for them and for others but without a significant relevance to their field; and big-c, which occurs when individuals come with ideas that revolutionize their fields. However, this dichotomy has two limitations. First, it makes that many ideas that revolutionize a field but are not yet broadly accepted fall in the little-c group. Second, there is not clear distinction between ideas that contribute in the field, but are not that relevant to fall as big-c, and ones that are relevant to individuals. To solve this, Kaufman and Beghetto proposed four types of creativity [26]: little-c, big-c, mini-c and pro-c. Mini-c is the creativity inherent in the learning process and as consequence relevant at individual level [93]. Little-c is the creative that involves novelty beyond individuals. Pro-c could be positioned between little-c and big-c, and it embedded ideas that are considered with significant valuable in their field but their contribution has not been recognized as big-c.

12.1 SOCIAL CREATIVITY

Social creativity is distributed in nature and product of different shaping forces: the individual, mixture among individuals (different interests, skills and knowledge that compose specific communities); the interactions between them and their social and technical environment. MC Squared project has identified social creativity as complex concept, therefore they selected dimension relevant to their objectives. They focus on a) social creativity b) boundary crossing (as aspect of creativity) c) documentational genesis (the evolution of teacher resources).

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12.2 TYPES OF IDEAS GENERATION

Boden suggest three different ways on how creative ideas are created [94] [95]: Combinational, Exploratory, and Transformational. The first type produces unfamiliar combinations of ideas from familiar ideas. The second and third are related between them. The second (Exploratory) is done when new ideas are generated through the exploration of accepted styles of thinking. In the last type (Transformational), styles of thinking are transformed by altering one or more dimensions.

12.3 CREATIVITY PROCESS

Literature offers variety of creative processes. Ones described creativity process in four steps that could vary from authors focus. For example [30] proposed generation, incubation, evaluation and implementation. While Warr and O'Neil are focused on analysis of the problem, generating ideas, evaluating ideas and donating (sharing). Additional steps have been added to point out points that could be helpful to consider, such as Couger, who identified five steps [96]: problem definition, compilation of relevant information, generation of ideas, evaluating and developing. Others have tried to highlight the importance of technological tool in the creativity process, such as Shneiderman who proposed eight steps [97]: search of previous information, use of visualization tools, relate, thinking, exploring, use of composition tools, reviewing, and disseminating. As it could be observed, there is not a unique process that could be used in all type of situations, but rather the creative process should be selected depending on the specific situation [30]. For example, MC Squared project aims to foster creativity in mathematics. Therefore, the authors proposed the following steps: framing the problem, coordination, reflection and transformation.

12.4 FOSTERING CREATIVITY: REQUIREMENTS

Although creativity could happen naturally in many cases, the creation of environments, that promotes creativity, is also possible. The following are characteristics identified to promote individuals' creativity:

- Definition of clear goals [27]
- Balance between knowledge and challenge [28] [27]
- Creation of a climate where students are not fear about failure [28] [27] [29] [30]
- There not should be competitions or rewards after finishing [28]
- Motivate students to be creative [31]

In case of groups' creativity, the following are the required characteristics:

- Differences in the group (symmetry of ignorance) - [92] Mentioned also in MC squared and disagreement [98]. Here, it is important to notice that the degree of differences is important.
- Use of boundary objects – expressing and integrating different opinions and interpretations [92]
- Need for reflection of the individual [92]
- Externalization [92]

12.5 ELEMENTS IN ROBOTIC ACTIVITIES

Nelson proposed the following elements specifically to activities that involves robotics [32]:

- Ability to visualize solutions, for example sketching or building prototypes of robots.

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- Thorough knowledge base in the domain, for example building on previous robotic projects
- Ability to decompose and manipulate partial solutions
- Ability to take informed risks, which include tasks with no right or wrong answers
- Flexibility to try alternative techniques
- Creativity friendly environment
- Practice

12.6 EVALUATION METHODS

Methods to evaluate creativity depend on the emphasis of the researcher [91]. Those researchers who emphasize social appraisal will use rates and judgments; those who focus on person-centre will use mechanisms to evaluate personal traits (e.g. intelligence). Some examples are personality test, biographical inventories, and behavioural assessment; those who are interested in the process will focus on the steps followed; those who interest are in the product would evaluate the originality of the final product; and those who are concern about role of the environment will focus on climate for creativity.

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13 APPENDIX 4: LITERATURE REVIEW ON CRITICAL THINKING

Governments and educators have recognized critical thinking as an important skill [33] [99]. Unfortunately, researchers have seen that it is not taught adequately in schools nor universities [33] [100] [34]. Some authors suggest that this is due to insufficient theory connecting learning experience and development of it [100]. This could be due to a misinterpretation of critical thinking with other skills, as problem solving [101] [33], and a missing consensus on the definition of critical thinking [33] [99] [102]. This consensus will take some time, due to the existence of philosophical or psychological perspectives [99] of critical thinking. Philosophical perspective tend to come with definition of critical thinking that are not realistic. In many cases providing a list of criteria to define a critical thinker. On the other hand, psychological definition focus on the types of action that critical thinking involves, including skills and/or procedures. These two perspectives have found agreements between them (e.g. dispositions and abilities) but they still have some disagreements (e.g. transferability to new context) Despite the multiple perspectives and definitions, it is possible to define critical thinking as the act of identify, analyse, and evaluate arguments and truth claims [103] [101] [104] . This process of identifying, analysing and evaluating requires knowledge, other abilities and disposition that have been already well documented in the literature. For the whole list on other abilities, metacognitive skills, barriers and dispositions refer to [103], [101], [35] and [104].

13.1 EVALUATING METHODS

In the literature is possible to find three standard test used to evaluate critical thinking. This test are:

- Cornell Critical Thinking Test
- Watson-Glaser Critical Thinking Appraisal
- Smith-Whetton Critical Reasoning Test

Nevertheless, some researchers, as Larsoon, argue that these tests reduce the complexity of critical thinking to a multiple option questions, which could hinder the critical process. Therefore, Larsoon [100] proposes the use of essays to evaluate students' capacity to critic a statement.

13.2 TEACHING CRITICAL THINKING

Researchers have identified as main problem for teaching critical thinking is schools and universities is that curriculums are focus on subject, leaving small space to teach generalizable skills [33]. Pithers and Soden [33] suggest the following ideas to teach critical thinking in a classroom:

- Make students to think about the process of thought more explicit, making them reflect upon their thinking
- Make students to think about the strengths and weaknesses on their way of thinking
- Teacher could make connection between the subject and other topics
- Teacher should aim to challenge current student ideas. For example generation of hypothesis, interpretation of information or data, helping to understand the judgmental process.

Moreover, Walker and Finney [34] concluded that self-awareness through reflection has helped students to improve their critical thinking.

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13.3 INHIBITING CRITICAL THINKING

Raht [35] recognized eight behaviours that should be corrected on students:

- Act without thinking - impulsive
- Need help at each step – over dependent
- Use goal-incompatible strategies – do not perceive cause-effect relationships
- Have difficulty with comprehension – miss meaning
- Are convinced of the rightness of their belief – dogmatism
- Operate within narrow rule sets – rigidity/inflexibility
- Are fearful – not confident
- Condemn good thinking as a waste of time – anti intellectual

Sternberg [36] identified fallacies of stakeholders (e.g. teachers, parents and students) that inhibit critical thinking. These are:

- Believe that teachers and professors do not have nothing to learn from students
- Critical thinking is solely the lecturer's job.
- Believe that there is a correct programme for the delivery of critical thinking. It depends on the programme goals, content, context or culture.
- The choice of a critical thinking programme is based on a number of binary choices
- The right answer is important.
- Notion of mastery-learning.

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14 APPENDIX 5: LITERATURE REVIEW ON COLLABORATION

Collaboration has been identified as main factor for the success of projects [23] [17] and it has been included in the set of 21st century skills. Collaboration is considered a skill [21] [20] that need to be learnt and improved. Nevertheless, creating groups would not imply that group-members collaborate within them [17] [18] [19]. If a group is not created properly, it could jeopardize the expected final outcome [17] or the learning process [19]. Therefore, collaboration must be taught and trained. However understanding collaboration is not as easy because there is a misconception on its meaning and scope. For example, Tjosvold et al. [105] use interchangeably the concepts cooperation and collaboration to mean collaboration. This brings up the following questions: what is collaboration? What is the difference between collaboration and cooperation?

The previous questions could be answered through an overview on the differences and similarities between collaboration and cooperation. The main similarity is their general definition, which is a group of people working together to achieve a common goal [19] [18] [17] [106] [24]. However, the difference comes up when they are look in detail. Korzar [18] uses the following example to illustrate their differences. She says that cooperation is like an assembly line, in which the problem is divided in small parts and each part is assigned to each group member. However, there is not big interaction within members and in some cases one person could make the whole work. On the other hand, collaboration involves [23] communication, coordination, mutual support, balance of members contribution, and cohesion within members. Therefore, collaboration includes cooperation but not the other way around.

Although cooperation and collaboration are used to describe process and activities, they do not provide any information about the organization of the people. Two words are commonly used to describe the organization during collaboration or cooperation: team and group. Once again, these two words are used interchangeable. Beebe and Masterson [21] defined group as three or more people working together with a share purpose, sense of belonging and that could influence each other. On the other hand, they defined team as a coordinated group with a highly structure, which embraces a clear specification of roles, expectations, and organization. In words of Beebe and Masterson [21] "*teams are small groups, but not all the groups operate as a team*". In addition, they dissect these two words on goals, roles and responsibilities, rules and methods. This differentiation is presented in Table 4.

	Groups	Teams
Goals	Goals may be discussed in general terms	Clear, elevating goals drive all aspects of team accomplishment
Roles and responsibilities	Roles and responsibilities may be discussed but are not always explicitly defined or develop	Roles and responsibilities are explicitly developed and discussed
Rules	Rules and expectations are often not formally developed and evolve according to the group's needs	Rules and operating procedures are clearly discussed and developed to the help the team work together
Methods	Group members interact, and work may be divided among group members	Team members collaborate and explicitly discuss how to coordinate their efforts and work together. Teams work together interdependently.

Table 4 Differences between groups and teams [21]

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14.1 WORKING OR NOT IN A TEAM

As the example of the assembly line, not all real problems require the creation of team to work on a problem. Identifying when to bring together a team or a group could save time and resources. To learn how to identify this, it is required to understand first the advantages and disadvantages of working in a team. Beebe and Masterson identified the following [21]:

- *Advantages*: share of knowledge within members, stimulate creativity, involvement of members in decisions, satisfaction on the decisions made, and gaining a better of their self.
- *Disadvantages*: some members could pressure to conform to the majority opinion in order to avoid conflict, one person could dominate discussions, team members could rely too much on others to get the job done, the answer to the problem is already by one of the members, and working with others takes longer than working alone.

Finally, Peter Scholtes et. all [24] suggest that a team is required when the task is complex and the effort of one person is not enough, creativity is needed, the path to come with a solution is unclear, an efficient use of resources is required, high commitment is desirable, cooperation is essential to come with a solution, members have a stake in the outcome, the task or process involved is cross-functional, and none has enough knowledge to solve the problem.

14.2 TYPES OF TEAMS AND GROUPS

As it was already mentioned, groups and teams are different and as a consequence they have different objectives. Beebe and Masterson [21] identify two type of groups: primary and secondary. They define primary groups as groups that exist with the solely purpose of creating association within people, such as family groups and social groups. On the other hand, secondary groups are defined as groups that are created to accomplish a task or achieve a goal. In this level, they identified six sub-groups. i) *Problem solving groups*, which are created to overcome obstacles and achieve specific goals. ii) *Decision making groups*, which are established when discussion and decision is required. iii) *Study groups*, which are created to share and learn from others. iv) *Therapy groups*, which members work together to overcome personal problems and provide encouragement. v) *Committees*, which are created from the election of their members to solve an specific task. Finally vi) *focus groups*, which are asked to participate on a particular topic or issue to help other to get a better understanding of that specific topic.

Similarly, Teams could be named depending their goals. Peter Scholtes et. all [24] identify two main types of teams. The first type is project teams, which are temporary and have specific focus, such us research projects. The second type is ongoing or functional work teams, which last for long periods. In this category, the authors recognized five different teams. i) *Natural work teams*, which are created from people that come from same area in the organization and who share responsibility for complete a work. ii) *Self-directed work team*, which is a "natural" work team that also shares management responsibilities. iii) *Process management team,* which focuses on sharing responsibility for monitoring and controlling a work process. iv) *Management* team, which is created when managers have interdependent functions. And v) *virtual teams*, which have a limited face-to-face interaction and could be geographically distributed. Although the work is done distributed and the face-to-face interaction is limited, face-to-face meetings are helpful to create good working relationships and promote the team cohesion.

14.3 CREATING A TEAM

Bringing people together with a common purpose is not enough to success in the endeavour [17]. Kennedy and Nilson identified four phases for the correct creation of a team [20]. The first phase is *forming*, in which members meet and it is socialized the activities that are going to be carried out during the time the project is together. At this initial point, some of the members cannot understand the purpose of the team. Therefore, it is important to discuss within all team members the expectations, roles, responsibilities, and establish ground rules. The second phase is *storming*, which is characterized by individual assertiveness, hidden agendas, conflict and discomfort. This phase is of vital importance for the performance of team in subsequent phases. Therefore, it is important to involve all members in the communication and start creating the membership into the team. Once all initial frictions has been solved, the team starts to work on its objectives. This phase is called as *norming*. With a high integration within team members, the team pass to the next phase called *performing*. This phase is recognized due to the close attachment within team members and the constructive mechanism to resolve conflicts and ideas. Nevertheless, the time that each phase lasts depends on team members, leaders and objectives.

Improving the team cohesion

To facilitate the creation of the team, there are some behaviors that could be encourage to create he feeling belong. These behaviors are [21] [22]:

- Talk about the task.
- Motivate trust within members.
- Share time formal and informally with the team members.
- Create effective communication channels.
- Generate an environment where team members feel that they are heard.

14.4 ROLES

The roles when people is working in a team are presented in Table 5.

Role	Description	Responsibilities
Team Members	People who share knowledge, experience and expertise that work together with others	• Contribute to the project. • Share knowledge and expertise. • Participate in meetings and discussions. • Assist the team leader managing meetings. • Communicate effectively with colleagues. • Listing to others and stay open to their ideas.
Team Leaders	People who orchestrate team activities, maintain team records, and serve as a link within team members	• Serve as contact point for communication between the team and the rest of organization. • Develop ways of updating others who might be affected. • Keep official team records. • Help the team to resolve its problems.

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Coaches	People who teach and support team leader to facilitate the work of the team	• Attend to meetings but not as member or leader. • Focus more on team process than tasks. • Help team leader revise plans in response to suggestions. • Encourage the team to seek the causes of problems before identifying participants.
Sponsors	They identify improvements, review and support the work of the teams	

Table 5 Roles and responsibilities in a team [24].

14.5 CONFLICTS IN TEAMS

People with different background, personalities and ideas that could create disagreements inside teams that could finish in a conflict compose teams. Despite most beliefs, conflict is something that must not be avoid or fear [22]. However not all conflicts are originated from the same reason and determining the real reason is important. Three types of conflict are identified [22]: i) *zero-sum*, which is a pure win lose conflict; ii) *mixed-motive*, both can win, both can lose, one can win and the other can lose; and iii) *pure cooperative*, both can win or both can lose. Once the reasons has been stablished, it is required to face the disagreement with respect and come with a solution. The following are three suggestions:

- Explore your interests and other's interests to identify the common and compatible interest that all share as base to find a solution to the conflict.
- Define the conflicting interests as mutual problem to be solved cooperatively within the parts involve. This facilitates recognizing the legitimacy of each other's interest and the necessity to search for a solution responsive to the needs of all.

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15 APPENDIX 6: LITERATURE REVIEW ON SUSTAINING AND MAINTAINING ATTITUDES TOWARDS STEM

There have been a number of studies in the last years, which investigated the reasons why sciences, technology, engineering, and mathematics (STEM) are so unpopular in school. There are different reasons why young pupils are losing interest in STEM. One study published several reasons for the loss of interest in STEM There are too much content in several curriculums. The teacher use wrong teaching methods, the reputation of the discipline are not popular at the peers. The learning process is not easy most of the pupils get bad marks in STEM subjects and think STEM disciplines are too difficult. The wrong teaching methods are frontal teaching reading of instructional text and too theoretical than learning through making and train exercises during the lesson. Therefore, schools need more possibilities (e.g., money, material) for making lessons more practical. To achieve this, the teacher education at universities has to change. [107]

These reasons concern pupil in elementary school as well as in high school or senior classes. The researches of the German Physics Society (DPG)found out that the sciences classes are so unpopular because of the pupil experience them as difficult and not belonging to the education like classical disciplines, such as languages and social sciences [108]. The DPG also suggested some solutions to this problem. One would be that the same contents are taught in a practical way, especially sciences should impart the feeling of experimenting with something new [109]. In order to do so, the DPG sees a necessity in changing teacher education at the universities [110]. Only if pupils see their self-efficacy in the science classes, their interest in the content will grow [56]. “Therefore the strongest direct influence on positive attitudes towards science is that of a high quality, inspirational teaching” [56]. However, teacher education is just one area where basic conditions need to be improved. Another important point is the need for a higher budget for the STEM disciplines in school. In this way, the opportunities for experiential learning could be increased and the pupils broaden their horizons through “learning by doing”. This reason could be connected with the context of constructivism, which mean to design learning environments for fostering “learning by doing” [111]

An interesting study from 2016 explicitly shows the view of secondary school pupils and their opinions about the STEM industry and associated careers. [112]

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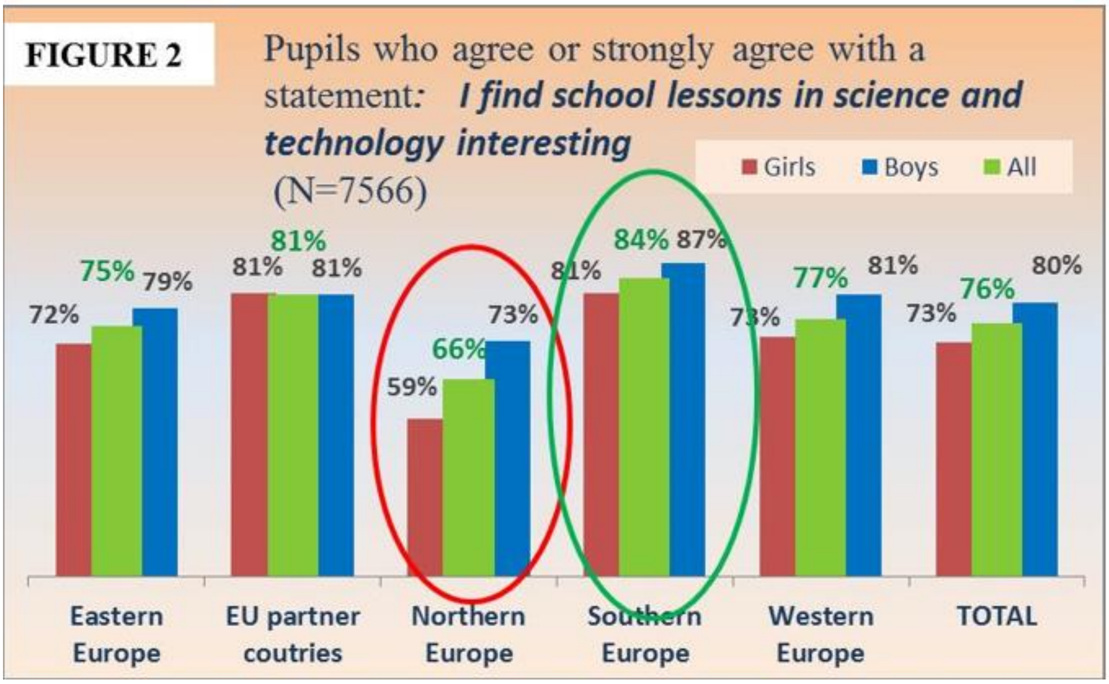

Figure 6 Pupils interest in science and technology by gender [112]

Kudenko and Gras-Velázquez [112] tried to measure the level of pupils' interest in and enjoyment of science, mathematics and technology in and out of school. They ascertained that more than 70% of the pupils were interested in science and technology. However, coincidently, they found a big difference between genders and between regions. Out of school, just 60% of the boys and 44% of the girls stated that they were learning science and technology. This shows pupils' main contact with STEM is in school. Also extracurricular activities contains important chances to increase the interest of young pupils in STEM. For example, the German Federal Ministry of Education and Research (BMBF) has initiatives such as roadshows or campaigns like the 'nanoTruck' [113]. In the United States, there is a program called iQUEST (investigations for Quality Understanding and Engagement for Students and Teachers). This program aims to raise students' interests in STEM careers and organizes special summer camps for middle school pupils in order to do so [114].

Pupils' personal relevance and social view of STEM as a career are also factors, which play a role in the interest in STEM. More than 75% of the girls and 80% of the boys agreed that STEM has an important relevance for their education and career, while 39% of girls and 29% of the boys think that they do not have the skills for a career in STEM. [112]

Moreover, just 29% of the North European girls could imagine a career in STEM compared to 51% of the boys. The study by Kudenko and Gras-Velázquez [112] shows that there are gender differences in the STEM area. Girls seems less confident to be successful in STEM than boys, even if they are interested. One research [21] shows the lower self-confident level of girls than boys. This does not automatically cause girls to lose their interest in STEM, but they often do not choose more STEM subjects in school than is necessary [115]. Therefore, it would be useful to identify the factors that influence young girls' confidence and reinforce them in trying STEM. Heaverlo's study [115] focuses on how young girls lose interest in STEM and how to counteract them. Thus, this study addresses parents, educators, politicians and administrators, who are important for intervening in the process of losing

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interest in STEM. The study underline that not one actor or sector alone have the possibilities to increase the interest in STEM, but that all have to collaborate.

On the other hand, there are factors out of school: in their leisure time, children are not concerned with STEM. There are insufficient offers for children to be exposed to STEM. Both parents as well politicians and administrators could specifically search and initiate programs, workshops, summer schools etc. [116]

Another factor is the difference between the genders. Girls have less self-confidence in their skills. Teachers could motivate girls in school, for example, to choose an elective STEM subject.

At least the question about the future, respectively the careers, in STEM areas is an important factor in the studies. Young pupils think they are not smart or good enough for a career in the STEM industry. Therefore they do decide against STEM subjects, even if they are interested in them.

15.1 PISA REPORTS IN STEM SUBJECTS

According to recent reports prepared within the framework of the Programme for International Student Assessment (PISA) [117] that the Organisation for Economic Cooperation and Development (OECD) organises globally, 15-year old students from Switzerland, Finland, South Korea, China, Singapore, Hong Kong and Taiwan demonstrate highest performance levels in mathematics and science. These countries also demonstrate the lowest proportions of pupils under-performing in these subjects. Likewise, these countries have been also found to exhibit high levels of research and development, economic performance and science-related output. [116] Furthermore, historical PISA data suggest that national-level programmes aimed to improve the quality of teaching practices, such as increasing pupil participation and teaching creativity. For example in South Korea, the government tend to strengthen student performance on STEM subjects by supporting graduate students in science and engineering fields. Whenever teaching standards are weaken and teaching hours are reduced, such as in Japan before 2008, consistently declining student performance. Among all countries that have demonstrated high levels of achievement in STEM disciplines, policies aimed at increasing the comprehensiveness, depth and engagement of students from the initial grades up to the secondary education level [116].

15.2 COUNTRY-LEVEL VARIATION IN INTEREST IN STEM SUBJECTS

According to OECD data [116], in Austria, the proportion of male graduates (about 70%) in STEM subjects is less further behind than that of OECD average female graduates (about 10%) on the post-secondary education level. Additionally, international comparisons of interest in science-related subjects in school have indicated that, in countries in Northern Europe, such as England, UK, both female (about 20%) and male (about 40%) students demonstrate relatively low interest levels in science. Whereas Central European countries, e.g. Germany and Austria, have been found to show interest levels in science that are close to 60%, with minor gender differences. At the same time, East European countries, such as the Czech Republic, Poland, Latvia and Estonia, have been found to show levels of interest in science that closely variate around 40% with limited gender differences. Southern European countries, such as Portugal, Spain and Greece, have been found to demonstrate consistent gender gaps in interest in science between boys and girls by about 10%, with male pupils showing higher levels of interest, ranging from circa 30% to approximately 60% more than female ones [118].

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15.3 CONCLUSIONS AND SUGGESTIONS

To sum up there are indicate some factors, which influence the interest in STEM positively. They are to increase the self-efficacy during lessons that are more practical and a good relationship between teacher and students. So it is required to implement teaching methods, which foster learning through making and give students a feeling of success to increase their self-efficacy. It will necessary in and out-of-school activities with shared spaces for their different disciplines of STEM. In addition, it is advisable to implement constructionist activities, shared spaces to express their results and ideas in and outside of classrooms.

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16 APPENDIX 7: LITERATURE REVIEW ON COMMUNICATION

Communication is one of the key components of 21st century skills. Communication skills can be understood as children's capacity to write and transmit the ideas and information received in class though technological mediums [25]. In addition, Communication research has often focused on teacher-to-student communication (e.g., how to make sure students attend to the topic at hand), or explicitly teaching communication at the collegiate level (e.g., public speaking or leadership) [119]. The following sections explain theories and concepts of communication.

16.1 THEORIES AND MODELS

Communication research is a broad field covering topics such as mass communication [120], computer-mediated communication, interpersonal communication, and many other areas [121]. Interpersonal immediacy behaviours have also been useful in the study of classroom communication, namely teacher immediacy behaviours. Immediacy is defined as behaviours that indicate a desire to communicate, and teacher immediacy has been shown to have a positive impact on student learning [122]. Immediacy behaviours in the context of a classroom are things like eye contact, repetition of a student's name, nodding, and other such behaviours. These behaviours have been shown to increase student satisfaction [123] as well as motivation [124].

Several studies of communication focus on classroom climate [125]. For example the social and emotional learning (SEL) studies, which is more than just communication, positive peer and teacher relationships [126]. Social skills are not the same as communication, but they incorporate aspects of communication. Researchers are already implementing interventions in K-12 classrooms focusing on SEL. For a review of classroom interventions focused on social and emotional learning [127]. For the ER4STEM project is the focus on communication in peer groups and the teacher relationships. One simple model to explain the individual communication is from Argyle (1972) the motor skill model (Figure 7), which was a slightly modified version of Welford`s, in which the flow diagram was simplified by: removing the memory store blocks; combining sense organs and perception, control of responses, and effectors; and adding the elements of motivation and goal [128].

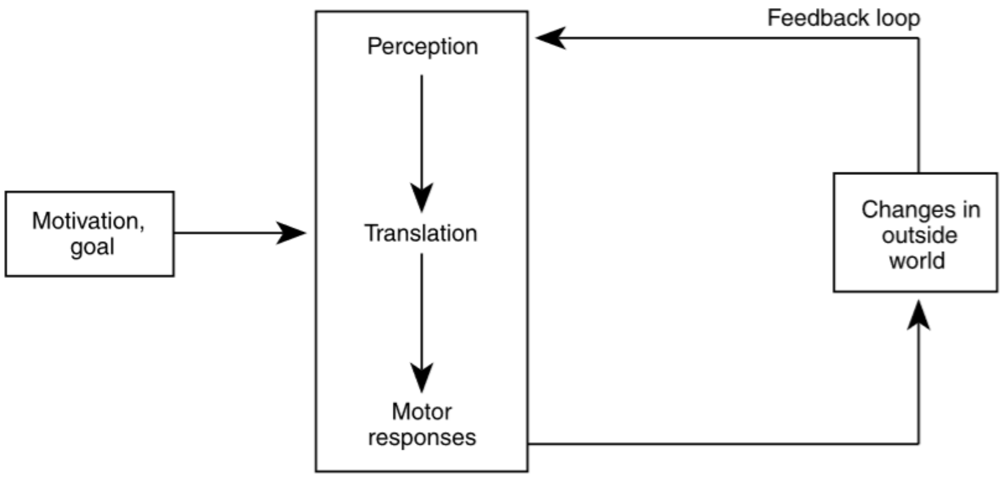

Figure 7 Argyl's motor skill model.

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One example of the application of this motor skill model to a social context would be a student needing support (**motivation**) on one task. Then, he/she asks to one of his/her peer group or the teacher for help (**goal**). There are different ways to accomplish this (e.g. ask directly, move near the teacher for a possible conversation). One of these is then carried out, such as the direct request: "Can you help me?" (**response**). This will result in some response from the other person: "How can I help you?" (**changes in the outside world**). His/her response is available as feedback, which student hears while also observing the non-verbal reactions (**perception**). The student can then move on to the next goal (e.g. follow-up response, or explanation).

16.2 KINDS OF COMMUNICATION

Communication takes place when a sender expresses an emotion or a feeling, creates an idea, or senses the need to communicate for a goal. The communication process is triggered when the sender makes a conscious or an unconscious decision to share the message with another person—the receiver.

Every communicative act is based on something that conveys meaning, and that conveyance is the message. The message may be either verbal (spoken), written, or nonverbal (body language, physical appearance, or vocal tone). Messages may also come from the context—or place and time—of the communication. For instance, if you choose to make a critical comment to someone, the place and the time you choose to make that comment will make a big impact on how it will be received.

Every message is sent and received through one of our five senses—it is seen, heard, touched, tasted, or smelled. The sensory media through which messages are sent and received are communication channels. In a work setting, messages may be seen through body movement, letters, memos, newsletters, bulletin board notices, signs, emails, and so on. Messages that are heard come through conversations, interviews, presentations, telephones, radios, and other audio media. Sight and sound are the two most frequent communication channels used in our society.

When the receiver gets the message (through seeing, hearing, feeling, touching, or smelling), he or she will usually give feedback (return message) unconsciously or consciously. Thus, the communications process is on-going.

The worst assumption a sender of a message can make is that the message will be received as intended. So many things can go wrong during the communications process that we should always assume that something will go wrong and take steps to prevent that occurrence. Barriers to good communications are always present. For instance, the language itself can be a barrier—unclear wording, slang, jargon, the tone. Another barrier is the failure of the sender to realize that his or her body language might contradict the spoken message. The channel used to convey the message might be wrong. For instance, you would not use the telephone to relay a lot of statistical information; you would need to write that message on paper. Poor listening skills can constitute a barrier also.

16.3 NONVERBAL COMMUNICATION

People transmit their intentions and feelings, whether they are aware of it or not. They become unintentional senders when they do it unconsciously. The messages we convey to others go far beyond the words we speak. Probably over half of the meaning that others connect to our spoken message come not from the words of the messages themselves but from the tone of voice and from our body language. This nonverbal impact comes particularly from the face, eyes, body, clothing, gestures, and touch. We have to be careful not to assume that just because a person displays one nonverbal signal that we are interpreting that signal correctly. We must look at the whole cluster of signals to see if they support our reading of that person. For instance, a person who crosses his arms might be expressing defiance, but he might also just be feeling cold. We would need to check out his facial expressions and other nonverbal signs to determine the correct reading.

Most of us depend on our reading of others' facial expressions to judge how they feel about us or a particular situation. We depend on the face as the most trustworthy indicator of emotions such as happiness, surprise, fear, anger, joy, sadness, disgust, contempt, interest, concern, and embarrassment. We also look at the face for insight into a person's character (for example, an "open, honest face," a "strong chin," or "beady eyes"). A man who has a moustache, beard, or long hair might suggest conformity or nonconformity, depending on the time and the context. The grooming of hair says much about a person's meticulousness. Narrowed lips or jutted-out chin might mean a person is angry or defiant.

The eyes convey much meaning. Eye contact—or a lack of it—might tell us something about a person's confidence, friendliness, honesty, or desire to dominate. The pupils themselves can signify interest or disinterest, among other things. Pupils dilate when a person is interested or excited; they grow smaller when a person is bored or uninterested. The brow area and the narrowing of the eyes tell a receiver much also. Frowns, scowls, and raised eyebrows might indicate displeasure or intensity. Narrowed eyes can suggest anger, irritation, or doubt.

The body is another rich source of nonverbal confirmation or denial of our verbal message. We draw conclusions about people before we ever exchange words based on their sex, posture, height, weight, and skin colour. For instance, people often stereotype others by thinking that tall people make good leaders, overweight people are jolly, and women are too emotional. We notice how the senders of messages hold their bodies. We consider crossed arms to be a sign of defensiveness, defiance, or withdrawal. Hands on hips say that a person is goal oriented or ready and able to take something on. Leaning back in a chair with hands clasped behind the head can be interpreted as a sign of superiority, smugness, or authority. A slouched posture can be read to mean humiliation, defeat, or submission. Using our arms, bodies, and legs to block in others or things can be a sign of territorial feelings. Turning your shoulder or body slightly away from someone can be a sign of rejection of that person.

Our appearance can disclose several pieces of information about us. Someone who dresses immaculately is likely to be a careful person who attends to detail. Someone who prefers "old-fashioned" dress might be very conservative in his or her opinions and values. A person wearing excessive jewellery is possibly displaying signs of a materialistic nature. Our clothing during working hours can tell others what we do for a living. For instance, a blue-collar worker's clothes are designed to help or protect him or her in doing the job. The white-collar worker usually wears more formal clothes considered appropriate for business but having little to do with protection.

Our most common form of social physical contact—the handshake—is often relied upon as a source of data about another person. The handshake is an indication of welcome, liking, acceptance, and greeting. Therefore, it is considered extremely rude not to accept an offered hand. The way you shake hands is another source of data about you. A bone-crushing grip can be seen as a desire to dominate and a limp grasp as a sign of insecurity or a negative outlook on life. A mechanical pumping up and down of another's hand in a series of convulsive jerks suggests mental rigidity, strong will, and inflexibility. Other than the handshake, we have to be very careful with touching others in the workplace because of harassment issues.

People who are better readers of nonverbal messages tend to do the following things:

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- They look at the totality of cues rather than isolated ones (e.g. the crossed arms).
- They take context (time and place) of the message into account.
- They attempt to compensate for their own biases and prejudices.

16.4 ORAL COMMUNICATION

People who are successful communicators take full responsibility for success in the communication process. These people take responsibility for being certain that you understand what they are saying. They recognize that barriers to good communications exist so they speak in simple, grammatical, and understandable terms. They also give examples, ask for feedback, put what they said previously in different words, and make it easy for you to gain the true intent of their communications. However, this in no way frees the listener from responsibility from the process. Without proper listening, communication does not occur.

16.5 LISTENING SKILLS

Effective listening is active participation in a conversation. It is an activity which helps the speaker become understood. The listener must actually hear and not understand what is said by the speaker. A passive listener is attentive but does nothing to assist the speaker. Active listeners sit or stand alertly, maintain eye contact with the speaker, concentrate on the speaker's words, make verbal responses, and summarize parts of what has been said when clarity is needed.

Because there is a difference in how fast one can speak and how fast others can listen, a time lag exists in conversations. Good listeners do not daydream during this lag; they use the time to organize what is being said and to relate to the message. The listener must guard against distractions to the message. The speaker's mannerisms, accent, dress or grooming, language style, or delivery can be distracting if the listener does not learn to tune them out. In addition, listeners need to learn to avoid letting first impressions of a speaker colour their ability to hear the message.

We cannot learn anything from others if we try to do all the talking. Therefore, let speakers finish out their own sentences. Do not interrupt them to interject your own thoughts. We need to pay attention to the tone of the words and the nonverbal cues of the speaker. Sometimes, these things undermine the actual meanings of the words themselves. For instance, someone might be telling you that he or she is not upset, but the tone or the body language might tell you otherwise.

Overall, effective listening can be expressed as follows. You should concentrate so that competing external and internal distractions are eliminated. You should probe and reflect by asking questions to seek clarification and greater understanding. You might ask, "Is this what you mean?", "Could you repeat that?", or "Are you saying that…?" Finally, you should summarize (paraphrase) and feedback to the speaker what you think you have heard. When the speaker agrees that your understanding is indeed accurate, then effective listening and effective communication have taken place. [129]

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17 APPENDIX 8: REVIEW OF CURRENT STRATEGIES ON NATIONAL AND EUROPEAN LEVEL THAT ENCOURAGE STEM EDUCATION AMONG THE YOUNGER POPULATION

The main objective of this research is to provide a brief review on current strategies on both national and European level that encourage STEM education among the younger population. Moreover, this research aims to compare the stated measures with the needs and requirements of the STEM professionals and the STEM industries. The results of the research will inform and benefit the development of the ER4STEM Framework (WP1) and inform the evaluation of project's objectives (WP6).

17.1 OVERVIEW AND STRUCTURE OF THE REVIEW

Within the ER4STEM project, one of our core objectives is to create a continuous STEM schedule by leveraging already existing European approaches of innovative science education methods and measures based on STEM and educational robotics. This document presents the collaborative effort of the ER4STEM project partners to review twelve (12) European Strategies and strategic initiatives regarding STEM education and educational robotics.

The current strategies on a European and national level consider encouraging STEM education among the younger population. Although the reviewed strategies do not address directly and specifically educational robotics, with the ER4STEM Framework on educational robotics, we believe that we are able to reach beyond specific robotics implementations. More precisely, with the educational robotics activities, carried out under the ER4STEM Framework, apart solely the STEM domains, we target further areas of study, such as Arts and Business, as well as Life Skills. Not only this, but the ER4STEM approach targets the cultivation of 21st century skills.

This review provides a summary and conclusions of the scope of the portfolio of the strategies reviewed. We draw out conclusions related to the ER4STEM project (**CONCLUSIONS FOR ER4STEM**) and we propose policy recommendations based on the ER4STEM approach (POLICY RECOMMENDATIONS).

Following this analysis, we present a detailed review of each of the 12 strategies under a common structure that were considered by the ER4STEM project consortium. The strategies per analyzing partner are reported in Table 6.

Table 6 Strategies' title and partner responsible of its analysis.

Analyzing partner	Country	Strategy title
AcrossLimits	Malta	Malta: Women in ICT Focus Group
AcrossLimits	Malta	Malta: eSkills Malta Foundation
Cardiff University	UK	UK Government Strategy: Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy
Cardiff University	Welsh	Welsh Government Strategy: Science, Technology, Engineering and Mathematics (STEM) in education and training. A delivery plan for Wales

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ESI CEE	Bulgaria	Bulgaria: Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020
ESI CEE	Bulgaria	Bulgaria: National strategy for development of scientific research in the Republic of Bulgaria (2017 – 2030)
PRIA	Austria	Austria: Schule 4.0 – Jetzt Wird's Digital
PRIA	Austria	Austria: Talenteförderung in Niederösterreich
TUWien	Spain	Spain: Competencias Digitales en España ¿Cómo Mejorarlas?
TUWien	Italy	Italy: Piano Nazionale: Scuola Digitale
UoA	Greece	Greece: ESERO (European Space Education Resource Office)
UoA	Greece	Greece: Greek Ministry of Education and religious Affairs' Strategic Initiatives

17.2 INFORMATION SOURCE

A notable disclaimer is that the concept of formalized STEM education might not be well defined in many EU countries yet. Similarly, STEM education is likely not labelled as such, but it could be expected that it is included in the policies, strategies and plans using other relevant terminology.

The list of the key sources of information includes but is not limited to:

- European Union institutions;
- European Union research projects;
- National ministries of Education per each country. In addition to the ministries and government structures responsible for education as well as those in charge of information society issues, a number of other ministries may also have policy initiatives related to STEM education, such as ministries in charge of innovation, employment and industrial policies and others;
- STEM related NGOs - it could happen that in some cases NGOs and even private companies set up their own STEM initiatives in the Member States.

For identification of additional policies and initiatives of relevance to the topic, the research was extended to:

- web sites and newspapers / magazines;
- policy papers, publications, reports;
- academic research (published or ongoing);
- Interviews with policy makers (optional).

In addition to the data /information already available at the sources published, the researchers might conduct meetings with experts in order to validate data and to obtain more detailed information.

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17.3 ANALYSIS AND CONCLUSION ABOUT THE RESEARCHED STRATEGIES

We analyzed 12 different strategies on national and European levels in this strategy review. The strategies on a national level inform on strategic initiatives in 8 different countries: Austria (2), Bulgaria (2), Greece (2), Italy (1), Spain (1), Malta (2), Wales (1) and the UK (1). One of the strategic initiatives reported, ESERO (European Space Education Resource Office) is on a European level, but the strategic initiative's review focuses on the activities implemented in Greece, among other countries. All of the analyzed strategies and strategic initiatives were active in the first trimester of 2018, when the strategies' review took place, with the exception of Piano Nazionale: Scuola Digital, which was implemented and completed in 2015 in Italy.

Regarding stakeholders of the strategies, all of the reviewed strategies have "*government*" as a stakeholder (see Table 7 ER4STEM review of 12 European and national strategies). It is interesting to point out that one of the strategies, reviewed by TUWien, "*Competencias Digitales en España ¿Cómo Mejorarlas?*" Does not have "*education*" as a stakeholder. According to the strategy's review, the strategy recognizes the need to increase digital competencies, on a government and a societal level but does not have "*education*" as a direct stakeholder, which poses the need of more educational initiatives, aimed at increasing students' motivation in pursuing STEM education and careers, in order to increase the digital competencies' level.

Other strategies and strategic initiatives, such as ESERO (European Space Education Resource Office), target as direct stakeholders *industry* and *government*, as was the case with "*Competencias Digitales en España ¿Cómo Mejorarlas?"* However only few of them point out specific skills that would need to be developed, according to the review of the strategies. In the strategic plans of the initiatives, there is often a recognized need for more educational initiatives, including non-formal and extra-curricular, and in several cases, there is a budget for the encouragement of more educational initiatives. However, a careful review of the strategic documents reveals not many of them (5 out of 12 strategies) have a clearly established mechanism for the monitoring and control of the sustainable alignment to the strategies' plans, goals and visions. Similarly, again 5 out of the 12 strategies and strategic initiatives analyzed provide publicly, both formally and informally, reports and results out of the strategic actions, or at least none were found available during the first trimester of 2018. This tendency reveals a need for evaluation mechanisms of the educational initiatives and activities, carried under the strategies, as well as mechanisms and toolkits for the ethical sharing of results. Such evaluation toolkits were applied by the ER4STEM project for the assessment of the educational robotics activities' impact and the collection of data related to it, and we believe, that it could be adapted to assess other educational initiatives, not necessarily related to educational robotics as well.

On a different topic, each one of the strategies and the strategic initiatives reviewed by the ER4STEM consortium has conducted research, leading to the conclusion that ***further STEM career encouragement is needed***. Strategies often identify a *gap between industry needs and education*, for example the UK Government Strategy: Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy and the Bulgaria: Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020 strategies. Furthermore, a lack of informed understanding on the STEM skills issues by the government is realized and strategies, such as **Fehler! Verweisquelle konnte nicht gefunden werden.**Bulgaria: National strategy for development of scientific research in the Republic of Bulgaria (2017 – 2030) aim to serve as information units on those issues and provide toolkits for their solution. Strategies, such as Greece: ESERO (European Space Education Resource Office) and also

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Greece: Greek Ministry of Education and religious Affairs' Strategic Initiatives report on improvement on a government level of the understanding and coordination on resolving STEM issues, by introducing age appropriate educational initiatives, both in the formal educational contexts, as well as in the informal and extra-curricular setting.

The need for **further STEM career encouragement**, underlined by all researched strategies is in alignment with the **ER4STEM mission** to turn curious young children into young adults passionate about science and technology with a hands-on use case: robotics.

On the other hand, we also see efforts to improve the quality of STEM education in order to benefit the development and the encouragement of digital fluency, i.e. **Austria: Schule 4.0 – Jetzt Wird's Digital** and **Austria: Talenteförderung in Niederösterreich**, however other strategies reviewed show us that there is a certain lack of consistent definitions for STEM both in the context of education and industry such as Welsh Government Strategy: Science, Technology, Engineering and Mathematics (STEM) in education and training. A delivery plan for Wales; UK Government Strategy: Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy; Italy: Piano Nazionale: Scuola Digitaleand others.

We also see strategic initiatives related to the need of improvement of gender balance issues in the STEM domains. Strategies in the UK and Malta recognize that females are underrepresented in STEM and aim to investigate and mitigate the reasons for this.

All strategies identify the need of ***alignment between industry and education*** *when it comes to STEM*. UK Government Strategy: Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy identifies that only 24% of STEM graduates were working in a STEM occupation within 6 months in 2016 and **Bulgaria: Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020** identifies a mismatch between the industry needs and the academic preparation.

We see a ***tendency of better teacher training in STEM for schools***, *meeting some targets for improving the skills of non-specialist teachers in the subjects of maths and physics*, as in Greece: ESERO (European Space Education Resource Office), UK Government Strategy: Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy, **Austria: Schule 4.0 – Jetzt Wird's Digital, Austria: Talenteförderung in Niederösterreich,** and Italy: Piano Nazionale: Scuola Digitale.

Strategies identify educational activities as a way to ***improve student's interest in STEM*** (Austria: Schule 4.0 – Jetzt Wird's Digital, Austria: Talenteförderung in Niederösterreich, Greece: ESERO (European Space Education Resource Office) and Greece: Greek Ministry of Education and religious Affairs' Strategic Initiatives) as well as for way to improve students' and teachers' involvement in STEM education (Italy: Piano Nazionale: Scuola Digitale and Welsh Government Strategy: Science, Technology, Engineering and Mathematics (STEM) in education and training. A delivery plan for Wales).

We believe that throughout the three project years, *we at ER4STEM have created a set of tools that can be effectively applied to benefit strategic initiatives*, related to STEM education and could serve the successful planning, implementation and evaluation of educational robotics activities specifically.

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Table 7 ER4STEM review of 12 European and national strategies

Analyzed by	Strategy title	Year, status	Responsible organization	Geographical scope	Relevance to STEM direct, indirect, partial	Are there specific industry needs/skills defined	Stakeholders						Strategy plans and initiatives	Good Practices	Monitoring mechanism in place	Reports/ results
							Government	Education	Industry	Society	Other					
AcrossLimits	Women in ICT Focus Group	Active	eSkills Malta	Malta	Direct		Yes	Yes	Yes	No			Yes	Yes		Informal
AcrossLimits	eSkills Malta Foundation Strategic Initiative	Active	The eSkills Malta Foundation is a coalition of various representatives from Government, industry and education	Malta	Direct		Yes	Yes	Yes	No		If you answered with "yes", provide more information here.	Yes	Yes		Formal
Cardiff University	Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy	Active	UK Government - UK National Audit Office	UK	Direct	Yes	Yes	Yes	Yes	Yes	Yes	Stem Charity bodies, Museums and Libraries	Yes	Yes	Yes	Formal
Cardiff University	Science, Technology, Engineering and Mathematics (STEM) in education and training. A delivery plan for Wales.	Active	Welsh Government	Wales	Direct	Yes	Yes	Yes	No	No	No		Yes	Yes	Yes	Informal

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Analyzed by	Strategy title	Year, status	Responsible organization	Geographical scope	Relevance to STEM direct, indirect, partial	Are there specific industry needs/skills defined	Stakeholders					Strategy plans and initiatives	Good Practices	Monitoring mechanism in place	Reports/ results
							Government	Education	Industry	Society	Other				
ESI CEE	Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020	Active	Ministry of Economy, Council of Ministers, and the Ministry of Education and Science	Bulgaria	Indirect	No	Yes	Yes				No	Yes	Yes	None Publicly Available
ESI CEE	National strategy for development of scientific research in the Republic of Bulgaria 2017 – 2030	Active	Ministry of Education and Science	Bulgaria	Indirect	No	Yes	Yes				No	Yes	Yes	None Publicly Available
PRIA	Schule 4.0. – jetzt wird's digital	Active	Austrian Federal Ministry of Education, Science and Research	Austria	Direct	No	Yes	Yes	No	No		Yes	Yes	No	None Publicly Available
TUWien	COMPETENCIAS DIGITALES EN ESPAÑA ¿CÓMO MEJORARLAS?	2015	Foro de Formación Digital	Spain	Direct	No	Yes	No	Yes	Yes		No	Yes	No	None Publicly Available
TUWien	PIANO NAZIONALE: SCUOLA DIGITALE	Active	Italian Ministry of Education	Italy	Direct	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	None Publicly Available

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Analyzed by	Strategy title	Year, status	Responsible organization	Geographical scope	Relevance to STEM direct, indirect, partial	Are there specific industry needs/skills defined	Stakeholders						Strategy plans and initiatives	Good Practices	Monitoring mechanism in place	Reports/ results
							Government	Education	Industry	Society	Other					
UoA	ESERO	Active	ESA	Europe	Direct	No	Yes	Yes	Yes	No	No		Yes	Yes	No	None Publicly Available
UoA	Greek Ministry of Education and religious Affairs' Strategic Initiatives	Active	Greek Ministry of Education and religious Affairs	Greece	Partial	No	Yes	Yes	No	Yes	No		Yes	No	No	None Publicly Available
PRIA	Talenteförderung in Niederösterreich	Active	Government of Lower Austria	Austria	Direct	Yes	Yes	Yes	Yes	No	No		Yes	Yes	No	Informal

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17.4 CONCLUSIONS FOR ER4STEM

Only four strategies and strategic initiatives in total, from two countries (Austria and Greece) mention educational robotics as educational tools to keep children motivated to learn STEM. Within **Schule 4.0. – jetzt wird's digital**, educational robotics appears in the strategy two times with relation to child-friendly programming environments, robotics and creative digital design. Namely, part of the strategy is the organization of competitions. One of those competitions, the "computer creative wettbewerb" ("computer creative competition") is about projects handed in by school students that are then rated by a jury. It is stated that projects regarding various topics can be handed in with robotics being one of these topics. Furthermore, the strategy names the establishment of Education Innovation Studios at the University Colleges of Teacher Education throughout Austria, which are meant for increasing teacher competences regarding child-appropriate programming environments, robotics (e.g. LEGO WeDo) and creative, digital designing. Another strategy, again from Austria, that considers educational robotics is **Talenteförderung in Niederösterreich** for fostering young talents specifically regarding STEM topics. Robotics was chosen as core domain as it represents a multi-disciplinary field. Two modules are offered: 1) Robot programming for 12 to 14 year-olds and 2) Robot construction for 14 to 16 year-olds. **ESERO**, a European strategic initiative, currently being implemented in Greece, envisages *robotics and automation workshops for primary and secondary school teachers*. During the workshops, participants are guided through activities that can be performed in the classroom, such as creating robots using LEGO WeDo or Arduino platform, and using them to perform a 'mission to Mars' with specific discovery objectives. Last but not least, the Greek Ministry of Education and Religious Affairs' strategic initiatives aim at involving a large number of teachers and students with new technologies, science and robotics. However, no specific initiatives were mentioned within the strategy review.

As per ER4STEM's results, robotics allows ALL learners to engage with the four areas of STEM education through the design, creation and programming of tangible artefacts to create personally meaningful objects and address real-world societal needs. This is why we believe educational robotics and the ER4STEM Project could provide valuable tools and artifacts to support the strategies that already envisage robotics as part of their activities and initiative and further provide arguments for the inclusion of educational robotics as a tool to explore STEM concepts. As many of the reviewed strategies encompass not only the development of technical skills but also of soft skills that are of importance for professional life, multidisciplinary domains such as robotics, could provide support to achieving the objectives and core goals of the strategies related to STEM.

Furthermore, following the industry needs analysis, conducted under WP6 of the project (D.6.5 Evaluation and Analysis of 3rd Project Year), identifies most required skills by the employers are active learning, critical thinking, problem solving and interpersonal skills, as shown within Figure 1 below:

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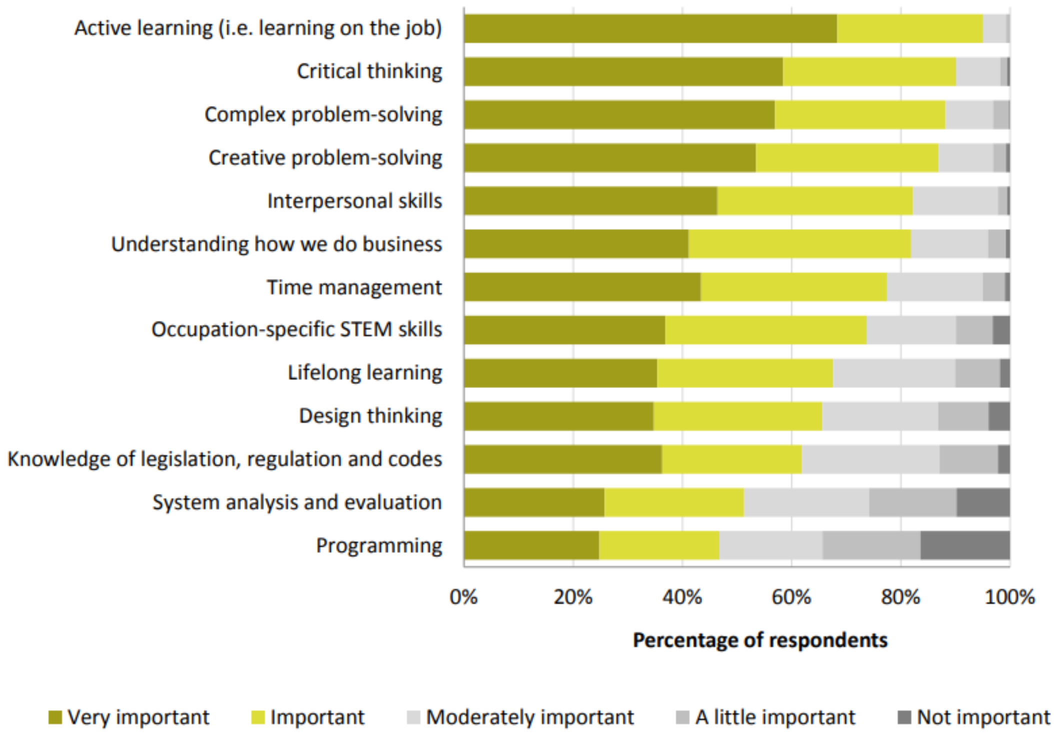

Figure 1 The skills that employers need from STEM graduates (D.6.5 Evaluation and Analysis of 3rd Project Year)

The strategies reviewed all aim to increase student's interest in STEM and reflect on the needs of the industry, which corresponds closely to ER4STEM's objective to turn curious young children into young adults passionate about science and technology with a hands-on use case: robotics. In the case of ER4STEM, the domain of robotics was chosen because it represents a multidisciplinary and highly innovative field encompassing physics, mathematics, informatics and even industrial design as well as social sciences. Our evaluation results further show that approaching STEM from a creative side creates multiple entry points to engage children from different backgrounds, with different interests and motivations.

This makes a compelling case for the integration of educational robotics as part of the strategic initiatives on a European and national level to increase interest in STEM education and careers.

17.5 POLICY RECOMMENDATIONS

Based on the analysis of the 12 strategies and strategic initiatives reviewed and considering the results from the ER4STEM project, we can conclude that educational robotics could serve as an effective instrument for teaching STEM disciplines in schools and informal educational settings. Moreover, educational robotics effectively addresses the needs for developing 21st century skills. The educational robotics activities were well accepted by both girls and boys from a range of backgrounds.

The potential provided by educational robotics could be more fully exploited within national and European strategies through:

- becoming part of the strategic educational activities in STEM related strategies on both European, national and regional levels;
- being promoted as an innovative way to engage and motivate students in STEM-related disciplines in schools;

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- initiating and funding educational robotics initiatives for non-formal educational organizations, which could result in raising young learners' interest in STEM and support the development of soft skills and 21st century skills;
- being a highly multidisciplinary vehicle for learning - encompassing all STEM disciplines and requiring a plethora of soft skills, which could serve as a great instrument for the cultivation of 21st century skills to meet the needs of industry. Further research on educational robotics is needed in order to gain further perspective on this potential;
- qualification programs for teachers which provide opportunities to develop both pedagogic and technical knowledge, so they are supported in the introduction and integration of educational robotics in the schools;
- practical guidelines and validation/certification mechanism to assure the effective, efficient and informed use of educational robotics for STEM;

inclusion of evaluation mechanisms for the educational initiatives and activities, carried under the strategies, as well as mechanisms and toolkits for the ethical sharing of results. Those mechanisms will provide the necessary feedback loop for evaluation of the results and effective strategic planning.

17.6 STRATEGIES ANALYSIS PER COUNTRY

Austria: Schule 4.0 – Jetzt Wird's Digital

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

The digitization strategy "**Schule 4.0. – jetzt wird's digital**" (in English: "**School 4.0. – now it's getting digital**") by the Austrian Federal Ministry of Education, Science and Research has been rolled out in autumn 2017 and is thus currently in progress. The concept for the strategy encompasses the complete school landscape for ensuring that school students acquire digital competences and critical thinking skills in the context of using digital content. The strategy encompasses four pillars:

1. Digital basic education from elementary school
2. Digitally competent teachers
3. Infrastructure and IT-equipment
4. Digital learning tools

The digitization strategy "**Schule 4.0. – jetzt wird's digital**" was created by the Austrian Federal Ministry of Education, Science and Research.

In addition, other ministries take part in executing the strategy:

- In a cooperation with the Austrian Federal Ministry of Families and Youth, the University College of Teacher Education in Vienna was equipped with digital tools for establishing the first Austrian Future Learning Lab.
- In a cooperation with the Austrian Ministry for Transport, Innovation and Technology, schools are equipped with better Internet connections.

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

As the future is digital, not only innovation and creativity are important, but also technical expertise. With the digitization strategy "**Schule 4.0. – jetzt wird's digital**", the Federal Ministry has presented a comprehensive concept that covers the entire school career. With the implementation of the strategy,

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all students in Austria acquire digital skills and learn to critically deal with digital content. It involves a broad portfolio of competencies: from media literacy to critical handling of information and data, security in the network to knowledge about technology, coding and problem solving.

Educational robotics appears in the strategy two times:

- Part of the strategy is the organization of competitions. One of those competitions, the "computer creative wettbewerb" ("computer creative competition") is about projects handed in by school students that are then rated by a jury. It is stated that projects regarding various topics can be handed in with robotics being one of these topics.
- The strategy names the establishment of Education Innovation Studios at the University Colleges of Teacher Education throughout Austria, which are meant for increasing teacher competences regarding children-appropriate programming environments, robotics (e.g. LEGO WeDo) and creative, digital designing.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

The digitization strategy "**Schule 4.0. – jetzt wird's digital**" does not relate directly to industrial needs but states that the future is digital, which is why school students need to acquire also technical know-how. School students shall obtain various competences:

- Media literacy
- Critically dealing with digital contents
- Security in the internet
- Knowledge about engineering, coding and problem solving

The acquisition of these competences shall be checked in the 4^{th}, 8^{th} and 12^{th} school grade using 3 different so-called "digi.checks".

RESUME OF THE STRATEGY

The objective of the digitization strategy "**Schule 4.0. – jetzt wird's digital**" is to empower all students in Austria with digital skills and the ability to critically deal with digital content.

In elementary school, digital skills are anchored in the curriculum. The focus is on media education and the reflected use of the Internet, as well as a playful approach to technology and problem solving. At University Colleges of Teacher Education throughout Austria as well as at 100 elementary schools so-called "Education Innovation Studios" are established, which represent a learning environment where the handling of robotics and coding is learned in a playful way

From the fifth to the eighth grade, a compulsory "Digital Basic Education" exercise with its own syllabus of 2 to 4 hours per week will be introduced. Each school decides autonomously on the concrete design. Implementation takes place either integratively in subject-specific lessons or in dedicated hours. In order to check the learning success, a measurement of the digital competences of the pupils takes place in the eighth grade ("digi.check"). In these 4 years, the following competences shall be acquired:

- Social aspects of media change and digitization
- Information, data and media competence
- Operating systems and standard applications
- Media design

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- Digital communication and social media
- Security
- Technical problem solving
- Computational thinking

STRATEGY PLANS AND INITIATIVES

As mentioned above, the strategy “**Schule 4.0. – jetzt wird’s digital**” encompasses 4 pillars, which are detailed in the following.

Pillar 1: Digital basic education from elementary school

In elementary school, media education and the playful use of technology and problem-solving are in the foreground. The focus is on the third and fourth school grade. All pupils should have the first digital basic skills and be able to apply them after completion of the elementary school.

In addition to media education, digital basic education is now being anchored systematically in the curricula. Particularly innovative schools already started to implement the model with the school year 2017/18. The experience gained will be passed on to all other schools in the form of best practice examples and expertise transfer. The students receive proof of their basic digital education in the form of a collective passport.

At the end of the eighth grade, young people should have a basic knowledge of computer science as well as the use of standard programs. Second focus is the communication of the critical handling of social networks, information and media. “Digi.komp 8” defines the competences students should have at the end of the eighth grade.

From the fifth to the eighth grade, a compulsory “Digital Basic Education” exercise with its own syllabus of 2 to 4 hours per week will be introduced. Each school decides autonomously on the concrete design. Implementation takes place either integratively in subject-specific lessons or in dedicated hours. In order to check the learning success, a measurement of the digital competences of the pupils takes place in the eighth grade (“digi.check”).

Pillar 2: Digitally competent teachers

The prerequisite for achieving the goals are well-trained educators who use digital media effectively in their lessons. They must themselves have digital skills and media literacy in order to convey them to the students. These competences were defined in the model "digikompP".

From autumn 2017, all new teachers acquire standardized digital skills. Educators demonstrate their digital skills, including digital subject didactics, until the end of the career entry phase in the form of a mandatory portfolio. It consists of the following components:

- Digital competence check (digi.check) at the beginning of the career entry phase
- Completion of a modular course of 6 ECTS for digital subject didactics within 3 years of starting school
- Reflection of own teaching in a digital portfolio

In order for educators in professional life to be able to expand their digital skills, the course is also offered in continuing education and training.

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School leaders will be given the opportunity to access this advanced training at the colleges of education and to offer it at their location.

Education Innovation Studios have been established at colleges of teacher education in all federal states. Their goal is to increase the teachers’ skills in dealing with child-friendly programming environments, robotics and creative digital design.

In addition, the first Austrian Future Learning Lab was established in cooperation with the Austrian Federal Ministry of Families and Youth at the University College of Teacher Education in Vienna. In the future, teachers will be able to experiment with digital tools and be trained in their application.

Pillar 3: Infrastructure and IT equipment

Modern infrastructure is also an important requirement for digital education. At around 50 percent of the federal schools, WLAN is available in all rooms and 96 percent of all classrooms are connected to the Internet. 31 percent of compulsory schools have Wi-Fi throughout, and 78 percent of classrooms have Internet access.

The Austrian Federal Ministry of Education, Science and Research has launched a broadband initiative for schools in cooperation with the Austrian Ministry for Transport, Innovation and Technology. The "Connect" funding program pursues the goal of achieving a sustainable improvement in the connection of compulsory schools to the fiber-optic network.

Together with the school keepers, the Austrian Federal Ministry of Education, Science and Research has prepared recommendations for a basic IT infrastructure in schools. They provide the basis for a development plan to develop the technical infrastructure in the schools.

The Austrian Federal Ministry of Education, Science and Research has also concluded framework agreements with the providers. They offer special conditions for educational institutions, which minimizes the costs of ongoing operation.

Pillar 4: Digital learning tools

To convey digital content, the educators need easy and free access to teaching and learning materials.

Through OER (Open Educational Resources), content is made available and the active use of digital media is stimulated.

By creating the Eduthek, a portal for digital teaching and learning materials is achieved. It bundles a variety of content and media offers and makes them accessible via a central access point.

The content will include teaching and learning materials, educationally recommended apps and games as well as innovative tools for modern teaching formats. Exemplary application scenarios show the teachers examples of how they can effectively integrate digital media into their lessons.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

The strategy aims to establish activities throughout the school career of students from entry into primary school until graduation from secondary school. Only the offer of ongoing activities will ensure the acquisition of the expected competences. Consequently, this represents a meaningful practice that

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should be taken into account regarding educational robotics activities – only ongoing offers throughout the school years of students will have a long lasting effect.

Very important is also pillar 2 of the strategy, which aims at achieving digitally competent teachers. It is only possible to reach out to the students, if the teachers possess the necessary competences. If the practices of ER4STEM are meaningful for students, sustainability requires that teachers are confronted with these practices.

STRATEGY MONITORING AND RESULTS

As the rollout of the strategy has only started in autumn 2017, no strategy results are yet presented.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

The strategy "**Schule 4.0. – jetzt wird's digital**" involves activities for students throughout their school career as well as measurements for teachers and for schools. It is thus a very encompassing strategy.

It can be concluded that also ER4STEM needs to take students but also teachers into account. Performing workshops for the students is a core activity for evaluating the effectiveness of the workshops. But also regarding educators the project ER4STEM seems to be on a good way as the framework encompasses process-oriented knowledge for organizing workshops but also actual workshop content in a structured way (activity plans) through the ER4STEM repository.

Austria: Talenteförderung in Niederösterreich

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

"**Talenteförderung in Niederösterreich**" (engl. "**Talent Promotion in Lower Austria**") is an ongoing program implemented in the Austrian state Lower Austria for fostering young talents. It consists of two major activities:

- Begabungskompass (engl. Talent Check)
- Talentehaus NÖ (engl. Talent House Lower Austria)

The "**Talenteförderung in Niederösterreich**" is led by the department for science and research of the government of Lower Austria.

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

The Talent Check is intended for supporting pupils of the 7th or 8th school grade regarding their further orientation in professional matters. This encompasses various checks and analyses of potential of each pupil, which also specifically involves mathematics and technical understanding and therefore STEM topics.

The Talent House is intended for fostering young talents specifically regarding STEM topics. Robotics was chosen as core domain as it represents a multi-disciplinary field. Two modules are offered:

- Robot programming for 12 to 14 year-old persons

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- Robot construction for 14 to 16 year-old persons

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

The Talent Check is meant to analyze the skills of a young person so that he or she can better decide which professional path to follow. Consequently, the checked skills are based on the requirements of companies with a focus on STEM-related skills as can be seen in the following list:

- Spatial sense
- Logical-analytical understanding
- Mathematic skills
- Language skills
- Retentiveness

Various skills are developed when attending the modules of the Talent House. Apart from technical skills (e.g. programming, data structures, CAD, control technology) also, the following soft skills are fostered:

- Project management
- Teamwork
- Communication
- Time management
- Presentation

The Talent House cooperates with companies so it can be assumed that the skill requirements are at least partially influenced by those companies.

RESUME OF THE STRATEGY

The "**Talent Promotion in Lower Austria**" generally aims to foster young talents and has a focus towards STEM-related skills. On the one hand, it is meant for analyzing the potential of a young person (Talent Check) and on the other hand, it is meant for supporting the skills development (Talent House).

Children and young people who are supported at the Talent House benefit from flexible and tailor-made individual support in the form of classroom hours and supervised e-learning offers. In addition to individual support, group learning is promoted as well as focused self-research using the latest content from the World Wide Web. Interdisciplinarity and application-related content guarantee a promotion of excellence on the pulse of the time.

The promotion of excellence is carried out by experts under strengthening self-responsibility, professional time management and individual learning. Interest, motivation and diligence of children and adolescents are required.

The Talent House pursues an integrative approach to the promotion of excellence. A coordinator takes care of a seamless coordination of the school career with the promotion offers at the Talent House. Additional offers for personality development complete the offer.

As part of the robot programming module, the participants learn about and apply various programming languages and programming concepts. Content from the following subject areas is part of the curriculum:

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- Engineering work
- Foundations of computer science and robotics
- Algorithms and data structures
- Graphical programming
- Imperative programming
- Object-oriented programing
- Programming of humanoid robots (NAO)
- Team and project work

As part of the robot construction module, the participants are familiarized with the design of robots and all necessary components. Content from the following subject areas is part of the curriculum:

- Engineering work
- Foundations of computer science and robotics
- Machine elements
- CAD tools and construction
- Manufacturing processes
- Locomotion and kinematics
- Electronics and digital technology
- Measuring and control technology
- Actuators
- Sensors
- Embedded Systems
- Machine and robot construction

STRATEGY PLANS AND INITIATIVES

The Talent Check consists of 2 parts:

1. Talents Day: The Talents Day is held as a school-related event and includes the following parts:
   a. Talents Check: The Talente Check involves a computer test on spatial imagination, logical-analytical understanding, mathematical skills, language skills and retentiveness.
   b. Potential Analysis: The analysis involves tests of comprehension ability, contact ability, resilience, care/accuracy, technical understanding, craftsmanship, retentiveness, spatial imagination, logic and practical mathematics. In addition to the practical tests, detailed questionnaires are used to collect a profile of interest and the personality structure.
   c. Job Information Seminar: A short career orientation can be freely selected from modules.
2. Consultation: The results of the talent day are discussed by experienced professional experts together with the parents and pupils directly at the schools.

For the education at the Talent House in the field of STEM, the field of robotics was selected because it is a very comprehensive, technical crosscutting topic. There are currently two training programs each lasting 3 semesters:

- Robot programming
- Robot construction

The modules robot programming and robot construction can be visited independently. In addition to fostering the technical skills, the individual, personal development of the participants is an important component as well. The two focal points are complemented by psychological support. This includes a

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test to ensure a targeted and individually tailored support of the individual participants. In addition, a free consultation to discuss the test results is offered.

Attending the courses takes place both in the presence units and via e-learning. The presence units take place once a month. The e-learning activities are carried out continuously between the face-to-face meetings. Due to this blended learning approach, the participants have to work about 10 hours per week.

The costs for each course are € 450, - per semester (including rental robots and accommodation costs at summer block week/s). For socially underprivileged participants there is the possibility of a promotion.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

The Talent Check represents a good way for supporting pupils in regard of their career decisions. By knowing their own talents, they have a better basis for deciding which next steps to take.

The modules of the Talent House encompass not only the development of technical skills but also of soft skills that are of importance for the professional life. Both modules are designed for a period of 3 semesters, which is a long period. However, the long duration ensures the ongoing engagement with the technical topics of robotics and thus consolidates the acquired skills. Besides, a coordinator takes care of a seamless coordination of the school career with the promotion offers at the Talent House. This ensures that the pupil has enough capacity for the regular school tasks.

STRATEGY MONITORING AND RESULTS

Formalized reports seem not to be available. Regular news and blog posts are issued by the Talente House on its website to display for instance the achievements of course-attending pupils when they participate in robotics competitions.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

Checking the skills and potential of young people as it is done in the Talent Check is meaningful for supporting their decision finding with regard to the professional career. Consequently, integrating a reduced potential analysis into workshop formats could be beneficial.

The modules of the Talent House encompass not only the development of technical skills but also of soft skills that are of importance for the professional life. Consequently robotics workshops

Both modules of the Talent House are designed for a period of 3 semesters. Such long durations of one workshop series were not planned in the frame of ER4STEM. Nonetheless, longer durations help sustaining the developed skills and also the aptitude for continuing a STEM career after school. Consequently, longer workshop series could be planned for ER4STEM or likewise projects.

Following the example of the modules in the Talent House, the coordination with other school activities could be enhanced for ER4STEM workshops. Thereby, content of the robotics workshops could be aligned with other content learned during regular school lessons.

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Bulgaria: Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

The Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020 is approved by Council of Ministers' Decision №857/03.11.2015.[1]

For the development and implementation of the **Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020**, responsible institutions are the Ministry of Economy, Council of Ministers, and the Ministry of Education and Science. For sustainable and efficient governance of the implementation of the Innovation Strategy for Smart Specialization, the following structure has been proposed:

Management Board:

- Council of Ministers – Approves IS3, updates it if necessary, coordinates the annual budget;
- Council for Smart Growth with a Secretariat in the CM – Determines the major policy areas – thematic areas, vision, strategic objectives; coordinates the implementation of IS3, monitors the implementation of IS3;

Policymakers:

- Responsible ministries, peer network at central level – Formulation of policies in the field of action of IS3;
- Advisory level – National Council for Innovation, National Council for Science and Innovation, an advisory role. "Science, Education and Innovation" Directorate with MAF will coordinate activities of the ministry's participation in the monitoring process and will prepare needed information for the members of the Council for Smart Growth;
- Financial instruments, regional peer network – financial instruments funded by national and European public funds;

Stakeholders:

- Entrepreneurs, employers and professional organizations;
- Technology Park, Technology centers, Technology transfer offices, nongovernmental sector;
- Centers of Excellence and Centers of Competence;
- Higher schools, Bulgarian Academy of Sciences, AA and other research organizations;
- The National Innovation Council;
- The National Research and Innovation Council;

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

[1] Innovation strategy for smart specialization of the Republic of Bulgaria 2014-2020 (IS3) https://www.mi.government.bg/en/themes/innovation-strategy-for-smart-specialization-of-the-republic-of-bulgaria-2014-2020-is3-1470-287.html

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During the development of this document (first trimester of 2018), we were not able to identify strategies that target or even mention educational robotics and STEM educational initiatives in Bulgaria. The analyzed strategies set general objectives towards research and smart growth rather than concreate initiatives in educational robotics and STEM education.

The **Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020 (IS3)** and **National strategy for development of scientific research in the Republic of Bulgaria 2017 – 2030** declare the political will and vision of the government of the Republic of Bulgaria to achieve higher share of high-tech production and to overcome the most challenging socio-economic problems like labour productivity, demographic crisis and increasing the quality of life with the instruments of the digital economy. The considered national strategies do not mention explicitly educational robotics but provide valuable insights about the capacity for research and innovation performance at the national level and specific measures to address the major challenges that the society is facing. Among the major reasons for striving towards higher added value manufacturing are:

- the lower share of youth-oriented to study STEM (24% as a total share) comparing with EU level;
- a higher level of employment concentrated in middle and low-tech activities (82%);
- the ageing of ICT infrastructure in the educational system;
- lack of a modern cloud infrastructure based on which to create conditions for access to modern educational content;

The Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020 (IS3) considers and justifies two generic actions for overcoming the so-called Digital exclusion – the creation of a student-oriented learning environment and increasing the share of the digital literate citizens.

According to one of the most authoritative databases - Web of Science (WoS): during the last decades, Bulgaria has been continuously and steadily losing positions in relation to the number of the internationally recognizable scientific publications. From 35^{th} position occupied by Bulgaria in 1990, the country drops to 44^{th} place in 2000 and as a EU member since the beginning of 2007 Bulgaria reaches 51^{st} position and 59^{th} position in 2016.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

Although the adequate computer and Internet skills (digital literacy) are essential for the development of economic sectors with high innovation potential it is necessary to consider all skills related to STEM professions. ICT skills and digital literacy is the only competence considered by the **Innovation Strategy of Bulgaria (IS3)**.

The **Innovation Strategy of Bulgaria 2014-2020 (IS3)** indicates that only 42% of the population have some computer skills, which are well below the EU average of 67%. In 2013, people with medium or high Internet skills are 37% compared to the average for the EU of 47%. Interventions are needed at all levels of the education system and the system of training and retraining of employed, unemployed and disadvantaged people and groups to increase the digital literacy of citizens and avoid the so-called Digital exclusion.

RESUME OF THE STRATEGY

The Innovation Strategy for Smart Specialization of the Republic of Bulgaria 2014-20201 [ISSS] defines the vision of the Bulgarian state for promotion of innovations and smart specialization of the Bulgarian

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economy – By 2020 Bulgaria must make a qualitative leap in its innovation performance at a EU level to tackle public challenges in the field of demography (reversing brain drain and youth entrepreneurship), sustainable development, intellectual capital and the nation's health.

The strategy consists of the following main parts:

- Analytical part, which covers the socio-economic analysis, analysis of the capacity for innovation and research performance, and analysis of ICT and ICT potential. The SWOT analysis summarizes the conclusions of the analyses;
- Strategic part, which formulates the vision, strategic and operational objectives for realizing the vision; the proposed main activities associated with the achievement of the strategic objective, and an indicative financial plan;
- Proposal for effective and coordinated management of IS3 with an elaborated mechanism for monitoring and evaluation.

Bulgaria, as part of the EU, is facing serious economic challenges that require the implementation of an ambitious economic policy. Through the **Innovation Strategy for Smart Specialization** (IS3, ISSS, and the Strategy), Bulgaria declares its vision for a policy change and overcoming of the existing socio-economic challenges:

- Low labor productivity;
- Low share of high-tech production;
- Demographic crisis – ageing of population;
- Providing high quality and healthy life;

Strategic Goal: By 2020, Bulgaria will move from the group of "modest innovators" into the group of "moderate innovators"[3].

In practice, this change in the indicators will be implemented through an effective policy for promoting:

- Innovation, research and development of human capital;
- Investment in high-tech areas in which Bulgaria has traditions, has created professionals and successfully competes on the international market;
- Export-oriented industries.

The strategic goals will be realized by achieving two operational objectives:

Objective 1: Focus the investment for the development of innovation potential in the smart thematic areas (for creation and development of new technologies leading to competitive advantages and increase in the added value of domestic products and services).

Objective 2: Support for accelerated implementation of technologies, methods, etc., which improve resource efficiency and application of ICT in the enterprises in all industries.

Measures for implementation of the strategy will be secured financially mainly by the Operational programs OPIC and OPSEIG, and the part remaining for the account of the state budget will be at the amount not exceeding the allocated resources for innovation within the frame of the laws for the state budget for every year of the planning period till 2020.

The thematic areas of the strategy are:

- Mechatronics and clean technology;
- Informatics and ICT;
- Industry for healthy life and biotechnology;
- New technologies in creative and recreation industry;

There are 3 activities anticipated in the Strategy that refers to the development of human capital and addresses the educational and training needs:

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1) Strengthening the link between higher education and the requirements of the labor market; stimulating the training in technical and engineering specialities; enhancing the practical application of higher education;
2) Reforming vocational education and promoting lifelong learning.
3) Internationalization of innovation to further improve the quality of research and management of the phenomenon of “brain drain”.

The National Strategy of Scientific Research has been developed within the concept of research, technological development and innovation being the drivers of the knowledge-based economy. It is consistent with the objectives of the National Innovation Strategy of Bulgaria and its implementation measures for increasing the competitiveness of Bulgarian enterprises by strengthening the scientific capacity; joint financial instruments for support of science and innovation and building centers of competence in priority areas in the economy.
At the national level, the Strategy provides the scientific organizations, universities and the completely academic research community with the necessary framework within which they can formulate their views and plans for participation in national R&D activities, by giving priority to programme funding. Furthermore, the Strategy provides the society and the legislator with information about the Government striving for effective use of public funds for R&D.

STRATEGY PLANS AND INITIATIVES

Both Bulgarian strategies reviewed **do not have operational plans for execution**. They anticipate monitoring institutions, indicators for implementations, phases for implementation, but both have no specific budget dedicated to activities or indicative plans for implementation. Both of them consider the EU cohesion funds as the main source of resources and there is no clear vision about the national contribution or any figures of potential contribution from R&D activities of private companies. A realistic evaluation of private investments in science and research lacks, therefore any forecast about the next 5-10 years cannot be made.

Nevertheless, at the beginning of 2016, based on the **Innovation Strategy for Smart Specialization,** the Ministry of education and science started few positive initiatives towards recognizing the problem of shortage of STEM professions and searching for solutions. After a research of the needs of the labor market, in February-March 2016, the Ministry of Education announced a list of professional domains (the press-release of the Ministry mentions STEM disciplines explicitly) that should serve as a preparation for the admission in the public universities for the school year of 2017-2018. The Ministry coordinated this list with the rectors of universities in Bulgaria. *The definition of the priority domains reflects both the demographic crisis and the disproportions between the personnel prepared by the higher education institutions and the needs of the labor market* states the press release of the Ministry. The Ministry foresees the bounding of the state financing for the universities with this list. The state budget for 2017 stated new coefficients for financing the education of students in state universities. The biggest increase was regarding the programs within the STEM domain of subjects. At the beginning of 2018, the Minister of the Education announced that the Ministry considers dropping the university fees out for the priority domains and full suspension of the state financing for non-priority domains among which are economics, administration and management. The goal is to stimulate the interest towards domains that the labor market will need at most in the future.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

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There are no explicitly mentioned practices related to the ER4STEM project scope. Considering the **Innovation Strategy for Smart Specialization,** we can conclude that there is one significant project accomplished – Sofia Tech Park. A scientific infrastructure for over than BGN 20 million was put into operation. It supports the Bulgarian innovative business and scientific research ecosystem in Bulgaria. About 40 000 sq. m. new and renovated building premises were created. They accommodate applied science laboratories, business incubator, lecture /educational/ discussion forums, space for demonstration of new technologies, office areas.

The National Science and Research Fund (NSRF) is another supporting organization mentioned in the Strategy as a program that contributes to scientific research in Bulgaria. NSRF is a legal entity to the Ministry of Education and Science. It promotes the research initiatives at a national, regional and international level. Six standing expert committees are operating at the NSR Fund, reflecting the priority research areas: mathematics and informatics, natural sciences, biology and medical sciences, agricultural sciences, technical sciences, public sciences and humanitarian sciences. The key program, in which NSR Fund is currently participating, is called "Scientific Research Potential Development". It is operating under three strategic priority modules: improvement of the scientific research infrastructures in the universities and research institutes; modernization of the scientific research equipment in the universities, specialized laboratories and research institutes.

The *National Innovation Fund* (NIF) has been operating at the Ministry of Economy and Energy since 2005, promoting the private investments in the development of competitive and knowledge-based industry in Bulgaria. The Bulgarian Small and Medium Enterprises Promotion Agency is administering the Fund. The direct objective of the fund is to encourage the implementation of scientific research and development projects and technical feasibility study projects with the aim to create new or develop existing products, processes or services for increasing the economic efficiency, improving the innovative potential and enterprise technological level, and promoting the dynamics of the innovative processes.

STRATEGY MONITORING AND RESULTS

Although the **IS3** defines that the National Council on Science and Innovation will prepare yearly reports on the implementation of the Strategy, within the desktop research, the team could not find any published report. IS3 provides specific benchmark sources for defining the performance indicators. They are nationally and globally recognized sources where the progress and results can be tracked: Global Innovation Index, National Statistical Institute, Global Competitiveness Report, and Eurostat.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

We were not able to identify any concrete policies, activities and practices related to the promotion of STEM careers and education among young people. Many stakeholders have stated the need of STEM promotion and encouragement of the younger population to choose a STEM career and education but there is no national policy explicitly declared or, similarly, funding for the implementation of good practices and examples in this area.

If the target of the above-presented strategies is the strengthening of the research and innovation potential of Bulgaria, related activities for the promotion of STEM academic and professional development among the younger population should be envisaged. If core goals of the Bulgarian general

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and higher education include the improvement of the synergy t between the general education, industry and science at a national level, dedicated activities to encourage students to choose a STEM-related educational path.

Bulgaria: National strategy for development of scientific research in the Republic of Bulgaria (2017 – 2030)

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

For the development and implementation of the **National strategy for development of scientific research in the Republic of Bulgaria**, responsible institutions are the Council of Ministers, the Ministry of Education and Science (Implementation Agency for Science), the Ministry of Economy, Energy and Tourism and Ministry of Labor and Social Policy. The implementation bodies are the universities, Bulgarian Academy for Science and other scientific organizations.

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

During the development of this document (first trimester of 2018), we were not able to identify strategies that target or even mention educational robotics and STEM educational initiatives in Bulgaria. The analyzed strategies set general objectives towards research and smart growth rather than concreate initiatives in educational robotics and STEM education.

The **Innovation Strategy for Smart Specialization of Republic of Bulgaria 2014-2020 (IS3)** and **National strategy for development of scientific research in the Republic of Bulgaria 2017 – 2030** declare the political will and vision of the government of the Republic of Bulgaria to achieve higher share of high-tech production and to overcome the most challenging socio-economic problems like labour productivity, demographic crisis and increasing the quality of life with the instruments of the digital economy. The considered national strategies do not mention explicitly educational robotics but provide valuable insights about the capacity for research and innovation performance at the national level and specific measures to address the major challenges that the society is facing. Among the major reasons for striving towards higher added value manufacturing are:

- the lower share of youth-oriented to study STEM (24% as a total share) comparing with EU level;
- a higher level of employment concentrated in middle and low-tech activities (82%);
- the ageing of ICT infrastructure in the educational system;
- lack of a modern cloud infrastructure based on which to create conditions for access to modern educational content;

The **National strategy for development of scientific research in the Republic of Bulgaria** 2017 – 2030 states that if Bulgaria wants to achieve the average European level for number of scientists, considerable efforts must be placed towards encouraging and attracting young people to scientific career. In order to achieve that, the strategy anticipates measures for keeping the scientists in Bulgaria and for the attraction of more young scientists. The National strategy for development of scientific research does not consider activities for attracting more young citizens to choose STEM career and education, but it is focused only on the scientists and scientific institutions, most of which are public. There are 3 specific objectives with more than 50 measures and there is no a word on making the science more attractive for the young population and society as a whole. The objectives are defined in

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a very abstract way, for instance, Specific objective 10. *Significant intensifying of the connections among science, education, business and society* and Activity 10.1. *Strengthening the connections between the science and education on all levels.*

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

The **National strategy for development of scientific research in the Republic of Bulgaria** (2017 – 2030 focuses on the shortage of professionals, incl. young people, in scientific domains. The issue of acute shortage of human resources in science and technology and of the exodus of scientists to more developed economies such as the USA, Japan, Singapore and other countries has arisen at European level since 2005. The low interest of young people to engage in science, the general trend of population ageing and now the global economic crisis simultaneously depicts an adverse profile of the scientific community. These trends in Bulgaria are more distinct, as there are other barriers to scientists, particularly to young people. These are low wages, no freedom to choose workplace, slow career advancement. The adopted new Law for Academic Development aims at introducing flexible and expeditious procedures for obtaining scientific degree, but for now it does not solve the low-wage problem of scientists.

The exodus of young people from science and engineering professions is a factor conducive to low innovation activity. Engineering specialists are very important to the economy of every country, as on one hand, they develop innovations that are central to the technological prosperity and economic growth, and on the other hand, they help to enhance the economic competitiveness. Bulgaria is among the leaders within the European countries in terms of employment of engineers, but over 76% of the graduate engineers do not work according to their speciality while the average value is 28%. The ratio is highest in Bulgaria.

RESUME OF THE STRATEGY

National strategy for development of scientific research in the Republic of Bulgaria (2017 – 2030), approved with the decision № 282 of the Council of Ministers from 19.05.2017. [2]

The National Strategy of Scientific Research has been developed within the concept of research, technological development and innovation, being the drivers of the knowledge-based economy. It is consistent with the objectives of the National Innovation Strategy of Bulgaria and its implementation measures for increasing the competitiveness of Bulgarian enterprises by strengthening the scientific capacity; joint financial instruments for support of science and innovation and building centers of competence in priority areas in economy.

At national level, the Strategy provides the scientific organizations, universities and the entire academic research community with the necessary framework within which they can formulate their views and plans for participation in national R&D activities, by giving priority to programme funding. Furthermore, the Strategy provides the society and the legislator with information about the Government striving for effective use of public funds for R&D.

[2] http://horizon2020.mon.bg/?h=downloadFile&fileId=436

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At international level, the **National strategy for development of scientific research in the Republic of Bulgaria** reflects the Bulgaria's efforts to raise the investments in science and technological development to 3 % of EU's GDP, according to the objectives of "Europe 2020" by achieving accelerated use of the results of research and innovation, modernizing the scientific process and implementing efficient European models and practices.

The **Strategy for development of scientific research** reflects the EU priorities of building European Research Area:

- The concentration of public resources and investments in priority research areas;
- Support for research infrastructure and sustainable development of effective research organizations;
- Inclusion of the private sector into the research and innovation processes;
- Better coordination of education, research and innovation policies;

Promotion of the free movement of people, knowledge and technologies.

STRATEGY PLANS AND INITIATIVES

Both Bulgarian strategies reviewed **do not have operational plans for execution**. They anticipate monitoring institutions, indicators for implementations, phases for implementation, but both have no specific budget dedicated to activities or indicative plans for implementation. Both of them consider the EU cohesion funds as the main source of resources and there is no clear vision about the national contribution or any figures of potential contribution from R&D activities of private companies. A realistic evaluation of private investments in science and research lacks, therefore any forecast about the next 5-10 years cannot be made.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

There are no explicitly mentioned practices related to the ER4STEM project scope.

STRATEGY MONITORING AND RESULTS

The reporting on the results of the **National strategy for development of scientific research in the Republic of Bulgaria,** according the LAW FOR PROMOTION OF SCIENTIFIC RESEARCH, is a responsibility of the Minister of Education and Science. He prepares "*an analysis and report of scientific research and of international scientific cooperation in accordance with the National Strategy for development of scientific research*." An *Information System on the state-of-art and development of scientific research in scientific organizations and higher schools* is created but the access is complicated. On the Home page of the Information System, it is stated that the goal of the web portal is to collect data about state-of-art scientific research, however, there is nothing published or public accessible.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

We were not able to identify any concrete policies, activities and practices related to the promotion of STEM careers and education among young people. Many stakeholders have stated the need of STEM promotion and encouragement of the younger population to choose a STEM career and education but

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there is no national policy explicitly declared or, by the same token, funding for the implementation of good practices and examples in this area.

If the target of the above-presented strategies is the strengthening of the research and innovation potential of Bulgaria, related activities for the promotion of STEM academic and professional development among the younger population should be envisaged. If core goals of the Bulgarian general and higher education include the improvement of the synergy t between the general education, industry and science at a national level, dedicated activities to encourage students to choose a STEM-related educational path.

Greece: ESERO (European Space Education Resource Office)

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

ESERO[3] is an education project of the European Space Agency (ESA), co-funded by ESA and by national partners active in the fields of education and space. ESERO national offices are distributed across Member States, and staffed by local experts who work in strong synergy and partnership with their national education authorities and networks.

ESA has established twelve ESERO national offices in Austria, Belgium, Czech Republic, Denmark, Ireland, Finland, Netherlands, Norway, Poland, Portugal, Spain, Romania, Sweden and UK. Greece has been a member of ESA since 2005. General Secretariat for Research & Education is responsible for the participation of Greece in ESERO. Other stakeholders are:

- National Observatory of Athens
- Athens Academy
- University of Athens
- Hellenic Astronomical Society
- Eugenides Foundation
- Noesis

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

ESERO uses space related themes and the genuine fascination felt by young people for space to engage them in STEM subjects. ESERO also highlights the associated applications from space and raises awareness of the large range of career possibilities in the space domain. The ESERO activities help bring STEM subjects within the pupils reach, demolishing the misconception that science is only for geniuses.

The ESERO objectives are to use Space as a context to:

- enhance the literacy and competence of young people in science, technology, engineering and mathematics (STEM)
- motivate and enable young Europeans to pursue a career in the STEM field, in the space domain in particular
- increase young people's awareness of the importance of space research, exploration and applications in modern society and economy.

[3] https://www.esa.int/Education/Teachers_Corner/European_Space_Education_Resource_Office

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NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

CTI along with the Organization of Teacher Training, the Research Academic Computer Technology Institute (RA-CTI), the Pedagogical Institute (PI) and the Institute of Educational Policy (IEP) is responsible for the project "In-Service Training of Teachers for the utilization and application of ICT in the teaching practice" of the Operational Programme "Lifelong Learning", NSRF (2007-2013), which is being implemented with co-funding from the European Union and the European Social Fund.

The project is the continuation of an older respective project "B-Level in-service training" which was completed in 2008. The scope of the project is the in-service training of 28,100 educators of Greek primary and secondary education schools in the in-class teaching application of ICTs. This Teaching Practice involves two types of in-service training that are unavoidably interrelated:

a) The in-service training of 27,500 teachers in the principles of the educational utilization and application of ICTs, and in the acquisition of skills, according to their individual educational domain for the educational use of educational software and generic IT tools.

b) The in-service training of 600 educators, who will become the teacher trainers of the specific educational Action.

The implementation of the Educational Action presupposes the development of curricula, training material and studies, as well as the design, organization, implementation, monitoring and evaluation for the above types of training. It also involves the application of expertise and skills in the classroom, the support of teacher trainees, the certification of their acquired knowledge and skills in ICTs, the development and operation of supporting structures for the organization, implementation, monitoring, evaluation and control of the Educational Action.

RESUME OF THE STRATEGY

The European Space Education Resource Office (ESERO) project is ESA's main way of supporting the primary and secondary education community in Europe.

ESERO offers an annual series of national or regional training sessions for both primary and secondary school teachers. These are offered in collaboration with national partners who are already active in STEM education. Teacher training events are, wherever possible, officially accredited as part of continual professional development qualifications.

ESERO uses and disseminates existing ESA/ESERO space-related STEM classroom resources, and if appropriate, develops specific new resources tailored to the national curricula. Real space data and the application of real-life scientific methodology, accompanied by the role model support of real space experts such as scientists and even astronauts, are used as much as possible.

The ESERO project also help stimulate young people's awareness of Europe's space program and of its importance for modern society and economy.

STRATEGY PLANS AND INITIATIVES

ESERO offers an annual series of national or regional training sessions are offered in collaboration with national partners who are already active in STEM education. Teacher training events are, wherever possible, officially accredited as part of continual professional development qualifications.

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Robotics and automation workshops for primary[4] and secondary[5] teachers

During the workshops, participants are guided through activities that can be performed in the classroom, such as creating robots using LEGO WeDO or Arduino platform, and using them to perform a 'mission to Mars' with specific discovery objectives.

9th Summer Teacher Workshop from 10 to 13 July 2018 and 4th Autumn Teacher Workshop from 4 to 7 October 2018

Inspired by real and actual ESA space missions and programs, participants will be given stimulating talks and training on how to include space in their lessons to make science and technology exciting for their students.[6]

ESA's Education Office sometimes organizes training courses in association with the independent Galileo Teacher Training Program (GTTP). The emphasis is placed upon introducing science teachers to the resources that can be used to teach astronomy and astrophysics. The program aims to help teachers inspire young people to consider science careers. Workshops take place at various sites throughout Europe[7]

ESERO uses and disseminates existing ESA/ESERO space-related STEM classroom resources[8], and if appropriate, develops specific new resources tailored to the national curricula. Real space data and the application of real-life scientific methodology, accompanied by the role model support of real space experts such as scientists and even astronauts, are used as much as possible.

In the moment the department of educational policy supports the project OPEN SCHOOLS FOR OPEN SOCIETES - (OSOS), which aims in preparing the introduction of Open School innovation, focusing on STEM's natural sciences and subjects on subjects related to modern social challenges at all levels of Education.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

As mentioned, in the context of ESERO, pupils can be familiar with sciences, using the space context to make the teaching and learning of STEM subjects more attractive and accessible. A good example of a good practice in relevance to the above is an educational scenario, which was developed by UoA (An introduction to robotics: Exploring planet Ektonis). During the activities, students had to build and then program a robot in order to complete some missions on another planet.

STRATEGY MONITORING AND RESULTS

N/A

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

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[4] http://www.esa.int/Education/Teachers_Corner/Applications_for_ESA_robotics_and_automation_teacher_workshops_now_open_for_primary_school_teachers
[5] http://www.esa.int/Education/Teachers_Corner/Applications_for_ESA_robotics_and_automation_teacher_workshops_now_open_for_secondary_school_teachers
[6] http://www.esa.int/Education/Teachers_Corner/Apply_to_ESA_s_teacher_workshops
[7] http://www.esa.int/Education/Teachers_Corner/Galileo_Teacher_Training_Programme
[8] http://www.esa.int/Education/Classroom_resources

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Space is a subject which fascinates students and can provide an attractive context for the design of educational robotics activities, such as the one described above (An introduction to robotics: Exploring planet Ektonis). In the context of ESERO, "real space data and the application of real-life scientific methodology, accompanied by the role model support of real space experts such as scientists and even astronauts, are used as much as possible". Recommendations about ER4STEM project derived from the ideas of this strategy could include:

The development of activity plans which include real life data and scientific methologies, corresponding to real life research fields.

The inclusion of STEM researchers and STEM professionals in the development and implementation of the activity plans.

Greece: Greek Ministry of Education and religious Affairs' Strategic Initiatives

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

Greek Ministry of Education and Religious Affairs is responsible for developing and supporting STEM initiatives and, in general, the digital literacy of Greek students. Various departments of the Ministry implement European or national programs and involve a large number of teachers and students with new technologies, science and robotics. One of these is The Computer Technology Institute and Press "Diophantus". CTI has been supervised by the Greek Ministry of Education and Religious Affairs as a financially, administratively and scientifically independent institution since 1992. In 2001, it was renamed as Research Academic Computer Technology Institute (Law 2909, art. 2).

The Computer Technology Institute and Press (CTI) was founded in 1985 as the Computer Technology Institute in the city of Patra, Greece, as a Non Profit Private Legal Entity, supervised by the General Secretariat of Research and Technology (Presidential Decree 9/1985).

Since 1992 CTI has been supervised by the Greek Ministry of Education and Religious Affairs as a financially, administratively and scientifically independent institution. In 2001 it was renamed as Research Academic Computer Technology Institute (Law 2909, art. 2).

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

Greek ministry of education has supported various programs relevant to STEM education:

1. The Department of Educational Broadcasting implemented the program "MARCH make science real in schools"(sciencemarch.eu/index.php/el/) He set up a network of teachers and pupils who communicated and exchanged information through meetings and meetings.
2. The Ministry has invested in the creation of open-label workshops in public schools (https://www.minedu.gov.gr/lykeio-2/sxolika-nea-lykeio/23108-01-09-16-dimiourgia-ergastirion-anoixton
3. The Ministry of Education and Science linked schools with learning communities, professors, repositories through the OPEN DISCOVERY SPACE portal http://www.opendiscoveryspace.eu/en.
4. Greek ministry has also supported postgraduate programs such as the MSc Master of Science in Science, Technology, Engineering and Mathematics in Education Aspete, Department of Education. The specific aims and objectives of the Msc program focus on:

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- The creation of a critical mass of teachers with concise and compact knowledge of computational models that will be used by them for the development of Inquiry based educational scenario using the trans disciplinary approach
- The discovery by teachers and generally by Msc students of new research areas that combine STEM with Didactics, so they will be able to write research papers and develop artefacts
- To help students who will want to continue for PhD degree.
- The knowledge of epistemological models and how they can be integrated in the computational experiment approach
- The acquaintance of students with proper –well established repositories connected with STEM education
- The provision of stents to training of how they will write source code for education purposes, using environments like Lego Mindstorms ev3, LABVIEW,, Easy java simulations, Mathematica, Python and general STEM Technologies
- The knowledge of issues related to e-learning and authoring tools for e-learning.
- To teach students quantitative and qualitative methods for statistical analysis using SPSS and NVIVO.
- The development of serious games using the UNITY software.
- To get skills related to STEM Economy

The department of CTI is considered as the technological pillar supporting CTI in education. CTI has enabled all pupils, teachers and parents in the country to access digital material that is in aligned with the curriculum of all levels, in digital books, in digital educational scenarios, on e-me platforms, educational software and digital learning objects (http://dschool.edu.gr/). CTI is responsible for the administration of the Greek School Network, the largest user network in Greece and CTI has also supported various research programs relevant to STEM education.

For example, Make world (https://makeworld.eu/#/) was a research program implemented in 2014-2016 aiming in:

1. analyze the attitudes and skills around STEM of teachers and elementary students.
2. design and define a methodology for the teaching and learning of STEM, leveraging the engagement of social and gamified platforms, story-telling, computational thinking, social assessment and personalized learning.
3. develop an open, free, open source and expandable platform to promote a symbiotic relationship between STEM learning and computational thinking in the broad sense.
4. create content and activities for the platform to facilitate its use with different levels of involvement. This initial repository of materials will be published under free licenses that allow subsequent reuse, even beyond the scope of this project.
5. assess the quality and impact of the project, both in terms of attitudes and skills about STEM schools, and the quality of the methodology, platform, and materials developed.

The department of educational policy also supports the project OPEN SCHOOLS FOR OPEN SOCIETES - (OSOS). The European project H2020: "Open Schools for Open Societies - OSOS" ("An open school in an open society"), aims to create a framework for the "Open School".

The aim of the project is to prepare the introduction of Open School innovation, focusing on STEM's natural sciences and subjects on subjects related to modern social challenges at all levels of Education.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

CTI along with the Organization of Teacher Training, the Research Academic Computer Technology Institute (RA-CTI), the Pedagogical Institute (PI) and the Institute of Educational Policy (IEP) is responsible for the project “In-Service Training of Teachers for the utilization and application of ICT in

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the teaching practice" of the Operational Programme "Lifelong Learning", NSRF (2007-2013), which is being implemented with co-funding from the European Union and the European Social Fund.

The project is the continuation of an older respective project "B-Level in-service training" which was completed in 2008. The scope of the project is the in-service training of 28,100 educators of Greek primary and secondary education schools in the in-class teaching application of ICTs. This Teaching Practice involves two types of in-service training that are unavoidably interrelated:

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RESUME OF THE STRATEGY

Greek ministry of education and its department The Computer Technology Institute and Press "Diophantus" are the main responsible institutions for the implementation of initiatives and plans relevant to STEM education. CTI is a research and technology organization focusing on research and development in Information and Communication Technologies (ICT). Particular emphasis is placed on education, by developing and deploying conventional and digital media in education and lifelong learning; publishing printed and electronic educational materials; administrating and managing the Greek School Network; and supporting the organization and operation of the electronic infrastructure of the Greek Ministry of Education and Religious Affairs and all educational units. Since its establishment in 1985, and in the past decades of rapid technological development, CTI has actively contributed to many of the advances that today are taken for granted.

STRATEGY PLANS AND INITIATIVES

Greek Ministry if education plans on the continuation and further development of the integrated training for the exploitation and implementation of ICTs. in the didactic act, "Level 2 Training", which includes, among other things mentioned above, the extension of training to all sectors and qualifications of primary and secondary school teachers. "Level 2 Training" aims in developing content and training material for new disciplines and teacher competencies that are included for the first time in education for the educational use of digital technologies, developing certification material for new disciplines and teacher qualifications that are the first to be included in the training for digital literacy, designind and implementing internal evaluation actions during the implementation of the Act and for all types of training and certification.

In the moment the department of educational policy supports the project OPEN SCHOOLS FOR OPEN SOCIETES - (OSOS), which aims in preparing the introduction of Open School innovation, focusing on STEM's natural sciences and subjects on subjects related to modern social challenges at all levels of Education

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

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N/A

STRATEGY MONITORING AND RESULTS

N/A

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

N/A

Italy: Piano Nazionale: Scuola Digitale

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

The Italian ministry of education created this strategy with the objective of modernize Italian education system. The strategy involves the following stakeholders:

- Italian government
- Regional governments
- Schools
- Industry

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

This plan aims to improve the quality of didactics in school providing tools, training and skills to them.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

One of the objectives of this strategy is to create the matrix of skills that each students must develop. Nevertheless, they recognize the importance of 21st century skills.

RESUME OF THE STRATEGY

The authors highlight the importance of digital skills, their plan is mainly focus on the change of culture in the school. They consider that school is not just a physical place but it is a platform that provides the conditions to the students to develop skills for the life. Therefore technologies must be an instrument used to teach and not the ultimate goal. Moreover, they consider that it should be a collaboration between diverse stakeholders.

To have a better idea on the situation in Italy, they summarize diverse initiatives between 2008 and 2015:

- Initiative LIM tried to introduce smart whiteboards in the schools. This initiative include budget to train teachers on how to use it.
- Initiative Cl@ssi 2.0 aimed to promote the introduction of innovation in the school. It had the slogan "no more lessons in the lab, but lab in the lesson".
- Initiative Scuol@ 2.0 helped a small number of schools to move forward new organizational models that advantage the introduction of new technologies.

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- Agreement MIUR – Regioni was created with the objective to follow schools' process closely to improve the synergy between the central government and regions.
- Initiative Azione Centri Scolastici Digitali (CSD) was created to support regions in disadvantageous locations to introduce new technologies.
- Initiative Wi-Fi aims to increase the access to internet to all Italian citizens.
- Initiative Poli Formativi identified educational centres that could be used to provide courses to increase teachers' digital skills.

Based on the current situation and their objectives, they recognize four components to organize their plan: tools, skills and content, training, and accompaniment. For each one of these components, they identified critical objectives for each component.

STRATEGY PLANS AND INITIATIVES

For each one of the components identified, it was created activities that are translated in initiatives' objectives that help to reach the main objective.

Component	Action	Initiatives' objectives
Tools	Access	• Provide to all schools access to internet
	Spaces and environment for learning	• Improve the infrastructure of schools. • Transform laboratories in spaces where students can apply their knowledge. • Change from transmission of knowledge to active teaching.
	Digital management	• Complete the digitalization of the school management and reduce processes that involve paper. • Increment the use of digital services. • Open school's data to citizens and industry.
Skills and content	Students' skills	• Define a matrix of digital skills that each student has to develop. • Define with teachers educational strategies. Innovate the schools' curricula.
	Digital entrepreneurship and work	• Promote STEAM careers. • Promote the connection between schools and work.
	Digital content	• Incentive the use of high quality digital content. • Motivate the innovation, diversity and share of didactical content and digital works.
Training	Personal training	• Strength the preparation of schools' personnel in digital skills. • Promote the connection between didactic innovation and digital technologies. • Develop efficient and sustainable standards for training in education.
Accompaniment	Personal training	• Innovate new ways to help and follow schools. • Propagate innovation inside each school. Enable and strength tools for the intelligent collaboration between schools and external stakeholder.

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GOOD PRACTICES IN THE CONTEXT OF ER4STEM

Teachers must understand that robotics is an instrument to potentiate their didactical approach and it does not substitute good teaching practices.

STRATEGY MONITORING AND RESULTS

The strategy does not provide any results.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

- Technology is an instrument used to teach not the ultimate goal.
- They recognize the importance of supporting schools to get acquaint with new technologies.
- The challenge in the digital area is to make accessible education to everyone.

Malta: eSkills Malta Foundation

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

eSkills Malta Foundation. The eSkills Malta Foundation is a coalition of various representatives from Government, industry and education. The foundation brings together Government representatives from Education and MITA together with key entities in investment employment and Industry, including Malta Enterprise, Malta Communications Authority, The Malta Gaming Authority and The Chamber of Commerce.

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

One of the main national (and in fact European) concerns is the participation of certain groups in the society, both for the participation in the ICT industry and for having access to equal opportunities in taking advantage of the digital opportunities.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

N/A

RESUME OF THE STRATEGY

The eSkills Malta Foundation, set up in 2014, is committed to focus on the ICT skills that are fundamental to develop a resilient ecosystem of institutional and human capital, to sustain a Digital Economy through the further advancement of skills and competencies, related to ICT in Malta.

The Foundation will continue to work closely, with collaborating partners, to implement the underpinning policies, taxonomies, resource demand and supply monitors, supporting standards and incentives that Government, industry, and society require, nurturing the ICT skills, for a leading Information Society and Digital Economy.

The ER4STEM project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 665972

STRATEGY PLANS AND INITIATIVES

Ongoing plans and strategies are in the pipeline to continue raising awareness and improving ICT skills within the stakeholders. This includes the launch of a set of guidelines to increase and retain women in ICT. The eSkills Malta Foundation is funded by the Malta Information Technology Agency (MITA).

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

The foundation pushes many events such as Code Week, the ICT Career Exposure Experience and other events that boost the participation of ICT both for girls and boys.

STRATEGY MONITORING AND RESULTS

The results and publications from the foundation can be found at: https://eskills.org.mt/en/Pages/Home.aspx

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

N/A

Malta: Women in ICT Focus Group

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

eSkills Malta Foundation. The eSkills Malta Foundation is a coalition of various representatives from Government, industry and education. The foundation brings together Government representatives from Education and MITA together with key entities in investment employment and Industry, including Malta Enterprise, Malta Communications Authority, The Malta Gaming Authority and The Chamber of Commerce.

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

One of the main national (and in fact European) concerns is the participation of certain groups in the society, both for the participation in the ICT industry and for having access to equal opportunities in taking advantage of the digital opportunities. One of these target groups is the female gender where especially in the ICT industry the numbers are very low. In this respect, we feel a certain responsibility to try to address this. We would like to make our digital economy contribution more effective to women, and to this effect a focus group – Women in ICT has been set up made up of like-minded individuals coming from the ICT industry or organisations that make use of ICT.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

N/A

RESUME OF THE STRATEGY

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This focus group would like to make our digital economy contribution more effective to women, and to this effect a focus group – Women in ICT has been set up made up of like-minded individuals coming from the ICT industry or organisations that make use of ICT.

The proposed objectives of the group are:

- Increase the participation in the Digital industry or digital related industry by girls and women
- Having access to equal opportunities in taking advantage of the digital opportunities Increase on the Quality of Resources for the ICT Industry
- Discuss Gender issues at place of work in the digital environment and propose possible solutions
- Contribution to Policy to stakeholders
- Specific Projects

The focus group will meet once every two months to discuss gender issues and propose possible initiatives and solutions to address them. The Foundation will take these in consideration in proposing policies, and would be able to act in some of them.

STRATEGY PLANS AND INITIATIVES

Ongoing plans and strategies are in the pipeline to continue raising awareness and improving ICT skills within the stakeholders. This includes the launch of a set of guidelines to increase and retain women in ICT. The foundation eSkills is funded by the Malta Information Technology Agency (MITA).

A number of initiatives have already been done these include but not limited to:

- Promotion of EU Code week across schools and also to teenagers and to adults
- Promotion of examples of Women in ICT - https://eskills.org.mt/en/womeninict/Pages/Ambassadors.aspx
- Dresscode: The Untold Science of a Fashion Show
- Career & Guidance Teachers Training
- IT Professionalism Seminar
- Guidelines to Increase and Retain Women in ICT

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

The foundation pushes many events such as Code Week, the ICT Career Exposure Experience and other events that boost the participation of ICT for both girls and boys.

STRATEGY MONITORING AND RESULTS

The results and publications from the foundation can be found at https://eskills.org.mt/en/womeninict/Pages/About.aspx

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

N/A

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Spain: Competencias Digitales en España ¿Cómo Mejorarlas?

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

Members of "Foro de Formación Digital" in Spain created a press kit to summarize efforts around Europe, especially in Spain, to increase the digital skills. The press kit first compares Spain situation with the rest of Europe. Then the authors present different national and international initiatives that promote these skills. Finally, they conclude with suggestions based on their analysis.

In their definition of digital skills, they mention those that citizens and TIC professionals must have. In addition, they present two studies that shows how digital skills are related to STEM jobs, which are expected to growth in the following years.

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

European countries have understood the importance to increase digital skills literacy. Nevertheless, the increment of the digital skills is linked to the governments' disposition to use TIC as a based to move their economy. Nevertheless, Spanish government needs to commit more with initiatives and programs that help the increment of digital skills because there is still a lot of space for improvement. The authors suggest that digital skills and STEM play a fundamental role in increasing the employability of people, which is shown in two studies reported. One is a study done in United States of America, which reports the increment of STEM jobs in the future, and people working in STEM tend to earn 26% more than people not working in STEM.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

Authors are not go in deep about the requirements of industries but rather present two studies that show that digital skills, as they defined in the press kit, increment the possibilities of employability.

RESUME OF THE STRATEGY

The authors start defining what digital skills means. They suggest that the definition given by the European parliament in 2006 is outdated because new technologies such as social networks has been created since then. Therefore, they used as a based two projects that tried to create a framework to standardized the definition of digital skills. One is the European Joint Research Center, which came with five knowledge areas (i.e. Communication, Information, Problem Solving, Security and Content creation) to group the skill with three different levels of knowledge (i.e. Basic, intermediate and advance). The second is the European Committee for Standardization, which specified skills in TIC: European e-Competence Framework. This framework has five big areas (i.e. Plan, build, run, enable and management) with 40 skills. Using them, the authors suggest the skills that different stakeholders should have.

They started to make a comparison between Spain and the rest of Europe based on the desire skills for citizens and professionals. Therefore, they used two indexes: digital literacy activity and e-skills activity index. The digital literacy activity index measures the definition and execution of strategies to motivate the improvement of digital skills within the citizen. Spain is among the countries with high index. And the e-skills activity index measures the interest and activity of governments to improve the employability of professional. Spain is among the countries with low index. Moreover, they used the information provided by Eurostat to determine the status of specific digital skills in Spain. Their conclusion is that Spain has improved in both indexes. Nevertheless, they are still low in comparison to other European countries.

They report a study done in United States of America, which reported:

- STEM jobs are going to increment in the future.
- People working in STEM tend to earn 26% more than people not working in STEM
- A low rate of unemployment of STEM professionals.

They also found a similar study in Europe with similar conclusions.

With this information as ground base, they then analyse different initiatives that are trying to improve digital skills in Spain and Europe. They differentiate between four categories: public formal, private formal, public informal and private informal. In the category public private, they present three different initiatives. The introduction of a programming course (Madrid) initiative aims to introduce a programming course in high school in Madrid. The private formal initiates presented are mainly in UK and one from Ireland. In public informal initiatives, they presented the one created by the open education Europe, which aims to promote the use of new teaching methods using new technologies. In addition, three initiatives in Spain are presented. One is done by the region of Euskadi, which is promoting digital skills in the region. Other two are promoted by the regions of Cataluña and Galicia, which aims to certificate citizens in digital skills. Finally, private informal initiatives are presented: two internationals and two Spanish. One Spanish initiative is Talentum Schools, sponsored by, sponsor by Telefonica and Samsung, which aims to promote the interest in digital skills in children between 4 to 18 years old. The other is Generation Spain, sponsor by McKinsey, which aims to foster digital marketing skills in adults between 18 and 29 years old.

STRATEGY PLANS AND INITIATIVES

N/A

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

- Inform people why the skills that they are acquiring during the workshops are important because there is not much knowledge about the importance of digital skills among normal population.
- Involve teachers in any initiative because they are responsible of the implementation in schools.

STRATEGY MONITORING AND RESULTS

This press kit is an analysis on the digital skills in Spain through the comparison with other countries. Therefore, their contribution is on the better understanding of the situation of Spain to provide suggestions that could help Spain to improve its indicators in digital skills.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

They suggest that politics and industries are aware of the importance of digital skills in the development of economy. Nevertheless, people outside this circles and education do not consider these skills important. Therefore, they suggest that all the institutions involve in the promotion and teaching of these skills must show all the importance of acquiring these digital skills. In addition, they suggest that the educator should be the main stakeholder to motivate children to increase their digital skills. Any initiative without the contribution of teachers is condemned to failure. They also suggest the creation of a brochure with good practices to promote and teach digital skills. Likewise a creation of indicators to follow the improvement of these skills. They also suggest that children should be encourage to study STEM careers.

UK Government Strategy: Delivering STEM (Science, Technology, Engineering and Mathematics) skills for the economy

The UK National Audit Office released this report in 2018, examining the effectiveness of the governments approach to boosting participation in the STEM pipeline, at all levels. The last STEM strategy released by the government was the 2011 *Success through STEM* strategy. The audit makes a series of recommendations for the government, with the intention for these to be incorporated into their strategy.

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

Report written by the UK National Audit Office, with responsibility for the strategy falling on the UK government.

Key stakeholders involved are:

- Government Department for Education
- Government Department for Business, Energy and industrial Strategy
- The stakeholders of the government's *Success through STEM* strategy, which includes but is not limited to:
    - Sector Skills Councils
    - STEM charity bodies
    - Business Education Partnerships
    - Government Partners
    - Museums and Libraries
    - Teaching Workforce

RELEVANCE TO THE STEM EDUCATION AMONG YOUNG POPULATION

The audit focusses mostly of the development of STEM skills in those aged over 16, Higher Education and continued STEM skills development. This is relatable to the ER4STEM scope 1) as ER4STEM targets 7-18 year-olds, resulting in a crossover of the targeted group and 2) education of those under the age of 16 directly affects the strategy of over 16 year olds. However, the audit also reports on the "STEM education pipeline" at all levels, with a section focusing on the pipeline's performance in delivering STEM skills.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

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The audit's entire focus is on addressing the STEM skills challenge. Furthermore, it is reported not only where skills shortages lie but also where skills can be mismatched – for example with a lack in technicians but many biological science graduates who are then underemployed.

RESUME OF THE STRATEGY

The audit is constructed of three parts, which each have key findings:

- Government's understanding of the need for enhanced STEM skills in the workforce
    - Government does not currently gather robust intelligence on the STEM skills issues since the transfer of this responsibility onto the Department for Education.
    - Estimates of the STEM skills problem vary widely as they focus on different STEM workforces
    - There is a lack of consistent definitions for STEM both in the context of educational and work.
    - There is a STEM skills mismatch rather than a shortage, including an issue of skill quality rather than quantity.
    - The government is improving its coordination on STEM, with a STEM lead appointed in the Department for Education.
    - It is difficult to predict the impact on STEM from Brexit, although it may amplify the STEM skill shortage.
- The performance of the education pipeline in delivering STEM skills
    - Some initiatives are effective, such as those to increase A-level entries, but more overall coordination is required, with better evidence gathering.
    - Females are underrepresented in STEM most areas of education and work.
    - Participation in STEM-related vocational courses has increased in some areas.
    - Enrolment in undergraduate STEM courses has fallen slightly and those that have increased reinforce the STEM skills mismatch.
    - Only 24% of STEM graduates were working in a STEM occupation within 6 months in 2016.
- The latest initiatives to enhance the development of STEM skills
    - There are several new further education initiatives, such as 'Technician-Levels', which need to establish their ground in the complex landscape of STEM education.
    - The 2017 UK government Industrial Strategy proposes 'Institutes for Technology', which may struggle to find their position in a busy educational market.
    - There are some positive results of better teacher training in STEM for schools, meeting some targets for improving the skills of non-specialist teachers in the subjects of maths and physics.

The audit goes on to give recommendations for specific government departments to improve their STEM strategy.

STRATEGY PLANS AND INITIATIVES

The aim of the audit is to establish the current value for money of the UK Government STEM strategy and so makes various comments on the strategy's budget and impact. The document itself provides no operational plans for the government's strategy, as the government needs to instead adopt the audit's recommendations. At the time of writing this document, no official report has been released from the government as to how and if they are going to action the audit's recommendations.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

N/A

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STRATEGY MONITORING AND RESULTS

The audit itself is a form of evaluation for the initiatives and strategies led by the UK government.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

The audit emphasizes the larger STEM pipeline that ER4STEM fits into. This is particularly important with considering how educational robotics and ER4STEM can increase engagement in STEM subjects and encourage young people into STEM careers. Furthermore, ER4STEM lays a foundation for STEM skills that can then be developed at later stages. Finally, the audit's emphasis on overall coordination of STEM strategies and initiatives again resonates with the need for ER4STEM to consider how it fits into the broader framework of STEM strategies education as a whole.

Welsh Government Strategy: Science, Technology, Engineering and Mathematics (STEM) in education and training. A delivery plan for Wales

The Welsh Government produced this strategy in 2016, setting out the objectives for the provision of STEM education for 3 to 19 year olds. The strategy is in progress, with some ongoing objectives, so objectives for completion in 2018, and completed objectives – such as the development of a Digital Competence Framework in 2016.

INSTITUTION, RESPONSIBLE FOR THE STRATEGY AND RELEVANT STAKEHOLDERS

The Welsh Government released this strategy in 2016, for the provision of STEM for 3 to 19-year-olds in Wales. The strategy involves the following stakeholders:

- Welsh Government
- Regional Consortia
- Local Authorities
- Teaching Workforce
- Government Partners in STEM

RELEVANCE TO STEM EDUCATION AMONG YOUNG POPULATION

The strategy prioritizes evolving STEM teaching undertaken in schools, colleges and universities, whilst developing an education workforce capable of delivering a new and challenging STEM curriculum.

NEEDS RELATED TO STEM PROFESSIONALS, OF THE INDUSTRIES ADDRESSED

One of the priorities is to increase the uptake and development of STEM skills through the evolution of teaching. Another is to change current negative societal attitudes towards STEM and STEM-based careers, to encourage children to enter STEM professions in the future.

RESUME OF THE STRATEGY

In its introduction, the strategy references many recent reports that elaborate the importance of STEM skills (e.g. Policy statement on skills, 2014; Science for Wales – A strategic agenda for science and

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innovation in Wales, 2012). Each of the strategies objectives links to the development of these STEM skills in young people.

The priorities of the strategy are to:

- Build an Evidence Base:
  - Collect STEM performance data and undergoing impact analysis
- Support Learning and Teaching:
  - Evolve the teaching in schools, colleges and universities to support the development of STEM skills.
  - Develop an education workforce capable of delivering the STEM curriculum.
  - Ensure Welsh STEM qualifications have a standard as high as other countries.
- Change Perceptions:
  - Increase interest and participation in STEM learning, particularly among girls.
  - Equip young people with career management skills and knowledge of the options available to them in the STEM sector, so that they are able to make better-informed decisions on their futures.

STRATEGY PLANS AND INITIATIVES

For each aim (priority), the government has further categorized specific areas of work within the aim. It is then outlined both what actions the government has already taken towards this aim, and what specific objectives they have in place for the future. Whilst some of these objectives involve ongoing work, the majority have clear deadlines between 2016 and 2018. However, no clear budgeting is referenced in the strategy.

The subdivision of the aims is as follows:

Building an Evidence Base

- Collation and reporting of data
- Further research and analysis

Supporting Learning and Teaching

- Developing fit-for-purpose STEM curricula
- Enhancing and enriching the STEM curricula
- Introducing fit-for-the-future STEM qualifications
- Advice, guidance and teacher support
- Provision of bilingual resources
- Wider ICT support
- Developments in higher education

Changing Perceptions

- Reinforcing the importance of STEM
- Careers advice and guidance
- Women in STEM

A non-exhaustive example of the objectives set by the government includes:

- *"We will work with stakeholders to develop the details of an annual data report for first publication in 2016, so that all stakeholders have access to a single reference source for STEM in education progress in Wales. This can then be used to inform planning and monitoring arrangements."*
  - No such reports from the following years are found from an internet search, suggesting that this objective has not been met, although this report may not be publicly available.

- *"We will collate and make readily available to teachers in spring 2016 information on professional development opportunities in the fields of science, mathematics, ICT and computing linked to the New Deal for the Education Workforce."*
    - The government has created a "Professional Learning Passport" for the Welsh education workforce to record and access continued professional development, under which STEM is included.
- *"We will ensure computing remains a focus for STEM activities by the Higher Education Funding Council for Wales (HEFCW) and universities in Wales, including work on employer accreditation."*
    - Whilst HEFCW reports reveal no specific objectives surrounding computing in higher education, it appears to be generally taken into account within their funding.
- *"As part of 'Focus on science' activity in 2016, promote existing case studies with a focus on role models and career options, targeting enhancement of girls' engagement with STEM subjects, and disseminate widely."*
    - The Focus on Science campaign was released in 2016 and included case studies of women in STEM.

GOOD PRACTICES IN THE CONTEXT OF ER4STEM

Under the subsection *Advice, Guidance and Teacher Support* the objective is made that: "*We will through the ongoing funding of computing workshops for learners and teachers, ensure that every secondary school has at least one teacher with direct experience of coding by 31 March 2016."* This, as well as the broader aims of the strategy highlights the need not only to focus on the creation of a strong STEM education for children, but also to ensure this education can be delivered by teachers who are confident in STEM.

STRATEGY MONITORING AND RESULTS

There are no overall follow-up documents on the results of the strategy and there is no outline as to how progress will be monitored.

RECOMMENDATIONS TO/CONCLUSIONS ABOUT ER4STEM PROJECT DERIVED FROM THE STRATEGY

The strategy in part focuses specifically on girls in order to bridge the gender divide in STEM. This gender-specific targeting strategy includes targeting through the government's marketing, grant funding, following recommendations from working groups, and making it a requirement for Data gathering structure per each strategy

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