D 1.3 -TOWARDS AN EXTENDED DEFINITION OF ER4STEM FRAMEWORK

[Deliverable 1.3]

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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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DOCUMENT REVISION HISTORY

Version Number	Date	Description	Author
V 0.1	12/02/2017	The modifications suggested by Chronis and Markus are added from previous deliverable	Julian Angel-Fernandez
V 0.1.1	20/02/2012	Chronis suggested new corrections to the new version of the framework	Chronis Kynigos
V 0.2	10/02/2017	A literature review on creativity is added	Julian Angel-Fernandez
V 0.2.1	20/03/2017	New comments from Chronis are integrated	Julian Angel-Fernandez
V 0.3	26/06/2017	A literature review on collaboration is added	Julian Angel-Fernandez
V0.4	26/08/2017	First version of the ontology	Julian Angel-Fernandez
V0.5	05/09/2017	Description of the general knowledge use in ER4STEM	Christina Todorova and Johana Pullicino
V0.5.1	06/09/2017	Description of constructionism in ER4STEM	Chronis Kynigos
V0.5.1.1	06/09/2017	Description of pedagogical methodologies in ER4STEM	Marianthi Grizioti, Carina Girvan and Nikoleta Yiannoutsou
V0.5.1.2		Integration of pedagogical contributions and constructionism	Marianthi Grizioti
V0.5.2	06/09/2017	Description of specific knowledge in robotics	Wilfried Lepuschitz
V0.5.2.1	08/09/2017	Update of specific knowledge in robotics	Wilfried Lepuschitz
V0.7	25/09/2017	Marianthi provided comments and changes to the deliverable	Marianthi Grizioti
V0.7.1	25/08/2017	Integration of critical thinking	Julian Angel-Fernandez
V0.7.2	28/08/2017	Modifications base on Marianthi's comments	Julian Angel-Fernandez
V1.0	29/08/2017	Final version is released	Julian Angel-Fernandez

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1 CONTRIBUTORS

Name	Beneficiary	Section affected	Date of 1st contribution
Julian Angel-Fernandez		All	01/11/2016
Marianti Grizioti		General description of 21st century skills and Pedagogical Concepts and review of the whole deliverable	12/12/2016
Chronis Kynigos		All	30/09/2016
Carina Girvan and Nikoleta Yiannoutsou		Pedagogical Concepts	06/09/2017
Wilfried Lepuschitz		Specific Knowledge in robotics	06/09/2017
Christina Todorova and Johana Pollicino		general knowledge use in ER4STEM	05/09/2017

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2 EXECUTIVE SUMMARY

2.1 ROLE/PURPOSE/OBJECTIVE OF THE DELIVERABLE

The purpose of this deliverable is to present the work done during the second year towards the creation of a framework for pedagogical activities in educational robotics. A general idea of the framework was presented in D1.2. However this definition required detailed description of its characteristics and literature analysis on other frameworks. A revision of available frameworks in educational robotics showed that there is no other framework on educational robotics that provides a comprehensive guideline to the main stakeholders in educational robotics. As a consequence it was then review frameworks in technology to identify features that are relevant on those frameworks. Considering these factors and the stakeholders, identified in D1.1, a requirement analysis of these stakeholders was done in order to correctly pin-point areas in which the framework should focus. Therefore the framework is envision as a guidelines for educationally comprehensive use of robotics, making evident the connection that was not visible in most of the works reported on educational robotics: pedagogy, 21st century skills, specific knowledge in robotics and general knowledge. Base on this analysis, industry requirements, reported in D1.1, and suggestions provided in D6.3, it was done a literature review on critical thinking, creativity and collaboration to determine current tendencies on the evaluation and improvement of these skills. Additional, it is presented the conceptualization of an ontology[1] on educational robotics field, which in the future is intended to be implemented in a knowledge base. This base will be helpful on the creation of semantic search systems that could be also used in the repository once it is implemented.

2.2 RELATIONSHIP TO OTHER ER4STEM DELIVERABLES

This deliverable further develops the ideas presented in D1.2, proving a better understanding of the conceptualization of the framework, its aim, and related works that could be used as base to support the design decisions. D2.2 and D3.2 provide workshop and conference processes, respectively. These processes are used as part of the guidelines provided by the framework. D4.2 provides pedagogical artifacts that are used to improve the pedagogical quality of the workshop, and more general pedagogical activities. These artifacts are used as elements that are suggested to the readers. D6.3 provides the suggestions on the skills that are required to have a deeper study, which were critical thinking, collaboration, communication and creativity.

2.3 STRUCTURE OF THE DOCUMENT

This deliverable is organized as follows. Chapter 3 presents the related work on educational robotics, identifying the activities done and the skills developed in these activities. Also it provides a vision on the frameworks available in the literature on how to use technology in the classroom. Chapter 4

[1] The term ontology in this document is understood as it is in computer science. For further information please consult the Chapter 8

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presents the conceptualization of the framework and introduces main objective and components. Chapters 5, 6 and 7 present the literature review done in collaboration, creativity and critical thinking, respectively, to determine tendencies within diverse works and good practices that could be used to promote them in educational activities. Chapter 8 introduces a preliminary conceptual version of an ontology that aims to model the domain of educational robotics to enable semantic search.

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3 RELATED WORK

The use of robotics in education is not a new trend, neither are the benefits that it has for students' learning [1]. Most important, 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 [2] [3]. Altin and Pedaste studied the use of pedagogical methodologies based on constructivism used in educational robotics [4]. They found that most methodologies are discovery learning, collaborative learning, problem solving, project-based learning, competition-based learning and compulsory learning. Although there are differences in these methodologies, they are all based on constructivism. As a consequence, this chapter, rather focusing on the methodologies used in educational robotics, presents three studies done in order to determine current trends in educational robotics in schools. The first one is focus on the use of robotics in education. Therefore it investigates the domain and the use of robotics in the activities. The second study is focused on skills that are foster through the use of robotics. Finally, the third study is done to understand frameworks available in educational robotics. These three studies informed the framework with gaps in the literature that must be addressed.

3.1 ACTIVITIES

Stager [5] presents four case studies that he implemented using the robotic platform MicroWorlds EX. The first case was a ballerina that was developed by a five year-old girl. The researcher explained the girl how to use pushbuttons to control ballerina movements. So the kid decided to use two pushbuttons to control the ballerina's spin direction. This development took three morning sessions to be completed. The second project was a teddy bear, which was developed by a group of students, who worked for four consecutive mornings. The whole group decided to work on objects that could be found at a state fair and one group decided to bring a teddy bear to life. The third was a phonograph which was developed by a 15-year-old boy who had disabilities and poor records in school. The final case is connected to adult professional development, where researcher's audience was educators. The researcher used a similar methodology that he uses when he is working with children. The researcher also suggested five ways that robots could be used in teaching. (1) *Robotics as a discipline,* which is the traditional approach used in universities. (2) *Teaching specific STEM concepts* such as physics, programming, etc. (3) *Thematic units*, where participants model real life systems. (4) *Curricular themes,* where the robotic activities are specifically connected to topics in a formal curriculum. (5) *Freestyle,* where participants use robotics and other materials to create objects.

Riedo et al. present their own developed platform Thymio II [6]. They explain the weaknesses of the existing platforms (i.e. Bee-bot, Lego and Arduino) as motivation to create their own platform, which they call Thymio II. To test the final version of this robotic platform, they organized five different workshops during the Robotics festival 2013. The first workshop was designed to let kids play with pre-programmed robot's behaviors. Then kids were asked to deduce some rules about robot's behaviors. During this workshop, computers were not used by the participants. In the second workshop, again without the use of computers, kids with previous experience with Thymio II were asked to form groups and solve six different tasks. In the third workshop kids were taught how to program Thymio using the Visual Programming Language (VPL) and then they received diverse tasks to solve. The fourth workshop was similar to the third one and the only difference was the use of textual programming instead of VPL. The final workshop was developed aiming to give a complex task to the participants. Their results showed that participants were pleased with the workshops and they felt that they had learnt things related to iterations.

Based on their experience on Robocup Junior, Stoeckelmayr et al. [7] decided to create workshops for kindergarten students. Using the Bee-Bot platform, they created ten lessons with an approximate duration of 55 minutes each. They asked the kids to take pictures and record their artifacts produced during the lessons. The four first lessons focused on introducing the world of research, robots and how to use the cameras to report their work. The next two were focused on introduction and exploration of the platform. In the next three lessons participants had to solve some problems in groups, but no information was given about how the groups were formed. The final session was focused on the conclusions from the work done during the lessons. Their findings suggest that participants were interested in programming and robots. They also suggest that kids were looking forward to a sequel of the project.

Church et al. [8] present four activities with Lego Mindstorms to teach physics. The first activity was called *testing speed vs acceleration of drag cars.* In this activity students were asked to determine what is most important in a drag car: speed or acceleration. The second is *simple harmonic motion*, where the students were asked to use Lego microcontroller and the ultrasonic sensor to investigate changes in vertical motion of an oscillation spring. The third is a *ten second timer,* where students were asked to create a pendulum system. Moreover they should use the microcontroller and sound sensor to count 10 seconds based on the pendulum's movement and generating a sound when the time had elapsed. The final activity was *microphone sound reduction.* In this activity students had to create experiments to investigate the sound's variables (e.g. wave length). Their anecdotal results suggest that the students were really interested in the activities, where they were trying to analyze and improve each one of their artifacts.

Williams et al. [9] offered a summer camp to teach physical science and scientific inquiry to middle school students. The camp ran for two and half hours each day for a period of two weeks. It was organized during the summer of 2006. They enrolled 21 participants for this summer camp. They grouped the participants in small groups and for each group a facilitator was assigned. The challenges done during this period included Mars Rover Challenges, Tugof-war Challenge, and Creature Bot Challenge. They provided Lego Mindstorms robotics kit and Robolab programming environment to the participants. As part of day activity each group had the possibility to share ideas with other groups. To assess participants' knowledge, researchers did a pre and post-test. The test included question about Newton's law of motion, which were created by their team. For the scientific inquiry they used the material created by Harvard graduate school of education. Additionally, they used facilitator interviews and reflection to get a better understanding. Their results suggest that robots have an impact in physics but not in scientific inquiry learning.

Ashdown and Doria described an activity to teach Doppler Effect in a school [10]. They did an activity where first the phenomenon is explained to the students, and then they proceed to give required definitions to understand the effect. To give a practical application of the effect, the students are asked to create a set up where the effect is evident. They highlight that letting students to think about the experiment, allowed them to think about the concept. Moreover teachers observed students getting actively engage.

Alimisis and Boulougaris explore possibilities to use robots to foster students graphing abilities [11]. They suggest that understanding physical graphics could be difficult for students because they cannot make the connection between the physical variables and their connections. They mention diverse

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approaches to teach abilities to create physical graphics, which are mostly virtual activities. They suggest that doing these virtual activities students loose the possibility to get engaged with real objects, and intrinsic errors introduced by diverse factors (e.g. friction). To verify if robots have an impact in graphing skills, they designed an activity based on constructivism. Groups of five students were formed and they were asked to build a robot from scratch using the Lego Mindstroms NXT Kit. The students had to make the robot move forward and backward in a constant speed, acceleration or deceleration. Teacher was asked to provide basic support to students regarding the technology used. Also each group was given worksheets with open/questions. The activity was carried out in four sessions of two hours each. To evaluate student progress they decided to use open questions rather than multiple choices, which has been identified to have disparities [12]. Two tests were done, one before the sessions and one after. The results showed an improvement on understanding of kinematic concepts.

Hussain et al. [13] wanted to replicate the experiment done by the Peruvian government that at the end of 90’s tried to introduce Lego in schools around Peru. Peruvian researcher found a significant impact on the students learning. However the authors suggest that those findings cannot be generalized mainly because most of the students in Peru did not had any previous experience with computers, which could not be stated in Sweden. So they wanted to see if there is any impact on the pupils after using Lego Dacta material. They did a study for one year with two groups, control and test. The test group worked in groups of 3-4 pupils who worked with the robotic kit each time. They used quantitative (e.g. test in mathematics and problem solving) and qualitative (e.g. observations, interview and inquiry) methods to evaluate the study. Their results show that students used two different learning methods when they were interacting with the kits. One way to learn was by trial and error, and the other was cooperative. Moreover they found out that girls were more often willing to follow instructions while boys were not. They also found that there was not much improvement in logic skills, but there was an improvement in cooperative work. Furthermore they did not observe any difference between young and old learners in the ability to build, program or handle Lego material. Finally they provided some suggestions based on the patterns observed during the lessons. (1) It is necessary a large space to let the students spread and work on diverse solutions. (2) Working groups should not be big. (3) The task must be relevant and realistic to solve.

Sullivan et al. [14] used a programming software called Creative Hybrid Environment for Robotic Programming (CHERP), which is a tangible and graphical computer language. Students can create programs using interlocking wooden blocks or on screen programs. They implemented a curriculum using the positive technological development framework. The curriculum was design to be used in a pre-kindergarten classed and it had as a central topic the engineering design process. It involved about ten hours of work over the course of five days. All activities were focused on creating tools for assisting recycling process. Therefore, participants during these activities followed the engineering design process to create these objects. The activities were: (1) introduction to engineering design process and engineering; (2) introduction to robot (3); introduction to programming; (4) culmination of the project: Robot recyclers. In addition, participants received handbooks to plan, design and refine their robotic construction and programs. Their results show that all participants were able to create functional robots. Also each group had individual help from an adult to ensure that the final project was accomplished. In addition their results showed that after the week children had a better understanding about what an engineer is and what objects engineers create. Moreover participants showed an improvement in programming.

Sullivan and Bers studied how robotics and computer programming could be used in pre-kindergarten to second grade classrooms and what children could learn from them [15]. They developed an eight week curriculum focused on teaching foundations of robotics and programming concepts. They used

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the robotic platform KIWI, which was specifically design for young children (four years and up). KIWI platform is programmed using the Creative Hybrid environment for computer Programming (CHERP) and it does not require any computer to be programmed. The curriculum was focus on introducing robotics and programming. There were a total of eight activities, each one with duration of one hour. During these activities, students were introduced to diverse sensors (e.g. light sensors) and programming concepts (e.g. conditionals and cycles). As a final project, the researchers asked the students to draw a map of their neighborhood and program the robot to move along it. The projects for older children had a higher level of difficulty respect the young ones. The results suggest that children, even the youngest, were able to program correctly their robots. Also, the results suggest that pre-kinder students had difficult with sequential thinking. The researchers believed that this could be due young children working memory and capacity to remember parts of a story is still under development.

Teachers have not just used robotic platforms as tools in their classrooms. They have also started being suggested as autonomous agents that could motivate students in the classroom through real interactions. Werfel, in his position paper, introduced the idea of using robots as teachable agents in classrooms [16]. He suggests that the act of teaching requires a deep understanding of the material, which could be beneficial to students, who would require creating underlying connections to teach a specific topic to the robot. This approach has been used with virtual agents, but he believes that better results could be obtained through the use of robots due their physical embodiment. He gives some examples where robots physical embodiment has shown a positive impact in comparison virtual agents.

Continuing on the same line, Walker and Burleson use a Speed Dating method to stablish needs that users perceive when they interact with teachable robots [17]. To achieve this objective, they focused on geometry and used iRobot to create 24 scenarios. Their scenarios are created on the assumption that people can interact with the robot through gestures and speech. They asked participants to play one of the following roles: robot, peer tutor, classroom teacher, and peer tutor helper. They asked the peer tutor to teach the robot a particular concept with the help of the classroom teacher. Their results show that students complain when not enough support or too much feedback was given. Researchers identify that motion is important for the participants, because it helps break the monotony of class. Moreover, participants highlight the importance to visualize geometrical concepts in the real world and the interested on interact with the robot in pet-like way.

Once again the importance of robots' embodiment is used as motivation to create a tutor system. Serholt et al. [18] decided to focus on geography because they considered that this topic has not been explored enough in educational robotics. Therefore, they envisioned a robot taking the role of a tutor while students use a touchscreen table to do their task. Their idea was to focus on teachers' rather than students' requirements because they consider (1) teachers could or not accept this type of technology in their classrooms. And (2) teachers have experience knowing possible barriers that could come during the adoption of robots in classrooms. Therefore researchers conducted interviews to teachers from Portugal, England, Scotland, and Sweden. The interviews show that teachers do not want administrative overhead, generated by trying to manage the time that each student interacts with the robot. Also teachers suggest that the robot should be able to understand the classroom situation and collaborate with the teacher. Moreover teacher would prefer that the assessment responsibility remains with the teacher.

Kanda et al. evaluated the impact of a social robot as a tutor in a robotic activity [19]. They offered eight sessions of two hours, where participants learnt about programming and basic aspects of robotics. In the last lesson participants' learning achievement is measured via test. The robot tutor was

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implemented with diverse behaviors, which could fall into manage or social categories. Manage behaviors are related to behaviors that are used to control the activity, while social behaviors are used to motivate and interact with the participants. Their results showed that robot's social behavior motivated students to work during the first classes but this motivation decayed through the classes.

Brown and Howard studied the impact of verbal cues given by a robot into participants' performance in diverse math test [20]. To test if there is any positive impact, they did an experiment with a control and test group. They results suggest that the presence of verbal cues reduce the time required to complete the test, and make more enjoyable the test.

In order to have a better understanding on how these works could lead us to identify features that could be use in the framework, it was selected five elements. 1) The year in which they were implemented. This help us to consider technology capabilities and its limitations. 2) The country where the work was done. Traditions, schools system and political priorities influence how the technology is used and adopted in educational environments. 3) The knowledge domain in which the activity was focused. Robotics has been mentioned to be a field that could be used in diverse domains (e.g. Engineering, Mathematics and Biology), so it is important to understand how have been used. 4) The platform used and the role played in the activity. There are diverse platforms in the market with diverse capabilities, which let the robot to have different roles in the activity. Three types of roles were used in it, which are suggested by Mubin et al. [21]. These roles are:

- *Tool*: the robotic platform is used as teaching aids, where students would be building, creating and programming robots.
- *Peer*: the robot could have spontaneous collaboration with the kids or been a kid receiver.
- *Tutor*: the robot is going to support children learning, and in some cases motivating kids to continue with the activity.

5) The programming language used to program the robot. This is used so that some platforms could be programmed with more than one language. For example, Lego kits could now be programmed with their native language or scratch.

Table 1 is created considering each one of the elements, previously described. It could be observed that most of the works come from USA. This predominance should not be seen as USA is the only country working on educational robotics. Rather, it could mean that other countries are not disseminating correctly their work. For example the international conference on robotics in education (RIE) has been held in Europe for the last seven years. But just until 2016, the articles were published in an international library (i.e. Springer). Also, it could be observed that there is a big tendency to use Lego kits, with variations among years. This is due to the effort that the company has put on generating activities for its kits. In most of the cases the robot is used as tool with some specific exceptions, in which the robot was not completely autonomous. These exceptions use the robot as peer or tutor. This new tendency should be taken into consideration by the educational robotics community. It is expected that social autonomous robots capabilities will grow in the following years due to the effort and interests of the Human-Robot Interaction (HRI) community.

The domains are mostly focused on STEM domains (e.g. Engineering), with a predominance of programming language and physics. Here the question that comes is if robotics just could be used in STEM domains or it could be connected to other domains if there is an interconnected curriculum. For example what could happen if the robots are used in a theatrical play, where children has to not just use technical knowledge but also creativity and other type of skills. The possibilities are open to the

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imagination and the creation of new technologies that correctly combine robotics with other domains. Nevertheless, there are two components that are missing in the works presented in this section. The first is a clear description of their work that could let other reproduce it. The second is that in most of the works there is not a clear use of pedagogical methodologies used. Just the works done by *Sullivan et al.* [14] include in their work pedagogical approaches.

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Table 1 Summary of the works studied.

Work	Publication Year	Country	Domain	Platform; Role	Programming Language
Stager [5]	2010	USA	Programming and mechanics	Lego; Tool	Lego environment
Riedo et al. [6]	2013	Swiss	Programming	Thymio II; Tool	Thymio's Software
Stoeckelmayr et al. [7]	2011	Austria	Programming and Technology	Bee-Bot; Tool	Not required
Church et al. [8]	2010	USA	Physics	Lego Mindstorms: Tool	Lego environment
Williams et al. [9]	2007	USA	Physics and scientific inquiry	Lego Mindstorms; Tool	Robolab programming environment
Ashdown and Doria [10]	2012	USA	Physics	Lego Mindstorms NTX; Tool	Not specified
Alimisis and Boulougaris [11]	2014	Greece	Physics	Lego Mindstorms NTX; Tool	Lego education program
Hussain et al. [13]	2006	Sweden	Mathematics	Lego Dacta; Tool	Not specified
Walker and Burleson [17]	2012	USA	Geometry	iRobot; Peer	Not specified
Kanda et al. [19]	2012	Japan	Programming and Robot construction	• Robovie-R3M; Tutor • Lego Mindstroms; Tool	Not specified
Sullivan et al. [14]	2013	USA	Engineering design process	Lego education WeDo; Tool	Creative Hybrid Environment for Robotic Programming (CHERP)
Sullivan and Bers [15]	2016	USA	Programming	KIWI; Tool	Creative Hybrid Environment for Robotic Programming (CHERP)

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3.1 SKILLS DEVELOPED IN ROBOTIC ACTIVITIES

The general study of the works, presented in the previous section, helped us to understand the current situation in educational robotics. It showed that most of the activities in educational robotics are focused on STEM domains. But the real impact of it in education is not clear. Thus, it was decided to do a deeper study on the real potential of robotics in education. To fulfil this, it was decided to look on skills that have been reported in educational activities. In this way, it could be created a mapping between the fostered skills and schools' curriculum, which could facilitate the inclusion of robotics in schools. Therefore a systematical review in the following libraries was done: ieeexplore, acm and sciencedirect. The keywords were selected based on the objective of the research, which are: skills, robotics and schools. The last keyword was used to focus on the works done in schools, which is the main target in ER4STEM.

The query used in each library are presented in Table 2. For each of the works retrieved, it was done a pre-selection of articles by title. The abstract of the articles with relevant title were read and based on this, a new reduction was done. The remaining articles were read and analyzed to get the following information: skills, evaluation of the skills, description of the activity and the robotic platform used. Table 3 summarize the main information found in these articles. As it could be observed, the skills mentioned in these works are too general to know the specific skills that are used in their activities. For example, robotic activities have a positive impact in problem solving, would mean that these activities have a positive impact on all skills that embrace problem solving? Or just a set of skills are improved? And more important all the activities have the same amount of improvement? Moreover, it could be observed that most of the works do not evaluate if the skills were improved or not. The authors just assumed that participants improved the skills because they used that skills in some extended during the activity. This brings a problem to recognize the real impact of the educational activities with robots.

Table 2 keywords used in each library consulted

Library	Keywords used
ieeexplore	((skills or skill) and (robotic or robotics) and (school or k-12))
acm	((skills OR skill) AND (robotic OR robotics) AND (school OR k-12))
sciencedirect	((skills OR skill) AND (robotic OR robotics) AND (school OR k-12))

Also, it could be observed that the range of skills mentioned in the works is broad (Table 3), and it covers soft and technical skills. The skills reported are programming, engineering, Doppler Effect, problem solving, critical thinking, and team work. Nevertheless, there is not a good description of the activities nor how the skills were evaluated. This generates two problems. First, without the correct description of the activity or the context, it is not possible to replicate the activity. Second, without a good evaluation method, it is not possible to know if the skills mentioned in the activity are been fostered or not.

It is important to measure the real impact of robotic to foster skills. However, it is not possible to assess the real impact of all skills in the span time of ER4STEM. Therefore, it was decided to come with a set of skills to analyze. This skills were selected studying the industry requirements. The results reveal that six main skills are required in the industry. (1) *Problem solving* is a key aspect for admittance of a new employee in a company. Passive or technical knowledge is worthless if the person is not able to synthetize a new solution out of given facts. (2) *High level problem solving* is the ability to see problems in context and on a high level of detail. People with this skill are able to propose products and future trends. (3) *Specific knowledge* is the very detailed knowledge of a particular technology or knowledge

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area. (4) *Creative thinking* is a very high ranked skill and must be accompanied with major amount of self-reflection in order to objectively evaluate new ideas and reject wrong ones. (5) *Efficiency* is related to the time required to finish a given task. It usually is considered with no procrastination. (6) *Flexibility* to use various technologies and to adapt to a given problem is appreciated by employers very much. There may be many focused employees who do not wish to switch to a different technology or acquire new skills.

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Table 3 Summary of skills foster during diverse activities.

Work Title	Skills mentioned	The skills are evaluated?	Instruments used to evaluate the skills	Description of the activity	Robotic platforms used
A Deeper Understanding of Technology is needed for workforce Readiness [22]	Researchers mention diverse studies on skills in USA, OECD and ATC21S. They mention that SCANS work divide skills in two groups: • **Competences:** Resources, interpersonal, information, systems and technology • **Foundations/fundamental:** Personal qualities, Thinking skills and basic skills	Not specified	Not specified	Researchers presented a case study done in the Academy of Informational Technology and Engineering High School. Although they not give any description of the activities done in the institution, they present the experience of different people involved in these activities. The researchers give an important point about students and teachers in the school, which are provided with PC tablet computers.	Not specified
Application of the Cognitive Apprenticeship framework to middle school robotics camp [23]	Engineering design skills and developed skills in engineering, science, and computational thinking	Yes. Researchers' results suggest participants had an improvement in their scientific reasoning.	Researchers used which included the STEM semantic survey (SSS [24]). They also implemented pre/post questionnaires using Piagetian' variables [25]	Researchers used the cognitive apprenticeship and Carnegie Mellon to create their activities. They divided the activities in two parts: moon mission and pantheon. The activities took place for two weeks with three to four hours per day.	Lego Mindstorms
Developing technological knowledge and programming skills of secondary schools	Programming skills	No	Not Apply	Researchers created a six session activity, each session lasted five hours. During the first two sessions, participants get all the theoretical background, which includes robotics and constructionism topics. In the next three sessions participants have	Lego Mindstorms NTX and WeDO

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students through the educational robotics projects [26]				hands on robotics kits, and in the last session the projects were presented.	
Evaluating the impact of educational robotics on pupil's technical and social skills and science related attitudes [2]	Technical skills: • general programming and/or robotics • computer science • textual programming • mathematics and scientific investigation Science related attitudes and interest Social and Soft skills: • self-efficacy in robotics • problem solving • teamwork attitudes • social skills	Yes, Researchers did two groups: control and experiment. The experiment group was mainly kids that participate in Robocup Junior. Their results suggest a positive effect of robotics in mathematics and scientific investigation, teamwork, and social skills	Researchers used a pre and post questionnaire with 129 questions from diverse assessment tools, such as multiple choice and Likert-scale. They divided the questionnaires in four parts as follows: • Demographic and background • Technical skills • Science related attitudes • Social and soft skills	The activities were based on preparation for Robocup Junior	Lego Mindstorms and kits to participate in Robocup Junior
Fostering analogical	Analogical thinking skills	No	Not Apply	Students were asked to replicate some biological model using the kit provided. 14	Picocricket kit

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reasoning and design skills through creating bio-inspired robotic model [27]				sessions of two hours, where the following topics were given: Introduction to robotics; basics of construction and use of picocricket kit; sensors and control; DC motors and digital transmission; inquiry into a biological system; creation of robotic model; presentation and evaluation of the robotic model.	
Robots for educations [28]	Teamwork, communication, and problem solving.	No	Not Apply	The authors presented diverse works that have shown a positive impact on the development of teamwork skills, communication skills, and problem solving skills.	Not Apply
Improving engineering skills in high school students: a partnership between university and K-12 teachers [29]	Science skills and basic skills determined by engineering professors. These skills are: communications, reach to conclusions, find information, analyze situations, concept of function, develop of arguments, creation of hypothesis, derivatives, limits, tangencies, teamwork, scales and proportions.	Yes.	Test before and after the intervention was done in all the schools that took place.	The researchers first asked engineering professors to determine the weaknesses of engineering students. Once the weak points were stablished, they did a test in the schools that were participating in the research. Based on the results they created activities to be done in the schools to improve students skills in the areas determine as important. Then a second test to see if there was any improvement in the students.	Not Apply
Acquisition of Physics content knowledge and scientific inquiry skills in a robotics summer camp [9]	Physics and scientific inquiry: planning and conducting investigation, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific argument	Yes. Researchers had two researches question: do student participant exit the summer	Pre- and post-test were done to assess participants. These test consisted in multiple chose items that was created by them. The questions were focus on newton's laws of	Two week robotics summer camp. The participants were group in small group and each group had one facilitator. At the end of each day groups could share ideas among them.	Lego Mindstroms and Robolab programming environment

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		robotic program with increased content knowledge? Do student participants exit the summer robotic program with better scientific inquiry skills?	motions. For the scientific inquiry they used the material created by Harvard graduate school of education		
A robotics based design activity to teach the Doppler effect [10]	Doppler effect	No, but researchers had a clear learning objectives, which are inform	Not Apply	The phenomenon is presented in an intriguing way. Then they defined frequency, wavelength, and velocity. Then students are asked to create a set up where they show their understanding of the phenomenon.	Lego Mindstorms NTX

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3.2 FRAMEWORKS IN EDUCATIONAL ROBOTICS

To find existing frameworks designed or/and used in educational robotics, it was done a research on the following libraries: ieeexplore, acm, and springer. The queries used in each library are depicted in Table 4. Articles were filtered based on title and then by abstract. From the final set of articles, replicate articles were eliminated. After this process, just 14 articles remained.

Table 4 keywords used and results obtained in each library consulted

Library	Query used	Number of Results
ieeexplore	(robotics and framework and education)	158
ieeexplore	(((educational robotics) or (educational robots) or (robots in education) or (robotics in education)) and framework)	76
acm	(robotics and framework and education)	67
springer	(robotics and framework and education)	29962

A review of these 14 articles was done. From these review just two articles fit to the aim of the study. The first article presented any similarity with a framework in educational robotics. This article describes Roberta initiative [30], which aims to create a gender-balance didactic material and course concept.

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, 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.

The second article is a framework created by Chiou et al. [31], called EARLY. Their framework is based on the work done by Carroll [32], who identifies four critical components in activities that involve technology. These components are: people, activities, context and technology. As a consequence, the EARLY framework describes three basic components: participants (i.e. Teachers, learners, developers and experimenters), environment (i.e. computer, material, software and robot) and arena (e.g. problem based arena and soccer). A final element called scope embraces of all them to describe a specific situation or activity. Although the authors present five different case studies, the framework lacks literature support and formal evaluation.

Roberta initiative and EARLY framework give an initial point to start, but it does not give enough information about characteristics of activities that could be used by people who are not directly involved in the initiative. Moreover, the activities that fall under Roberta are just the ones that have been approved by the initiative. This restricts the possibility to be adapted adequately to other context. Therefore a broader search, not limited to educational robotics, was done to look for other frameworks developed in educational technology. This search was done google scholar using the following query:

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“(education AND framework AND technology)”. The results led us to identify five works that could be used as a base for the framework.

The national research council has created a framework for k-12 science education [33]. This framework describes major practices, crosscutting concepts, and disciplinary core ideas that all students in schools should be familiar at the end of their studies. The researches who worked on this framework had the idea to guide standards developers as well as curriculum designers, assessment developers, state and district science administrators, professionals responsible for science teacher, and science educator working in informal settings. Therefore, the framework encompasses three dimensions. The first dimension is scientist and engineering practices, which include major practices that scientist employ in their work. The second is crosscutting concepts, which defines a key set of engineering concepts. And finally the disciplinary core ideas in science and engineering. To reduce the amount of ideas present in science and engineering, they created criteria to pick the most relevant ideas in these areas of knowledge. These criteria are: (1) have a broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline. (2) Provide a key tool for understanding or investigating more complex ideas and solving problems. (3) Relate to the interests and life experience of students or be connected to societal or personal concerns that require scientific or technological knowledge. (4) Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. That is, the idea can be made accessible to younger students but is broad enough to sustain continued investigation over years.

The framework prosed by Cameron Richards tries to make a clear the connection between technology and pedagogy to develop activities supported by information and communication technologies (ICT) [34]. He suggests that current pedagogical methodologies are created to be used on face to face interaction. Therefore they cannot be extrapolated to other situation without doing adjustments. Moreover, the author identifies two problems that are encountered during the design of an activity with ICT. The first one is related to how these activities are created, which are first design without considering the role of ICT and then are “enriched” with ICT. The second is the suppositions around activities with ICT. People take for granted that these activities automatically involve learning elements (e.g. performance outcomes), thus this elements are not considered. As a consequence his objective in the framework is not just guide through the use of ICT in the classroom but also reconcile teaching methodologies with technology. This framework proposed two main ideas that are not further developed in the paper. One is the use of relevant context to engage learning in interaction, which can then be linked to formal learning objectives. The second is the convergent achievement of applied and transferable understanding or knowledge construction.

The history behind the framework created in 1990s after several conversations within Savage had with his colleagues is presented in [35]. This framework was created as a response to the changes that were detected in the profession of technology and the inability to react accordingly to the changes. Therefore it combines the human adaptive systems and domains of knowledge of the Jackson’s Mill Industrial Arts Curriculum Theory [36]. This framework is created from pieces and parts of many curricular ideas, educational philosophies, and ideologies that preceded it. The main contributions in the framework are six. (1) List of the universal attributes of technology. (2) Comparison of the features of the body of knowledge of technology to the features of science and the humanities/arts. (3) Development of technology method model. (4) Inclusion of a broader base of content for the study of technology. (5) Identification of the methodological and content characteristics of a quality technology education program. (6) A process model for a course of study.

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Greg Stoner creates a framework to integrate learning technology into courses, modules or units of study [37]. This framework is based on the system analysis and design methodologies, which are used to design and implement information systems. It is also informed by the instructional design and Laurillard's models of learning in higher education [38]. This framework presents seven stages for the introduction of technology in education. In (1) *Initiation*, first stage, is recognized problems and possibilities for the use of technology in the activities. It is also done a preliminary assessment of the situation to determine if using technology could improve learning experience. Once the situation has been detected, an (2) *analysis and evaluation* is done to determine objectives of the course of action and collect information about syllabus and current efforts in the organization. With these information is then (3) *selected the learning technology.* To achieve this, a search and evaluation of available technologies is done. With the technology selected, it is then (4) *design and integrate* the solution in the activity. Once this has been done, the (5) i*mplementation* takes place. In this stage documentation and required materials are produced, the technology is set up or install, and the organization staff is trained. Unfortunately implementing the solutions it is not enough. A continuous (6) *monitoring and adaptation of the solution* is required to improve or solve problems that come with each group of students. Finally, an (7) *evaluation of implementation* is required to determine the real impact of the solution.

Lewis and Zuga present a framework constructed from their previous experiences, current trends and future of technology education [39]. They use previous work in educational technology to outline activities and ideologies that have influenced the technology education. Then, they analyze current trends and proposed the used of Inquiry as a based to align science and technology education to a curriculum. Moreover they conducted a review on the available theory to see how technology education can be used as fundamental subjects in schools. Although they gather a lot of information and present an interesting layout of the framework, the way that is presented is understandable. Moreover, the links that they try to create for the use of technology education is not clear and do not provide any relevant information for the user.

Finally, Byron et al. proposed a theoretical framework that aligns the interrelated components of effective instruction when using educational technologies [40]. They recognize two main problems that should be addressed in their framework. The first is that use of technology should not occur without considering how people learn best. And second, the big number of technological innovations with educational potential along with the large number of educational pedagogics is a challenge for educators. As a consequence, they propose an adaptable framework that is based on cognitive, social, and technological presences to focus on who, what, why and how of the learning. Therefore, they proposed as starting point to develop activities to identify the role of the teacher in the activity and skills that students will learn in the activity. They also suggest that is important to consider learners' age, their cognitive skills, their group collaboration and technology skills during the design. They consider that a particular attention must be paid on the group size and gender balance because they influence the learning experience. Once all of these considerations have been taken, the technology could be chosen. At this point, they recommend connecting all of these factors with the correct cognitive and psychosocial theories, which will increase motivation and achievement in the participants. Then, the description of the outcomes must be done, which could be taken from a curriculum or created using any taxonomy (e.g. Blooms). They also recognize the importance of teachers' training, suggesting that teachers must be STEM knowledgeable to correctly influence students into STEM. Therefore, they suggest diverse strategies to make the framework to be used by teachers, such as active use of forums, where the researchers participate, or teachers training.

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Although the work of done by Sharkey is not a framework, the points that she bring up in her study could be used as guidelines in the use of technology in education [41]. Her main motivation to present these suggestions is that technology used wrong could jeopardize the learning experience. Therefore, she points out that some components must be considered to ensure the effective integration of technology into a course or curriculum. These components are students' audience, teaching methodologies and types of technologies available. She stress that although students who are immersed in the use of cellphones, video games and other technologies, this does not mean that they have developed technological skills to use higher-level applications. The use of complex applications would increase students' anxiety. To void this, teacher must use correctly the desired technology. Thus, she consider that a good activity should have well-written outcomes and an assessment. According to her, a good outcome is composed by three parts: (1) an action verb phrase, (2) the connection phrase, and (3) an accomplishment/achievement phrase. For the assessment, she suggests some key steps: (1) clearly identify in what ways the assessment matches the content and competencies established by the learning outcomes. (2) Identify alternate scenarios that could influence how students demonstrate the behavior or complete the assessment, which might include taking into consideration student motivation, relevance to what is being learned, or equal access to specific tools. (3) Establish what the assessment is supposed to do and what the data are expected to indicate. Moreover, she highlights the importance of considering students' learning style to correctly select technology, design the activity, and determine the best methodology for assessment.

3.3 CONCLUSIONS

In this chapter was presented three different studies on the literature available of educational robotics in schools. The first study was done to determine domains and roles of robotics in education. From this study, it was concluded that robotics has been used in diverse domains (e.g. Geography and Physics) with a high predominance in physics and programming. Nevertheless, it is important to notice that other domains in which would be expected to use robotics are not widely documented, such us mathematics, electronics and mechanics. Moreover, the limited existence of activities in electronics and mechanics could be due two main reasons. (1) The cost of the components to implement activities in these areas is high. (2) These areas are not included in many curriculums of schools. Furthermore, it is surprising that there are not a lot of works connected with this mathematics, considering the amount of mathematics involved in robotics, such as in kinematics, navigation, and computer vision. Although these topics required advanced knowledge of robotics and mathematics, a continue schedule in robotics could let the creation of activities that involve them. Furthermore, if these knowledges could be included in the long run in schools' activities, would help in the connection between robotics and real problems.

Regarding the roles of robotics platform in activities, they have been used mainly as a tool and in some cases as tutor or peer. This is mainly due the simplicity and high performance of the robotic platforms that are currently available and could be used just as tools. For example, Lego offers a huge variety of kits for all ages and with different functionalities, which make it suitable for novice and experts. Other examples of robotics platforms are Thymio II and BeeBot. On the other hand, the use of robotic platforms as tutor or peers is constraint to the improvement of autonomous robots. Nevertheless, special attention must be taken in how this technology is introduced in the schools. Such as it is noticed by Sharkey [35], the use of technology in the classroom should be align to students knowledge and environment otherwise it could be counterproductive.

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Besides the role of the robotic platforms and domains in which robotics are used, it was also done a study on the skills that have been reported in the literature. From this study, it could be seen that diverse skills have been reported to be fostered in activities with robotics. However, just one work has presented a formal evaluation of the participants to determine the real impacts. This leaves a big question on the real impact of robotics in the activities that must be studied to press their connection with schools' curriculum.

A third study was done to determine characteristics of frameworks in educational robotics. The first results showed that there is not a framework in educational robotics. The closes work is the Roberta initiative, which establish requirements and characteristic of teachers and activities to be considered as part of the initiative. Nevertheless, this initiative does not general enough to be used as a framework to design and implement robotic activities in education. Hence, it was done a study on frameworks in educational technology. The frameworks found in educational technology have been developed for several years and some of them have a strong pedagogical background to support their choices. A share objective found among some them is to make explicit the use of pedagogical methodologies in the activities in which technology is used. Because people think that just using technology the pedagogy will come implicit.

These three studies on the literature let us to come with a set of points that should be addressed in ER4STEM framework. They are:

- Creation of a mechanism to describe activities done in educational robotics. This must serve as mechanism to share them with other people.
- The silks foster during the activity are evaluated or assess to verify their improvement.
- The framework should not be just a set of activities that could be used by a teacher but it must let them to create activities that suit their needs.
- The activities must address all learners, not just female or male.
- The use of major practices and concepts on educational robotics should be described. This let people to have a better understanding about the field and how they can develop activities on it.
- Description of multi-disciplinary ideas that could let the use on educational robotics outside the traditional disciplines.
- The framework should create a clear connection between robotics and pedagogy.
- Use of cycle approach for the integration of robotics in activities into schools.
- Use of previous experiences in educational robotics to create a framework that could model the future of the field.
- Use of different approaches to cover different learning styles.
- The suggestions given by Sharkey [41] should be taken into account to improve the quality of educational robotics.

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4 FRAMEWORK

Robotics is a multidisciplinary field that involves a variety of fields, such as mechanics, electronic, mechanics and mathematics. Therefore, Robotics has been mentioned as a field with a potential in education [1]. Other researchers have suggested that robotics in education or educational robotics is a field that is growing and it is expected to impact teaching from kindergarten to university [3]. Moreover, the development of new technologies in robotics that could impact educational robotics (e.g. social robotics) and the current advance in educational robotics will create an amount of activities using robots in education, which will need to be created under some parameters and guidelines to have the desired impact in the learning experience. If these activities are created without following any criteria, they could counterproductive [41]. As a consequence, it is required to stablish a framework in educational robotics that could help on the proper creation of activities in educational robotics.

A framework that embraces methodologies and knowledge to improve the quality of the activities and as consequence increase the impact of robotic in education is not an easy task. A framework with this kind of objective should be created considering to main aspects: current weaknesses in the activities, future trends in the field, and stakeholders' needs. So to understand the current panorama, it is necessary to have a deep look on the people who are affected by educational robotics (stakeholders).

4.1 STAKEHOLDERS

Besides determine weaknesses on current activities in educational robotics (Chapter 3), it is also important to understand the people who are involve in educational robotics (stakeholders). The main reason is that they are the ones who will be affected or use the framework. In the deliverable 1.1 was recognized the main stakeholder that are affected by ER4STEM. They are teachers, organizers of educational robotics activities, researchers and industry. However the work done in D1.1 just identified stakeholder general objectives and requirements. Therefore it is required to determine the activities in educational robotics that these stakeholders are designing and implementing.

The amount of activities was limited to the activities found in literature review (Chapter 3) and the study done in D1.1. Therefore the activities considered were: workshops, presentation, research and lessons. Workshops are activities that are done outside the school and in many cases they are not connected with any schools' curriculum. Presentation activities are those were participants have the space to show the work done. In robotics in most of the cases they are competitions but they can also be conferences or fairs. Research is the systematic work done to advance the knowledge in educational robotics. Finally, lessons are activities that are as a part of a school's curriculum.

The activities and their requirements identified for each stakeholder are presented in Table 1. As it could be observed all stakeholders do workshops. Teachers, researchers and organizers do presentation activities. Just teachers and researchers do research, and just teachers do lessons. Regarding stakeholders' requirements of the activities, it is shown that most of the cases they require a good description of the activity to implement it. Just teachers and researches need activities that could be compared. On the other hand just teachers and organizers required activities that could be sustainable for long periods. The case of industry is particular because they required activities that let them promote their technologies.

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Table 5 Activities and Need for each stakeholder recognized as relevant in the framework.

	Teachers	Researchers	Organizers of Educational Activities	Industry
Activities	• Workshop • Presentation • Research • Lesson	• Workshop • Presentation • Research	• Workshop • Presentation	• Workshop
Requirements	• Pedagogical informed description • Compare activities and results • Well described activities • Sustainable activities	• Pedagogical informed description • Compare activities and results • Well described activities	• Well described activities • Sustainable activities	• Specific set of skills • Promote their technologies

In educational robotics a variety of researches come together. For example, in ER4STEM two types of research are present in the consortium: educational (University of Athens and Cardiff University) and robotics (TU Wien) researchers. Considering that these two types of researchers should be present in other educational robotics projects or initiatives, it was decided to analyze them deeper to determine their specific requirements and objectives. Regarding the objectives, it could be seen that educational researchers' main objective is to improve learning experiences and they have vast knowledge in pedagogical methodologies but limited in robotics. On the other hand, robotics researchers' main objective is to improve robotics platforms and they have knowledge in robotics.

It would be expected that these two types of researchers collaborate in educational robotics such as is depicted in Figure 1. In the ideal case, researchers communicate and establish common goals that are achieve through continue interaction within them. This produces ideas for new technologies and pedagogical approaches that could be used in education, which is reflected in the creation of workshops and lessons. These activities are expected to be described in enough detail that other people outside the group of work could implement them, which provides several benefits. They are: validate results, extend research beyond, and use on different settings. Once the activity has been completed, researchers analyze the information collected, which brings new questions and suggestions for pedagogy and technology. Using these results as a base, researchers begin again with the cycle. However the reality found in the works reviewed (Chapter 3) show a different situation. Besides this situation, the activities reported in many cases are not fully described, which limit their replicability.

Regarding the remaining stakeholder, teachers are the ones with more citied in literature. Some studies have shown that technology is taught in schools mostly by math and technology teachers [33]. This does not mean that other teachers do not recognized the importance of technology. In fact, in the study done by the *Teaching Profession in Europe* [42] is recognized that teachers' main concern is related to how to acquire the skills to use technology rather than the required knowledge to teach their subjects. As it could be seen, there is a gap within researchers and teachers in knowledge and needs.

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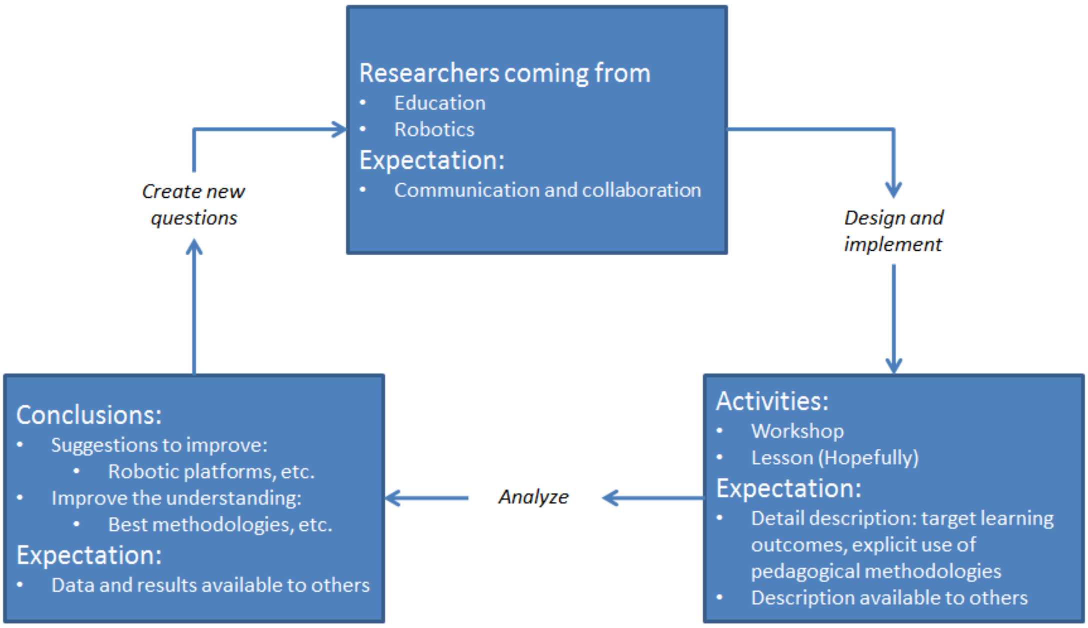

Figure 1 Expected research cycle in educational robotics

4.2 PEDAGOGICAL ACTIVITIES

Due to different interests and backgrounds, stakeholders have come with different approaches in developing activities in educational robotics. This is true even among researchers. As it could be seen in section 3.1, the workshops created and implemented are not well documented. In most of the cases these workshops do no included learning outcomes and evidence of learning. In other cases they are implicit but not correctly documented. More important, the real impact of robotics in education could be measure through them. This is of vital importance, because it is still unknown the real impact of robotics [43]. Furthermore, these two factors plus the adequate use of pedagogical methodologies have been identified by researchers in technological education as fundamental factors to be considered for the correct design and implement activities with technology [40] [41].

As a consequence, ER4STEM's workshops and lessons are treated as similar because both of them must have learning outcomes and evidence of learning. Thus, they are called pedagogical activities. From now on, it will be used the word pedagogical activity to refer to workshops or lessons in ER4STEM. If the word workshop or lesson is mentioned, it is to specify the activity that is done outside ER4STEM. ER4STEM pedagogical activities have the following characteristics: (1) 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). (2) Use of one or more pedagogic methodologic, which has to be described for each action in the activity. (3) Description of the activity using the activity template (D 4.1). However these characteristics by their own just would improve activities' quality and reusability. But it is still missing how to design, implement and evaluate them.

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4.3 ER4STEM FRAMEWORK

General speaking, it could be say that stakeholders are by their own when they have to design and implement a pedagogical activity. Therefore, a high knowledge in technology and education must have to correctly implement pedagogical activities. However few people have all of this knowledge. As a consequence, ER4STEM framework is created to guide any stakeholder on the design or adaptation, implementation and evaluation of pedagogical activities. This is achieved through the explicit connection among pedagogical methodologies, knowledge in robotics and other areas, 21st century skills, and increase interest in STEM. As a consequence all of these five components must be explicit integrated in a pedagogical activity. Figure 2 presents the elements of expected activity and their connection.

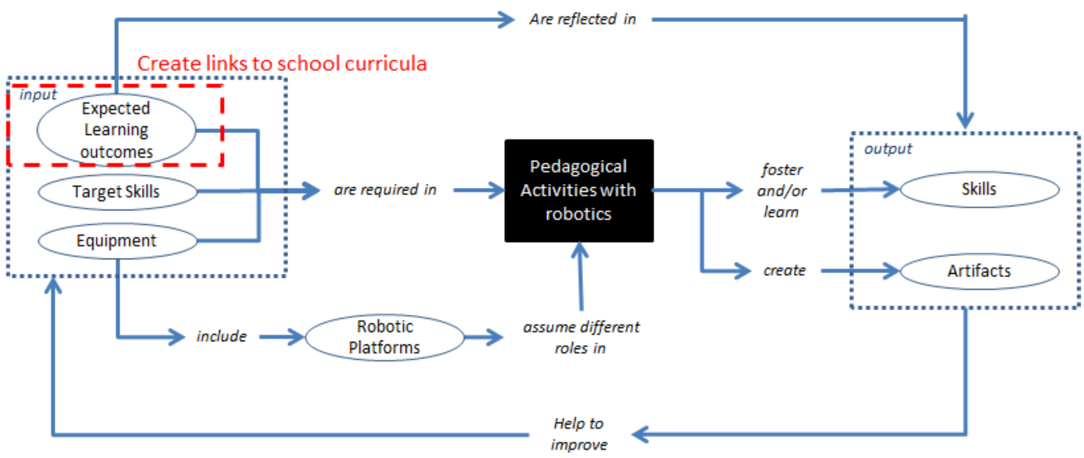

Figure 2 ER4STEM Framework expected pedagogical activity and connection among some of its elements.

To let stakeholder to design pedagogical activities that comply with the structure presented in the Figure 2. ER4STEM framework presents four components that are interconnect among them:

- Definition of words used in pedagogical activity using robotics, which include those words that have different meaning depending the field. An example of this is ontology, which Grimm et al. [44] defined as formal explicit specification of a domain interest that could be executed by a machine and understand by humans. Other definitions correspond to the definition of the nature of being. Some words also will include additional references that could be used by the reader to go deeper into the subject. For example, there are webpages that already give a clear idea about the pedagogical methodologies, such as the materials provided in the webpage SERC [45].
- Examples is created from practical experience. The practical experience corresponds to partners' activity plans and activity blocks (D4.2).
- Best practices are created from practical experiences and literature review. The first one corresponds to the results reported in WP6. The second one corresponds to the literature review presented in this deliverable.
- Processes are practically and theoretical defined in WP2 and WP3. The basic structure used to define these processes is explained in the following subsection.

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Process

To create a guideline suitable for pedagogical activities, it was determined the use of research cycles, professional teaching and learning cycles [46] as inspiration. Combining these cycles with features of the frameworks analyzed in Chapter 3, we came up with a process, which is depicted in Figure 3. This generic process is compound by four main phases: design or adaptation of a pedagogical activity, implementation in real settings, activity's evaluation or assessment, and improvement of the activity plan. The first phase is divided in two possible steps, which represents the possibility to design a pedagogical activity from scratch or adapt one from other existing activities. The second 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 phase provides instruments and procedures for evaluating the implementation. The fourth and last phase focuses on possible improvements of the activity plan based on information derived from the implementation in real settings, on reflections from the teachers, the students and the designers. Once the activity has been improved, the cycle should be continuing with adapting the pedagogical activity for future groups.

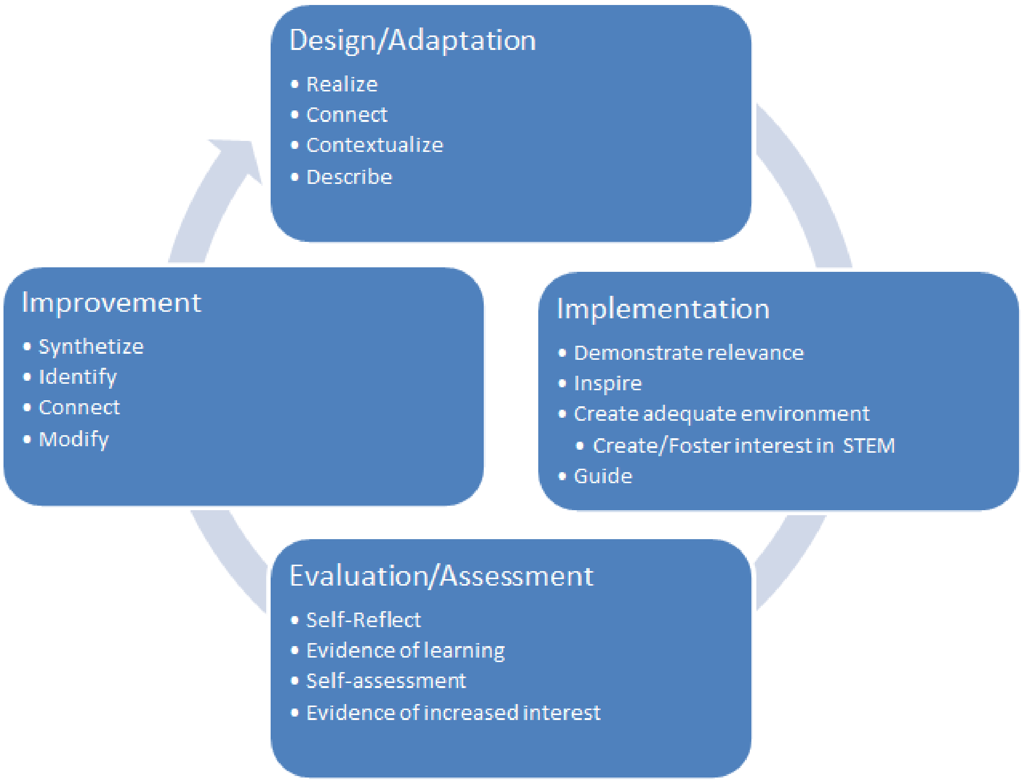

Figure 3 Framework's process definition

Although this process establishes main phases for pedagogical activities, it is still too generic and could fit to any other activities (e.g. presentation). Thanks to the considerations taken into account to the construction of this process, it was decided to use this process as macro-process or base process to create other processes in ER4STEM. Two type of presentation activities take place in ER4STEM. These activities are conferences are competitions, which are reported in WP 3. Therefore it was decided to create a conference and competition process in addition to the pedagogical activities process. Both

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processes are based on this macro-process (Figure 3) and they are explained in the following chapters. Pedagogical activities process is informed by WP 2, 4 and 6. While conferences and competitions process is informed by WP 3.

For each of these four phases, it is expected that the designer considered how general knowledge, specific knowledge in robotics, pedagogical methodologies, and 21st century skills are connected to the activity and phase. Table 6 presents an example of self-reflective questions that could be done in each phase for each pillar.

A further explanation of each one of these pillar is given in more detail in the following sections

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Table 6 Example of questions that could be done in each phase for each pillar.

	Design/Adaptation	Implementation	Evaluation/Assessment	Improvement
21st Century Skills	- Which skills are going to be foster in the activity?	- Is the environment right to foster the skills? - Should I motivate the participants to use the skills?	- Are the skills used? - How the skills were used? - What are the methods to evaluate these kinds of skills?	- How can I make the use of skills more evident? - What other steps in the activity would add to make clear the use of the skill?
General Knowledge	- Do I want to use robotics in a different context (e.g. Math or History)? - How the desired skills are connected with the curriculum? - How integrate robotics in the activity?	- How the skills are going to be foster in the participants? - How the skills are presented to the participants?	- Is the knowledge improved? - What approaches could be used to measure indirectly (e.g. write a postcard to a friend)?	- What other skills could be involved in the activity? - How these skills are involved with other activities? - What other steps would modify to improve the outcome? - What other materials would use?
Specific Knowledge in Robotics	- What is the role of the robot? - How are the participants going to interact with the robot? - What are the previous skills required for the activity?	- Participants know how to use all the tools (e.g. robotic platform, IDE)?	- Were previous skills enough for the activity?	- What other skills must be included? - How could be foster robotic skills in the activity?

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Pedagogic Methodology	- What is my role in the activity? - How is the activity going to look? - Can I combine diverse methodologies in the activity?	- Are you implementing correctly the methodology selected for the ***activity block***? - Is the methodology going along with the activity?	- What is the best approach to evaluate or assess participants? - Was helpful the methodology?	- Which methodologies could be used? - How could be used new methodologies in the activity?

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4.4 MAIN CONCEPTS

This section will extent the explanation of the concepts identified as part of the framework

Pedagogic Methodologies

Considering the design and planning of educational robotics workshops, an important element is the pedagogic methodology that will be followed. In ER4STEM we follow the constructionism learning theory and implement it with a variety of activities in the robotics context. Constructionism has developed in the past 50 years as both a learning theory and a framework for action and pedagogical design [47] [48]. It approaches learning as meaning making in a constructivist frame [49] [50] but extends individualistic approaches to learning to include collaborative, socio-constructionist learning environments [48]. Key features of constructionism are its epistemology for learning portraying knowledge and meaning making as fallible [51] and its focus on learning while engaged in bricolage with digital artefacts [1]. 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 [52]. 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 [53] recently including dynamic manipulation [54] . 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. The project partners have found fundamental value in designing a variety of approaches, thus every workshop implements activities which foster students to discuss, argue and communicate their ideas about STEM concepts in a meaningful context for them. One of the approaches was the award winning 'Half baked Robot', an Arduino-based solution for supporting discussion, negotiation and meaning generation in workshops with students with different knowledge backgrounds [55] [56]. This approach, based on the theoretical framework of 'boundary crossing' [57], 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" [56] 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.

General Knowledge

The approach to learning robotics is a multi-component one. Bringing in a plethora of skills ranging from various general knowledge fields, such as Mathematics, Science, English, History, Art, Business and Sociology to name a few, provides a multitude of opportunities for the younger learners, which is a sought outcome within the ER4STEM project and its framework respectively.

Educational robotics activities, as designed under the ER4STEM project, are focused around the construct of powerful ideas [1], inherent to constructionism. Thus, the educational robotics workshops under this framework are designed to involve the use of knowledge in new ways where learners can establish personal epistemological connections with various domains of knowledge [58]. Furthermore,

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Bers [59] analyzing powerful ideas, describes them as domains of knowledge where many diverse topics or subjects co-exist and become explicit.

Taking this into account, for the effective design or adaptation of an educational robotics activity, the ER4STEM project partners' experience is one of consideration of general knowledge subjects and subject-related topics that the educational robotics activities would address, require or aim to cultivate, along with the context of application and the specific needs the context might imply. By the same token, in the cases of curriculum-aligned educational robotics activities, it is taken into consideration the process, modules and specific activities that would show how robotics could be integrated as a tool to teach general knowledge and how robotics would fit subject-related education goals and learning outcomes.

Up to this point in the ER4STEM project 6 core general knowledge domains are at the center of the activity plans design and adaptation, namely science, technology, business, engineering, arts and mathematics. Those six knowledge domains are to compliment the primary domain covered, although all activity plans are multidisciplinary with their themes and tasks belonging to STE(A)M (please view Table 1 of ER4STEM's WP4: D4.2, "List of the operational release of activity plans, their technologies and the domains they cover per partner" for more information about the targeted domains).

General knowledge, as defined by Oxford [60] dictionary and understood by the ER4STEM project team, however, is the "knowledge of a broad range of facts about various subjects". It is important to note that under similar definitions, operate several robust lists of knowledge and subject domains, such as the list of 20 general knowledge subjects defined for further testing by Rolfhus and Ackerman (1999) [61] [62], which include further knowledge domains that might be taken into account in the design or adaptation phase of an educational robotics activity. Depending on the desired educational outcomes one may choose to adhere to other domains of general knowledge, if an interconnectivity with robotics is possible and provided that all other conditions of the educational robotics planning and implementation process could be met. However, referring to the respective national general education curricula when constructing an educational activity is recommended and will ensure that the notion of cultural literacy, referring to the ability to understand and participate fluently in a given culture (as described by Hirsch Jr., 1987) [63], is respected.

Specific Knowledge in Robotics

Robots are a powerful idea to engage with that cover a variety of fields and topics while being fascinating for children [64]. At the same time, robotics is an excellent tool for teaching science and technology [65]. As robots are a physical embodiment of computation [66] working with them involves a multitude of knowledge as follows:

- Mechanics: A robot incorporates a variety of mechanical parts, e.g. arms and legs in case of a humanoid robot or a gear that transmits the motion from motors to the wheels of a mobile robot. Thus, building or at least experiencing a robot, which allows insights to its construction, allows the exploration of such phenomena of mechanics [67].
- Electronics: To control the robot and host its software, a controller is commonly employed, which is made of various electronic components. Also the peripherals of robots contain electronic parts. Various robotics kits and courses exist that teach the students some basics fundamentals of electronics (e.g. [68]).
- Sensors: For gathering information from its environment, a robot incorporates sensors. For instance an often used educational settings for robotics involves a mobile robot with one sensor that is used for being able to follow a line (e.g. [69]). A multitude of sensors exist that can be employed for a robot such as light sensors or cameras.

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- Actuators: For manipulating the environment, robots rely on actuators. For instance grippers can be used for grasping objects. Likewise to the sensors, also a multitude of actuators exit that can be used for robots. In this context, the usage of actuators involves significant engagement with mechanics.
- Programming: Despite the fact that some (educational) robots are built purely hardwired (e.g. BYO-bots [70]), the majority of robots involves software that needs to be programmed. The usable programming languages range from graphical programming languages (e.g. Scratch [71]) to common textual languages (e.g. C++, Python). Programming a robot encompasses the relevant programming concepts such as loops and conditional statements.

- Artificial Intelligence: Robots designed with non-intelligent programs, which carry out defined sequence of instructions, are quite limited in their functionality [72]. Using Artificial Intelligence increases the range of automation and makes robots more adaptable to changing environments by being able to solve problems and make decisions in real time [73]. The implementation of Artificial Intelligence in robotics allows for solving of more complex tasks [72].

21st Century Skills

The P21 Partnership has developed a framework known as "The Framework for 21st Century Learning" [74], one of the most important definitions of the 21st century learning skills. This framework it is a blend of knowledge, skills, expertise and literacies that 21st century students must master in order to succeed in 21st century work and life. Other recognized 21st century learning skills include the "ISTE Educational Technology Standards" which is a set of standards published by the International Society for Technology in Education (ISTE) to leverage the use of technology in K-12 education [75], the "7 survival skills" by Tony Wagner who identifies the most important skills needed for today's workspace [76], as well as the "enGauge® 21st Century Skills: Literacy in the Digital Age" report [77] , issued by the North Central Regional Educational Laboratory and the Metiri Group.

Below is a list of the skills that we aim to cultivate through the ER4STEM project, based on the above researches for the 21st century skills:

- 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.
- 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.
- 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.
- Critical Thinking More specifically to be able to a) use various types of reasoning depending on the situation b) analyze and evaluate major alternative points of views c) synthesize and make connections between information and arguments d) Interpret information and draw

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conclusions based on the best analysis e) reflect critically on learning experiences and processes.

- 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
- Information literacy. This skill refers to a) accessing information efficiently and effectively and evaluates this information critically and b) uses and manages the digital information.
- 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 and media as tools to research, organize, evaluate and communicate information.
- Be a digital citizen Apart from knowing how to use the new technology and media students must use it in appropriate ways. In order to become "digital citizens" they should be able to a) engage in positive, safe, legal and ethical behavior when using technology b) have a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies (their rights and their obligations) c) manage their personal data to maintain digital privacy and personal security d) be aware of the permanence and the results of their actions in the digital world
- Computational Thinking (CT). CT involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. More specifically some skills related to CT are to be able to a) break problems into component parts, extract key information, develop models to understand complex systems b) use algorithmic thinking to develop a sequence of steps to create and test solutions d) understand basic computational concepts that can be transferred to programming or not programming concepts such as conditionals, data handling, events, sequences etc. e) be able to make abstraction and create patterns.

Life/career skills

- Flexibility and adaptability a) Be flexible refers to incorporate feedback effectively, understand, negotiate and balance diverse views and beliefs to reach workable solutions. b) Adapt to change refers to be able to adapt to varied roles, schedules and contexts.
- Leadership and responsibility a) use interpersonal and problem-solving skills to influence and guide others toward a common goal, b) leverage strengths of others to accomplish a common goal c) inspire others to reach their very best d) demonstrating integrity and ethical behavior in using influence and power e) act responsibly with the interests of the larger community in mind
- Global and cultural awareness a) use the 21st century skills to understand and address global issues b) Learning from and collaborate with individuals representing diverse cultures, religions and lifestyles in a spirit of mutual respect and open dialogue c) understand other nations and cultures
- Initiative and entrepreneurship This includes a) goals and time management b) monitor, define, prioritize and complete tasks without direct oversight c) demonstration of initiative to advance skill levels towards a professional level d) going beyond basic mastery of skills or curriculum to explore and expand one's own learning and opportunities to gain expertise.

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The following chapters will present the literature review done in creativity, critical thinking and collaboration. The review do not pretend to come with a definition but rather spot practices reported in the literature that could be used to integrate in pedagogical activities.

5 COLLABORATION

Collaboration has been identified as main factor for the success of projects [78] [79] and it has been included in the set of 21st century skills. Collaboration is considered a skill [80] [81] that need to be learnt and improved. Nevertheless, creating groups would not imply that group-members collaborate within them [79] [82] [83]. If a group is not created properly, it could jeopardize the expected final outcome [79] or the learning process [83]. 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. [84] 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 [83] [82] [79] [85] [86]. However, the difference comes up when they are look in detail. Korzar [82] 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 [78] 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 [80] 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 [80] "*teams are small groups, but not all the groups operate as a team*". Also, they dissect these two words on goals, roles and responsibilities, rules and methods. This differentiation is presented in Table 7.

	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 7 Differences between groups and teams [80]

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5.1 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 first understand the advantages and disadvantages of working in a team. Beebe and Masterson identified the following [80]:

- *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 [86] suggest that a team is required when the task is 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, and no individual has enough knowledge to solve the problem.

5.2 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 [80] 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 [86] 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.

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5.3 CREATING A TEAM

Bringing people together with a common purpose is not enough to success in the endeavor [79]. Kennedy and Nilson identified four phases for the correct creation of a team [81]. 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 [80] [87]:

- 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.

5.4 ROLES

The roles when people is working in a team are presented in Table 8.

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 8 Roles and responsibilities in a team [86].

5.5 CONFLICTS IN TEAMS

Teams are composed by people with different background, personalities and ideas that could create disagreements inside teams that could finish in a conflict. Despite most beliefs, conflict is something that must not be avoid or fear [87]. However not all conflicts are originated from the same reason and determining the real reason is important. Three types of conflict are identified [87]: 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.

5.6 SUMMARY

This chapter has presented a literature review on collaboration. This skill is in many cases misused and confused with collaboration. Moreover, it is possible to observe the following:

- Creating groups would not imply that group-members collaborate within them [79] [82] [83].
- If a group is not created properly, it could jeopardize the expected final outcome [79] or the learning process [83].
- Collaboration involves [78] communication, coordination, mutual support, balance of members contribution, and cohesion within members.
- There is a difference between team and group. Beebe and Masterson [80] 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.
- It is not always necessary to work in team. Peter Scholtes et. all [86] suggest that a team is required when the task is complex that the effort of one person is not enough, creativity is

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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 no individual has enough knowledge to solve the problem.

- Kennedy and Nilson identified four phases for the correct creation of a team [81]: forming, storming, norming and performing.
- Behaviors that increase team cohesion are [80] [87]: talk about the task, motivate trust within members, share time formal and informally with the team member, create effective communication channels, and generate an environment where team members feel that they are heard.
- Despite most beliefs, conflict is something that must not be avoid or fear [87].

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6 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 [88] [89]. Despite its importance, there is not a unify definition of creativity [90] [91] 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* [90]. It is important to notice that the interpretation of novel and useful is going to be given by the social context [92].

As a consequence, Fischer et al. [93] 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 [92]: 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 [94]: 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 [95]. 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.

6.1 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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6.2 TYPES OF IDEAS GENERATION

Boden suggest three different ways on how creative ideas are created [96] [97]: 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.

6.3 CREATIVITY PROCESS

Literature offers variety of creative processes. Ones described creativity process in four steps that could vary from authors focus. For example [88] 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 [98]: 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 [99]: 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 [88]. For example, MC Squared project aims to foster creativity in mathematics. As a consequence, the authors proposed the following steps: framing the problem, coordination, reflection and transformation.

6.4 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 [100]
- Balance between knowledge and challenge [91] [100]
- Creation of a climate where students are not fear about failure [91] [100] [89] [88]
- There not should be competitions or rewards after finishing [91]
- Motivate students to be creative [92]

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

- Differences in the group (symmetry of ignorance) - [93] Mentioned also in MC squared and disagreement [101]. Here, it is important to notice that the degree of differences is important.
- Use of boundary objects – expressing and integrating different opinions and interpretations [93]
- Need for reflection of the individual [93]
- Externalization [93]

6.5 ELEMENTS IN ROBOTIC ACTIVITIES

Nelson proposed the following elements specifically to activities that involves robotics [102]:

- 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

6.6 EVALUATION METHODS

Methods to evaluate creativity depend on the emphasis of the researcher [90]. Those researchers who emphasize social appraisal will use rates and judgments; those who focus on person-center will use mechanisms to evaluate personal traits (e.g. intelligence). Some examples are personality test, biographical inventories, and behavioral 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.

6.7 SUMMARY

This chapter has presented the literature review done in creativity. This is one of the skills that most of the people talk but it is difficult to explain in words. An important aspect that any fostering creativity is to avoid is to tell children that they are no creative just because the person is not creativity. Regarding this, it is important to remember that Kaufman and Beghetto proposed four types of creativity [94]: 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 embedded ideas that are considered with significant valuable in their field but their contribution has not been recognized as big-c. 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. Other important fact to remember are:

- The creation of environments, that promotes creativity, is also possible
  - Definition of clear goals [100]
  - Balance between knowledge and challenge [91] [100]
  - Creation of a climate where students are not fear about failure [91] [100] [89] [88]
  - There not should be competitions or rewards after finishing [91]
  - Motivate students to be creative [92]
- Elements proposed by Nelson to foster creativity in robotics [102]:
  - 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 most not be punish [89] [91]
- Creativity requires the following preconditions [91]:
  - The activity has a clear goals
  - Balance between challenge and skills
  - No fear to failure

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Use of diverse tool to motivate creativity [89], such us brainstorming, story boarding, lotus blossom, checklist, morphological analysis, and excursion technique.

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7 CRITICAL THINKING

Critical thinking has been recognized by governments and educators as an important skill [103] [104]. Unfortunately, researchers have seen that it is not taught adequately in schools nor universities [103] [105] [106]. Some authors suggest that this is due to insufficient theory connecting learning experience and development of it [105]. This could be due to a misinterpretation of critical thinking with other skills, as problem solving [107] [103], and a missing consensus on the definition of critical thinking [103] [104] [108]. This consensus will take some time, due to the existence of philosophical or psychological perspectives [104] 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, analyze, and evaluate arguments and truth claims [109] [107] [110] . This process of identifying, analyzing 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 [109], [107], [111] and [110].

7.1 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 test reduces the complexity of critical thinking to a multiple option questions, which could hinder the critical process. Therefore Larsoon [105] proposes the use of essays to evaluate students' capacity to critic a statement.

7.2 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 [103]. Pithers and Soden [103] 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 [106] concluded that self-awareness through reflection has helped students to improve their critical thinking.

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7.3 INHIBITING CRITICAL THINKING

Raht [111] recognized eight behaviors 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 [112] 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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8 TOWARDS AN ONTOLOGY FOR EDUCATIONAL ROBOTICS

As it was already introduced, the framework aims to make explicit the connection among pedagogical methodologies, knowledge in robotics and other areas, 21st century skills, and increase interest in STEM. As a consequence, the framework has four elements that are interrelated: definitions, examples, best practices and processes. Nevertheless, these components could have many manifestations, such as documents that could be tedious to read and more important to apply correctly. Thereby, it was decided to use the repository as instrument to represent the framework in a way that could be used by stakeholders in a way that they do not realized.

Before finding a way to integrate the framework in the repository, it was required to clearly determine the objective of the repository. This was achieve during a session in the annual meeting of ER4STEM held in Malta in September of 2016 and it was done in cooperation with AL, who is WP5 leader. A speed date approach was used to collect the information from all participants. The expected repository's features were:

- Inclusion of the activity plan, which is developed in WP4, in an appealing way.
- Recommendation of an activity and/or platform that could be used to teach and specific skill or motivate participants in specific topic.
- Consider user experience to offer diverse search option.
- Teachers' experience should be taken into account.
- An approximate cost of the activity
- A rating system is a plus.
- Users' previous experience should take into account to adapt the content.

Considering the expected features of the repository and framework's objective, it was identified the following ways that the framework could be incorporated in the repository:

- Providing suggestions during the creation of a new activity.
- Support on the search in the repository.

To fulfill these two objectives, it was decided to use an ontology, understood as in computer science. This is supported with the fact that ontologies are used in Semantic Web to make inferences through the knowledge. Ideally, this ontology will enable the repository to answer queries that could be difficult to answer using traditional methods. Also, an ontology allows the possibility to update the base of knowledge with new facts about the field of knowledge, which enable the possibility to add or delete facts depending on the situation of educational robotics.

8.1 WHAT IS AN ONTOLOGY IN COMPUTER SCIENCE?

An ontology as is presented by Grimm et al. [44] is a formal explicit specification of a domain interest that could be executed by a machine and understand by humans. According to Grimm et al. [44] an ontology has the following characteristics: formality, expressiveness, consensus, conceptuality, and domain specific.

Methodologies for creating an ontology

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There is not a body of knowledge with a precise procedure that could be used to create an ontology. Instead diverse procedures have been created by researchers to help in this endeavor. Grimm et al. [44] in their research on ontologies identified a general process present in most of the works reviewed by them. Their methodology involves the following steps:

1. *Requirement analysis:* is the first step in the methodology, which consist in determining the requirements of the ontology.
2. *Conceptualization:* involves the representation of the knowledge in terms of semantic vocabulary and statements about domain of knowledge.
3. *Implementation:* is the final step, which requires the selection of an adequate ontology language and the formalization of the knowledge collected in the previous step.

Concepts used in ontologies

Despite the domain of knowledge that is been modeled, there are basic concepts used to model it [113]:

- *Object:* is anything in the body of knowledge that is going to be modelled. It could be real objects as cars or abstract concepts as skills.
- *Instances or individuals:* represent specific objects in the domain of representation. For example in the case of educational robotics an instance would be Thymio II, which is a robotic platform for education.
- *Classes:* represent a set of objects. For example robotic platforms for education.
- *Properties:* describe the characteristics of an object in relation of itself and with other objects. They could be divided in:
    - *Object properties:* describe a binary relation between classes. For example a robotic platform for education is a specialization of robotic platforms.
    - *Data properties:* specify the binary relationship between objects and descriptive information. For example a robotic platform has sensors.
- *Statements:* are assertion on the body of knowledge using *classes* and *properties.*
- *Axioms:* are statements that are true in all the interpretations and they could be used for reasoning. For example Thymio II has infrared sensors. This statement will be true in all situations.

8.2 REQUIRMENT ANALYSIS

As it was suggested by Grimm et al. [44] the first step towards an ontology for educational robotics was to understand the type questions that are required to be answered using the ontology. As it was previously presented, the framework should provide (i) suggestions during any step on the creation of a new activity, which is supported by the artifacts created in WP4. And (ii) improve the search mechanism provided in the repository. To achieve (i), the ontology must model the underlying knowledge in the activity template. This required a collaborative work between the technical (TU Wien and PRIA) and academic partners (UoA and AL). The (ii) required the creation of possible queries that are expected to be answered by the repository.

Activity Template Analysis

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The activity template analysis was done in a meeting held in Malta in November 2016 between representatives of TU Wien, PRIA and AL. The main objective of this meeting was to decompose the activity template in logical parts that could be implemented in the repository. Doing this decomposition, it was possible to get a better understanding of the features that would be required in the ontology to model the activity plan.

Possible Queries Creation

The generation of possible queries was done in two steps. The first step was done during the Malta meeting, in which participants provided several queries that they expected to be answered by the repository. The second step was done after the Malta meeting using the set of queries collected. During this second phase, it were deleted queries that would answer the same question. The final set of questions are:

- What kind of activity I can use to for participants between x and y?
- Which activity I can use to improve an X skill?
- Which activities I can implement with an X robotic platform?
- What platforms I can use with Y programming language?
- What type of activities I uses an X pedagogical methodology?
- Which activities I can use for participants with X, Y and Z characteristics?

8.3 CONCEPTUALIZATION

Base on the requirement analysis, it was decided to focus on objects that intrinsically embedded in educational robotics, and avoid concepts and terms that could be describe in other ontologies that could not add any additional value to the base of knowledge. With this in mind, it was created a beta version of the ontology. This version included concepts that were included in the activity template. Once the first version was concluded, it was evaluated with the experts on education (UoA and CU), who provided corrections to the educational concepts. This new version was then share with all partners to have feedback from them. This feedback lead to the first stable version of the ontology.

To comply with the elements of the framework, it was decided to come with a meta-class that makes mandatory the introduction of a short description and possible links. The classes identified, data properties, and object properties are defined in the appendix 1.

Axioms

Based on the classes already mentioned already, it is necessary to start determining the statements about the knowledge space. For example:

- **Operating *systems*** cannot be ***Virtual space, programming language,*** or ***robotics***.
- ***Virtual space*** cannot be ***operating system, programming language robotics.***
- ***Textual Programming language*** cannot be ***graphical programming.***

Other statements would be created once it is done a final verification of the concepts and relations between them.

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9 CONCLUSION / OUTLOOK

This deliverable has presented the work done during the second year on the definition of a framework for educational robotics. A general idea of the framework was presented in D1.2. However this definition required detail explanation of its characteristics and literature analysis on other frameworks available. The revision of available framework in educational robotics showed that there is no other frameworks. The most similar work is the one done in Roberta project, which specifies a set of characteristics that activities and teachers must comply in order to be accredited as Robert activities and teachers. As a consequence it was done a review on frameworks in technology to spot features that were identified as important on those frameworks. Considering these factors and the stakeholders identified in D1.1, it was analyzed the stakeholders that would use the framework and current weaknesses found in educational robotics. As a consequence it was decided that the framework is a guidelines for educationally comprehensive use of robotics, making evident the connection that was not visible in most of the works reported on educational robotics, within pedagogy, 21st century skills, specific knowledge in robotics and general knowledge. To achieve this objective the framework has four components: definitions, examples, best practices and process.

Based on the suggestions provided in D6.3, it was done a literature review on critical thinking, creativity and collaboration to determine current tendencies on the evaluation and improvement of these skills. Additional, it was presented the conceptualization of an ontology [2]on educational robotics field, which in the future is intended to be implemented in a knowledge base. This base will be helpful on the creation of semantic search systems that could be also used in the repository once it is implemented.

The next year will be focused on the integration of the processes created in WP2 and WP3, pedagogical materials and examples provided by WP4, and best practices detected in WP6 into the final version framework.

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[2] The term ontology in this document is understood as it is in computer science. For further information please consult the Chapter 8

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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
CT	Computational Thinking
VPL	Visual Programming Language
UoA	University of Athens
CU	Cardiff University
AL	AcrossLimits
IDE	Integrate Development Environment

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12 APPENDIX 1: CONCEPTUALIZATION OF THE ONTOLOGY

Type: Class	
Name:	Concept
Inherits from:	None
Data properties:	• Description: *string* • Link: *string*
Object properties:	None
Description:	It is an abstract class to group classes that must have this properties. Instead of defining in each concept class these properties, they just have to inherit from this class.

Type: Class	
Name:	Educational Robotics
Inherits from:	Concept (Aggregation)
Data properties:	None
Object properties:	• Uses ***technological platform***: $n \geq 1$ • Has/involves ***stakeholder***: $n \geq 1$ • Encompasses ***activity***: $n \geq 0$ • Involves ***skill***: $n \geq 1$ • Improves ***skill***: $n \geq 0$ • Uses ***Pedagogy***: $n \geq 0$ • Involves a ***Domain of Knowledge***: $n \geq 0$
Description:	This class embraces the concept of educational robotics per se.

Type: Class	
Name:	Technological platform
Inherits from:	Concept (Aggregation)
Data properties:	• Name: *string* • Other names: *string* • Version: *numeric* • Features: *string*
Object properties:	• Is used in ***Educational Robotics***
Description:	The word platform has been used in many different field and it could embrace software platform or robotic platform. To group all kind of platforms that could be in educational robotics, it was decided to include this class.

Type: Class	
Name:	Virtual Space
Inherits from:	Technological platform (Generalization)
Data properties:	• Hardware requirements: list • Software requirement: *list*

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Object properties:	• Models ***Robotics:*** $n \geq 0$ • Requires ***Operating System (OS):*** $n \geq 1$ • Is executed in an ***Operating System (OS):*** $n \geq 1$
Description:	This class is related with the idea of programs that try to recreate virtually systems (Robots) and environments.

Type: Class	
Name:	Virtual World
Inherits from:	Virtual Space (Generalization)
Data properties:	None
Object properties:	None
Description:	Virtual worlds are a simulated environments where diverse users can interact within them.

Type: Class	
Name:	OpenSim
Inherits from:	Virtual World (Generalization)
Data properties:	• Name = “OpenSim”
Object properties:	None
Description:	This class gathers all the versions of OpenSim. Specific versions of this software are instances of this class.

Type: Class	
Name:	Mindcraft
Inherits from:	Virtual World (Generalization)
Data properties:	• Name = “Mindcraft”
Object properties:	None
Description:	This class gathers all the versions of Mindcraft. Specific versions of this software are instances of this class.

Type: Class	
Name:	Simulator
Inherits from:	Virtual space (Generalization)
Data properties:	None
Object properties:	None
Description:	This class represents the concept of virtual space which embrace virtual worlds and simulators.

Type: Class	
Name:	Webots
Inherits from:	Simulator (Generalization)
Data properties:	• Name = “Webots”
Object properties:	None

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Description:	This class gathers all the versions of Webots. Specific versions of this software are instances of this class.

Type: Class	
Name:	Operating System (SO)
Inherits from:	Technology Platform (Generalization)
Data properties:	• Hardware requirements: list
Object properties:	• Execute ***Integrate Development Environment (IDE)***: $n \geq 0$ • Execute ***Virtual space:*** $n \geq 0$
Description:	SO is the software that manages physical resources required by programs that are running on it. Sub-classes are Windows, Linux, etc. Instances from those sub-classes are their versions

Type: Class	
Name:	Integrate Development Environment (IDE)
Inherits from:	Concept (Aggregates)
Data properties:	• Name: *string* • Version: number
Object properties:	• Requires ***Operative System: :*** $n \geq 1$ • Supports ***Programming Language:*** $n \geq 1$ • Compiles ***Programming Language:*** $n \geq 1$ • Implement ***Compilers:*** $n \geq 1$
Description:	It is a software that provides all the required tools to facilitate the programming.

Type: Class	
Name:	Programming language
Inherits from:	Technology platform (Aggregates)
Data properties:	None
Object properties:	• Is compiled with ***Integrated Development Environment (IDE)***: $n \geq 0$ • Is used to program ***Robotics:*** $n \geq 0$
Description:	It is an abstraction used to facilitate the programming of actions done in the processor.

Type: Class	
Name:	Textual Programming
Inherits from:	Programming Language (Generalization)
Data properties:	None
Object properties:	None
Description:	It represents all programming language that are textual. Subclasses are: Linden Scripting Language (LSL), C++, C, C#, Matlab, Java, Python, etc.

Type: Class

Name:	Graphical Programming
Inherits from:	Programming Language (Generalization)
Data properties:	None
Object properties:	None
Description:	It represents all programming language that are visual or graphical. Subclasess are: Scrath, SNAP, Lego Mindstorms, etc.

Type: Class	
Name:	Robotics
Inherits from:	Technology platform (Generalization)
Data properties:	None
Object properties:	• Is programmed with ***Programming Language*** • Is modelled by ***Virtual Space***
Description:	Represents all robotic platforms available. Subclasses are: Lego Mindstorms, Botball, Arduino, Hedgehog, etc.

Type: Class	
Name:	Domain of Knowledge
Inherits from:	Concept (Aggregates)
Data properties:	None
Object properties:	• Involves ***skill:*** $n \geq 0$
Description:	It represents different areas of knowledge that are group ???. Subclasses are: Science, technology as domain, engineering, art and mathematics.

Type: Class	
Name:	Stakeholder
Inherits from:	Concept (Aggregates)
Data properties:	• Gender: *"string"* • Age: "*number*" • Name: "*string*" • Affiliation: "*string"*
Object properties:	• Designs ***activity:*** $n \geq 1$ • has ***skill:*** $n \geq 0$ • Uses ***Repository:*** $n \geq 0$ • Has ***Special needs:*** $n \geq 0$
Description:	It is people who is affected or involved in educational robotics. Subclasses are: teacher, workshop organizer, researcher, and learner.

Type: Class	
Name:	Special needs
Inherits from:	Concept (Aggregate)
Data properties:	• Name: *"string"*
Object properties:	None
Description:	This class gathers all instances relate to special need that could be required by certain stakeholders.

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Type: Class	
Name:	Activity
Inherits from:	None
Data properties:	• Name: "string" • Description: "string" • Date: "number"
Object properties:	• Is Designed by ***stakeholder:*** $n \geq 1$ • Follows an ***Organizational process:*** $n \geq 1$ • Requires ***Skill:*** $n \geq 1$ • Fosters a ***Skill:*** $n \geq 1$ • Requires ***Resource and Materials:*** $n \geq 0$ • Needs ***Space:*** $n \geq 1$ • Implements ***Theory:*** $n \geq 1$ • Produces ***Artefact:*** $n \geq 0$ • Has a ***Learning Outcome:*** $n \geq 0$
Description:	It is an abstract class that represents any kind of activity, which includes competitions, conferences, workshops, lessons and others. Nevertheless the pedagogical objectives could not be evident in this type of activity.

Type: Class	
Name:	Organizational process
Inherits from:	Concept (Aggregate)
Data properties:	• Description: "*string*" • Steps: "*list*"
Object properties:	Is followed to organize an ***Activity*** $n \geq 1$ Is followed by ***Stakeholder:*** $n \geq 1$
Description:	This class specifies the steps done to organize an activity.

Type: Class	
Name:	Skill
Inherits from:	Concept (Aggregate)
Data properties:	• Name: *"string"*
Object properties:	• Requires a previous ***Skill:*** $n \geq 0$ • Leads to a ***Skill:*** $n \geq 0$ • Is acquire in an ***Activity:*** $n \geq 0$ • Is improve in an ***Activity:*** $n \geq 0$
Description:	This class represents the skills that could be acquire through activities. As it could be it is recursive, which lets to know which skills lead to other skills.

Type: Class	
Name:	Resource and materials
Inherits from:	none
Data properties:	• Name: *"string"* • Quantity: *"numeric"* • Cost: *"numeric"*

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Object properties:	• Includes ***Robotics:*** $n \geq 0$ • Use to produce ***Artefact:*** $n \geq 0$
Description:	This class represents all the materials and resources that could be required in an activity. As it could be observed robotics is included as part of this class.

Type: Class	
Name:	Pedagogy
Inherits from:	Concept (Aggregates)
Data properties:	• Name: *"string"*
Object properties:	
Description:	This class represents the methods and practices for teaching.

Type: Class	
Name:	Pedagogical Activity
Inherits from:	Activity (Generalization)
Data properties:	None
Object properties:	• Has ***Learning outcome:*** $n \geq 1$ this should be an axiom • Is described in a ***Lesson Plan:*** $n \geq 0$
Description:	This activity represents activities that have a clear outcome and could lead to an evaluation.

Type: Class	
Name:	Learning Outcome
Inherits from:	Concept (Aggregates)
Data properties:	• Name: *"string"*
Object properties:	• Is evaluated in a ***Activity:*** $n \geq 0$ • Is evidenced in ***Artefacts::*** $n \geq 0$
Description:	This class represents the expected outcomes from an activity

Type: Class	
Name:	Artefacts
Inherits from:	None
Data properties:	• Name: *"string"* • Type: *"string"*
Object properties:	• Is produced by ***Stakeholders:*** $n \geq 1$ • Requires ***Resources and Materials:*** $n \geq 0$ • Includes ***Robotics:*** $n \geq 0$
Description:	This class represents any creation, physical of digital, produced by the stakeholders

Type: Class	
Name:	Compiler
Inherits from:	Concept (Aggregates)

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Data properties:	• Version: *"numeric"*
Object properties:	• Is implemented in an ***IDE:*** $n \geq 0$
Description:	This represents the software used to convert a program written in a programming language to hardware instruction

Type: Class	
Name:	Theory
Inherits from:	Pedagogy (Composition)
Data properties:	• Name: *"string"*
Object properties:	• Informs an ***Activity:*** $n \geq 0$ • Is used to design the ***Activity Template:*** $n = 1$ • Is used to create ***Praxis:*** $n \geq 0$
Description:	This class represents the theories of pedagogy. In this case this theories describe how should be the teaching process.

Type: Class	
Name:	Space
Inherits from:	None
Data properties:	• Location: *"string"* • Specification: *"string"* • Description: *"string"*
Object properties:	• Is need it to implement an ***Activity:*** $n \geq 0$ • Is suggested in a ***Praxis:*** $n \geq 0$
Description:	This class represents places where an activity could be implemented

Type: Class	
Name:	Robotics Pedagogical Activity
Inherits from:	Pedagogical Activity (Generalization)
Data properties:	None
Object properties:	• Uses ***Robotics:*** $n \geq 1$ • Is described in an ***Activity template:*** $n \geq 0$
Description:	This class represents activities that involves robotics

Type: Class	
Name:	Repository
Inherits from:	None
Data properties:	None
Object properties:	• Stores ***Activity Template:*** $n \geq 1$ • Is described in an ***Activity template:*** $n \geq 0$
Description:	This class represents any kind of repository

Type: Class	
Name:	Activity Template
Inherits from:	Lesson Plan (Generalize)

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Data properties:	• Name: *"String"* • Author: *"String"* • Short description of the activity: *"String"* • Curriculum: *"Boolean"* • Content: *"String"* • Objectives-Technology Related: *"String"* • Objectives-Business Related: *"String"* • Objectives-Engineering Related: *"String"* • Objectives- Art Related: *"String"* • Objectives-Further Social Skills: *"String"* • Time-Duration: *"Numeric"* • Time-Schedule: *"Numeric"* • Target Audience- Sex and Age: *"String"* • Target Audience-Prior Knowledge: *"String"* • Target Audience-Background: *"String"* • Target Audience-Social status: *"String"* • Target Audience-Special needs: *"String"* • Space-Organizational and cultural context: *"String"* • Space-Physical characteristics: *"String"* • Population-Students: *"Number"* • Population-Tutors: *"Number"* • Grouping-Criteria: *"String"* • Grouping-Setting: *"String"* • Interaction During the Activity-Actions: *"String"* • Interaction During the Activity-Relationships: *"String"* • Interaction During the Activity-Roles in the group: *"String"* • Interaction During the Activity-Support by the tutor: *"String"*
Object properties:	• Has an ***Activity -Block:*** $n \geq 1$ • Is store in a ***Repository:*** $n \geq 0$ • Covers a ***Domain of Knowledge:*** $n \geq 1$
Description:	This is a specialized lesson plan used to describe robotic educational activities

Type: Class	
Name:	Lesson Plan
Inherits from:	Concept (Aggregates)
Data properties:	None
Object properties:	• Describes a ***Pedagogical Activity:*** $n = 1$ • Includes ***Learning Outcomes:*** $n \geq 1$ • Specifies a ***Space:*** $n \geq 1$
Description:	This class groups all kind of templates used to describe a pedagogical activity

Type: Class	
Name:	Activity Block
Inherits from:	None
Data properties:	• Description: *"String"* • Duration: *"Number"* • Objectives: *"String"*

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	• Tags: “*String*” • Title: “*String*” • Type: “*String*”
Object properties:	• Uses a ***Praxis:*** $n \geq 1$ • Covers ***Learning outcome:*** $n \geq 1$
Description:	This class represents all the phases of the activities that could be used by others in their own activity

Type: Class	
Name:	Praxis
Inherits from:	Pedagogy (Composition)
Data properties:	None
Object properties:	• Is implemented in an ***Activity Block:*** $n \geq 0$ • Is derived from ***Theory:*** $n = 1$ • Suggest ***Space:*** $n \geq 1$ • Informs ***Activity:*** $n \geq 0$
Description:	This class represents the practical implementation of theories

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