BEST PRACTICE AND REQUIREMENTS

Deliverable 1.1

ER4STEM - EDUCATIONAL ROBOTICS FOR STEM

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DOCUMENT REVISION HISTORY

Version Number	Date	Description	Responsible
V1	31.01.2016	First version	Julian Angel-Fernandez

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1 EXECUTIVE SUMMARY

This deliverable presents the process that was executed to determine best practices and requirements in educational robotics. The extensive research shows that existing approaches have gaps in the description and implementation of activities to be comparable, replicable and engaging to all children. Additionally, approaches are mostly outside of schools, defragmented and unconnected; knowledge is scarcely well transferred. The educational robotics community needs a common solution that addresses these gaps. The ER4STEM framework will be based on the identified needs and become the catalyst to improve young people's learning experience through the use of robotics in formal and informal spaces. It will bring the educational robotics community forward by creating processes, tools and artefacts that allow the use of robots in learning spaces so that a creative and critical use of educational robotics is realized to maintain children's curiosity in the world. A first step for a common solution is the understanding of the different stakeholders and their needs. Thus, this document analyses the stakeholders that affect and are affected by educational robotics activities. Furthermore, the need for a common process to identify best practices is addressed. The newly developed activity plan for educational robotics (a tool of the framework) is based on profound research and experience on pedagogical methodologies, and has been used by all consortium partners to describe their educational robotics activities. Following the identification of the stakeholders' needs and the development and testing of the activity plan, newly developed parameters and criteria are presented to determine good practices in educational robotics. Based on the identified needs, first ideas on the ER4STEM framework are given as an outlook.

1.1 ROLE/PURPOSE/OBJECTIVE OF THE DELIVERABLE

The present deliverable, entitled *Best Practice & Requirements* aims to gather requirements and best practices in curricula development based on identified current approaches for encouraging STEM education and careers among young people. The review of literature and existing practices has shown that there are not commonly accepted parameters to identify best practices. Based on these findings, the deliverable did not only identify ER4STEM main stakeholders and summarize their requirements on ER4STEM but also took on the objective to define suitable parameters to describe best practices by adapting pedagogically informed activity plans for educational robotics.

1.2 RELATIONSHIP TO OTHER ER4STEM DELIVERABLES

This deliverable is going to be used as a base for the creation and development of the framework (D1.2.). The identified requirements and practices will also flow into D2.1, D3.1, D4.1, D5.1 and D6.1.

2 INTRODUCTION

ER4STEM envisions the realisation of a creative and critical use of educational robotics to maintain children's curiosity in the world. There are already many successful approaches in educational robotics in Europe and worldwide. Yet, most of these approaches are outside of schools, defragmented and unconnected; knowledge is scarcely well transferred. In schools, on the other hand, computers, tablets and other technologies have been introduced to classrooms. However, these technologies have not been correctly integrated in the schools' curriculum to improve the learning process (Schleicher, 2015).

As (Crosier & Simeoni, 2015) have identified, the current challenge is to find a way to integrate and use technologies to foster children's learning. Unfortunately, new technologies have been introduced by mainly providing the necessary processes to integrate them in schools but without providing enough resources for educational activities (Education, 2011). This difficulty has created the misconception that technology is "something not interesting", and led children to lose their curiosity towards STEM. As a consequence, it seems important to align educational activities with the complexity of the technology used and to recognize the schoolteacher as an important stakeholder designing these activities and conveying the information and enthusiasm.

Along school teachers, parents are also important decision makers when it comes to the exposure of their children to STEM fields, e.g. when they sign their children up for certain outside school activities. Educational robotics has become quite popular in recent years for various reasons. Besides the fascination of robots on children and the working parents' need to have children occupied during school holidays, robotics is different from other modes of learning because by being a multi-disciplinary field it involves more subject areas than other motivating contexts (Johnson, 2003). Consequently, there are many different activities offered in the context of educational robotics ranging from workshops over competitions to conferences.

This deliverable analyses current approaches and best practices in educational robotics workshops, curricula, conferences, competitions, pedagogical activities design, and educational technologies that could feed the ER4STEM framework development to foster children's curiosity in the world. In section 3 of the document, we present an overview on the educational robotics landscape and analyse requirements to fill the gaps that we have identified during our research. In section 4, we describe all different stakeholders who are either affected by educational robotics or have an impact on educational robotics. In section 5, we describe parameters and criteria that will lead us to identify and establish good practices for generating educational robotics activities that impact learning experiences and foster children's curiosity. These parameters are based on the educational robotics activity plan that has been developed combining the rigorous research on existing approaches with the consortium partners' experience in educational robotics including first-hand knowledge about pedagogical methodologies and main stakeholders' requirements. Each partner in the consortium who organizes workshops has filled the activity plan to describe previous or recent workshop activities. Some of these can be found exemplary in the Annex of the deliverable. Based on the research on existing approaches, a first analysis of main stakeholders and their requirements, and the development of educational robotics activities with the support of the activity plan, first ideas on the ER4STEM open and conceptual framework have been formed, so a basic vision of the framework is described in section 6. We conclude the document in section 7 by also giving an outlook on the next topics that need to be addressed.

3 BEST PRACTICE RESEARCH

The educational robotics landscape is vast and defragmented in and outside schools. In the last two decades, robots have started their incursion into the schools. Although diverse researchers have pointed out their benefits in schools, the slow pace of their introduction is partially justified by the cost of the kits and the schools' different priorities in accessing technology. Recently, the cost of kits has decreased, the capability offered by the electronic components has increased (Papert, 1980) (Miller, 2014), and availability of support materials and software for robotic kits improved (Alimisis, 2013). With these benefits, educational robotics kits are more appealing to schools, thus organizations offering educational robotics invest in the creation of different learning activities around these kits to employ in and outside of schools. These organizations are a perfect starting point to search for best practices that foster children's curiosity in the world with educational robotics. They are presented in different sections reflecting their objectives and scopes.

In section *3.1 Research Studies on Educational Robotics*, we present our conclusions from the literature research done. Since we have identified that there are no commonly accepted criteria for best practice in educational robotics, we waive the presentation of an extensive state of the art to allow us more space on the process that we have developed to identify best practices. In the remaining sub-sections, we present some successful approaches to give an overview of the vast landscape of educational robotics. The rational behind our selection and the process are explained in section 5. The remaining research is structured into projects focusing mainly on educational robotics in section *3.2 Educational Robotic Projects*, and outside school activities offered by a variety of organizations in sections *3.3 Workshops and Curricula* and *3.4 Conferences and Competitions*. Finally, in section *3.5 Educational Technologies* a very brief summary over current educational robotics kits is provided and current widely used open internet resources where students, teachers, parents or other involved stakeholders are offered information about projects in robotics or educational activities are analysed.

3.1 RESEARCH STUDIES ON EDUCATIONAL ROBOTICS

Research has been conducted in the use of robots in education for over 30 years. The seminal work of Seymour Papert on constructionist learning with on-screen and physical turtle robots has led much of the research in the field over this time. This review provides a state-of-the-art, based on the past 10 years of research into educational robotics for science, technology, engineering and mathematics with children between the ages of 7 and 18 years old. The review includes literature from Europe, America, Africa and Asia.

The main findings from the review are:

- All reported learning activities currently focus on the robot as a tool for learners to either make or control. There is insufficient evidence of the robot acting as a peer or tutor.
- Whilst they are not always stated, the pedagogical theories that appear to underpin the learning experiences are social constructivism and constructionism. However, how these theories are used to inform the design of the learning experiences is unclear.
- Research questions focus on increasing interest in science through the use of robots and learner experience, but many are unspecified or vague. Through pre/post-tests some studies examine whether engagement with robotics can increase subject knowledge, whilst others consider the development of 21st Century Skills.
- Randomized control trials and quasi-experimental approaches are infrequently used. This may be due to the scale required but would also be inappropriate for many of the research questions presented.
- While some research is presented as a case study, it often lacks the detailed description of the learning context and design of the learning experience to meet the requirements of this research methodology.
- Data collection often takes a mixed methods approach, using pre/post-activity questionnaires, interviews and observations.
- Lego Mindstorms is a dominating educational robotics platform both as hardware and as software.
- Vast majority of works rely on desktop software.
- Between 7 and 900 participants took part in the research projects reported, representing the range of large and small-scale research. It should be noted that scale should not be taken as a proxy for validity of results or quality of the research.
- The literature suggests that educational robotics can increase students' engagement and interest in STEM subjects, with some literature specifically focusing on girls. It should also be noted that a review of post-positivist research in the field found variances across studies from no significant effect, through to a significant effect on student outcomes in the areas of subject knowledge and interest in STEM. Additionally, some research also examined students' 21st Century Skills. However, it is unclear from the research what aspects of robots or the design of the learning experiences were particularly efficacious and therefore it is difficult to draw any conclusions from the research that can be used to inform the design of learning experiences by researchers or teachers.

3.2 EDUCATIONAL ROBOTICS PROJECTS

One of the most successful and long lasting initiatives to promote STEM, especially focusing on girls, is Roberta – learning with robots (Roberta, 2016): *"Using special, gender-*

appropriate teaching and learning materials and specific coaching concepts a range of educational courses have been developed over the last ten years which not only take into account how girls and boys 'experience STEM' but also how they access STEM topics. Regional Roberta Centers and certified Roberta teachers share their knowledge and experience in a network that now spans across whole Europe. Networking has been made easy via the Roberta portal. Certified Roberta teachers are also given access to a wide variety of Roberta materials free of charge." The main goal of the project is to engage and motivate girls and boys to take a sustained long-term interest in science, technology, engineering and math (STEM).

Another interesting project about Educational Robotics is the European project TERECOP (Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods) (European), which took place from 2006 to 2009. The project is based on constructivist and constructionist pedagogical theories and the main theory adopted for the project's theoretical frame was the socio-constructivist approach. The overall aim of the project was to develop a framework for teacher education courses in order to enable teachers to implement the robotics-enhanced constructivist learning in school classrooms, and report experiences from the implementation of this framework. The project leads to a number of papers and events about teacher Education on Robotics and about the implementation of the educational framework. This framework can be very helpful in designing activity plans and new curriculums that enhance STEM and Educational Robotics education.

Centrobot is another European project, which took place from 2008 to 2010 and its goal was to stimulate the interest of children and young people in technology and research. The Centrobot project organized international competitions in the Vienna-Bratislava region, a world championship and a European championship. In addition, it conducted two scientific conferences as well as three summer schools and an exchange program within the educational sector. In that way students engaged in robotics, learned about STEM and got involved in activities with students from other countries.

3.3 WORKSHOPS AND CURRICULA

The Academy of Educational Robotics

The Academy of Educational Robotics (Robotics A. o.) provides a complete portfolio of classes for Educational Robotics and STEM. There are seven different classes:

1. Educational Robotics (ages 6-16, 12 students max)
2. STEM - I Play and I understand (ages 9-16, 12 students max)
3. Open Lab - Free Creation (ages 5-55, 15 students max)
4. Parents and children become friends with robots (ages 6-16, 12 students max)
5. Robotics for children with autism (ages 6-16, 12 students max)
6. Robotics and automation technologies (ages 15-60, 10 students max)
7. Teacher training (ages 22-55, 12 students max)

The courses are designed to cover a large variety of opportunities for workshops through discovery learning and collaborative learning for children in the age range from 6 to 16 years. Moreover, children have the opportunities to participate in the workshops together with their parents, so that they can work as a team in the Academy. The technical portfolio consists of different platforms ranging from proprietary technologies, such as Lego Mindstorm and Nao, to open technologies, such as Arduino-based kits. The robots can assume a variety of roles such as teacher, peer or tool. All the courses are presented in a modern visual way with self-explanatory pictures and videos, available on the web page of the Academy with a very user-friendly interface for selecting and booking a course. The target audience of the workshops is not only children who are interested in learning the basic concepts of robotics but also people interested in becoming instructors and trainers in the field of educational robotics and in the integration of robotics concepts in other disciplines.

The Creative Technologies in the Classroom

The Creative Technologies in the Classroom (CTC) initiative has built workshops on the concept of collaborative learning (Classroom C. T.), which incorporate the emerging technologies within the already existing technology classes. Students are encouraged to explore electronics through a series of coding projects and hands-on construction.

Students gain understanding on the foundation principles of programming, electronics, and mechanics. The user-centric free access website provides tutorials, as well as community based support in the forums in which everybody is welcome to document their project and make it available for teachers and students to follow and learn from. The projects and teaching materials are organized in four blocks and are neatly illustrated with schemes, pictures and videos for a better understanding.

The series of workshops are based on the Arduino platform, which is open, easily accessible, cost-effective and well known within the technical community. On the whole, the program is aiming to be implemented in 50 schools, for 1200 students and with the participation of 100 teachers. The same or similar initiatives are operational in Skane, Sweden. The initiative is an excellent example of integrated approach for scalable framework and workshops for educational robotics.

Hummingbird robotics kit educational curriculum

The Hummingbird Robotics Kit is a spin-off product of Carnegie Mellon's CREATE lab (Robotics H. , 2015). Hummingbird is an electronic board designed to enable engineering and robotics activities for children of the age of 13 and up and for children from 8 up to 12 years old with adult supervision. Those activities involve the elaboration of robots, kinetic sculptures, and animatronics built out of a combination of kit parts and basic craft materials.

Hummingbird is a great way to introduce kids to robotics and engineering with construction materials that they are already familiar with and combined with easy-to-use software environments such as Scratch, Snap!, the CREATE Lab Visual Programmer, and Ardublock. At the same time, Hummingbird continues to provide new challenges by allowing programming in the Arduino environment, Python, Java, and Processing, and by supporting Raspberry Pi.

The company's website provides access to an educational curriculum, classroom resources and instructions for teachers as well as tutorials, software, hardware and technical support for students. Most of the examples shown in the website use a DIY approach and everyday materials, such as boxes, plastic bottles, among others.

Virtual Worlds

Modern virtual worlds such as Second Life, ActiveWorlds and Minecraft, provide flexible environments with a range of educational opportunities. Modern virtual worlds provide a simulated 3D environment, hosted on a server and connected via a client to the user's computer. Within the 3D environment the user is typically represented as an avatar and through the client-server architecture, can act and interact within a shared space with others. While there has been increasing interest in the use of virtual worlds in education, there is a dearth of research literature on the educational potential of these environments for children. While the actions of learners within these environments are virtual and may not appear compatible with traditional concepts of educational robotics, namely the tangible nature of the robot which is often described as important for learning, virtual worlds provide a space in which learners can interact with an 'unbreakable' robot, with others who can be co-located or many thousands of miles away. Here, we consider two instances of robots in the virtual worlds of Second Life (marketed as a user-generated environment) and Minecraft (marketed as a game).

SECONDLIFE AND SLURTLES

Educators have been involved in K-12 and adult education in Second Life, and later OpenSim, since its first release in 2003. In 2008, SLurtles were first developed as a programmable robot in Second Life, designed for use by adult learners with little or no experience of programming, to provide them with an easy to use robot which can be programmed to create other objects and move around the virtual world (Girvan, Tangney, & Savage, SLurtle Soup: a conceptual mash up of constructionist ideas and virtual worlds, 2010). A modified version of Scratch was used to provide a drag-and-drop programming interface that generates the C-style syntax required for objects in Second Life. Thus, not only was an entry level or low-floor programming environment available to interact with SLurtles but it provided a route for transition between graphical and text-based languages, which can be a barrier for many learners (Girvan, Tangney, & Savage, SLurtles: supporting constructionist learning in second life, 2013). The SLurtles takes the traditional idea of on-screen and physical turtle robots and moves them into a 3D environment where learners can explore 3D geometry through the process of creating artefacts within the virtual world and in collaboration with others.

MINECRAFTEDU

MinecraftEdu (Minecraftedu, 2015) provides a great example of integrating popular gaming tools in modern technology education. MinecraftEdu is built on the concept of the Minecraft game but it provides products and services that make it easy for educators to use Minecraft in the classroom to teach robotics fundamentals. The game includes additional features that make it more useful and appropriate in a school setting such as options for constant teacher monitoring, customizing the gameplay so as to match the educational purposes, manipulating the in-game settings, environment and tasks making it available for students to learn subjects from STEM to Language and History of Art.

The activity includes programming a virtual "*turtle*", its surroundings, and completing missions with the aid of visual programming. Complex task are also available, there is the option to write the commands directly without the use of any visual aid. Furthermore, it includes features such as sequence of actions and other complex commands that are very native to the concepts of programming robots through visual commands to perform simple tasks. The game target group is children between the age of 7 and 18 years old, teachers, and parents.

The main characteristic of this activity is the online community-based approach that is applied for ensuring the continuous improvement and sustainability of the initiative. Currently, this community consists of more than 6000 teachers, who are constantly developing and improving materials based on the game, as well as educational technologies, lesson plans, materials, glossaries, etc. all available for free in the website of the MinecraftEdu initiative.

Robopartans

Robopartans (Robopartans, 2015) offers extra-curriculum workshops for students in the age group between 8 to 16 years old. The workshops are age-based and require teamwork and leadership skills from the participants in order to successfully complete the projects. All projects are LEGO-based and tailored to the age group so as to make them appropriate for the students' interests and experience. The activities are also competition-based. In other words, the groups compete among them after they have successfully completed their assignments. The instructor does the role of a consultant and does not directly offer solutions to the children.

The workshops offered are oriented towards the development of problem-solving skills in the children, as well as project-oriented thinking, analytical and logical thinking, and creativity. Robopartans offers a vast portfolio of workshops that ranges from a regular four-hour workshop to an intensive summer school or after class daycare service.

Robopartans has also become a sponsor and partner of most of the educational robotics initiatives in Bulgaria, aiming to encourage further interest in the field. Although they do not offer resources or make their educational curriculum publically available, Robopartans presents a comprehensive example of a successful business-driven approach for ensuring sustainable interest and results in the field.

Project THOOL

The project Thool started (Thymio, 2015) in 2014 and will end in 2016. Its goal is to create pedagogical robotics kits to use in public schools to teach and support the STEM disciplines with educational robotics. The workshops offered are divided into several categories - firstly based on age and school grade and secondly based on a particular STEM discipline.

Their educational model, workshop plans and materials are currently being implemented as a part of a regular school curriculum in several schools for general education in Switzerland and all the materials used are available on its website. The workshop's duration is about 45 minutes, a regular school hour. The workshops include the Thymio robot and visual programming to teach STEM concepts and foster creative thinking in children.

The workshops are project-based, thus the robot has to perform a certain set of activities to complete a task, such as "fishing" for paper fish and others activities of the same kind. The workshop begins with a short introduction of the robot, which is ready to use, and its basic functions and continues with a brief presentation of the visual programming software and jumps straight into practice. In some of the workshop plans, there are suggestions for competition-based tasks as well as games to further master the concepts that are being taught. A lot of materials are made publicly available - for teachers and students as well, such as handouts and pedagogical approach suggestions. All materials are available in French only.

Carnegie Mellon Robotics Academy EV3 Curricula

The Introduction to Programming EV3 is an educational curriculum designed by the Carnegie Mellon Robotics Academy to teach core computer programming logic and reasoning skills through the use of robots. It provides ten projects and a capstone challenge, which are organized around two main concepts: robotics and programming. These projects are created from “real-life” problems and are designed to encourage the students to think towards patterns and structures, not just in the field of robotics but also in the sphere of programming, STEM and generally. One of the major goals of the initiative is that by the end of each project students become better thinkers, instead of just better programmers.

The online version of the curriculum is open for public use after a simple registration into website. The classroom version of the educational technology provides additional functionalities and downloadable content and can be directly purchased.

EduACT

EduACT (Education T. O., 2016) is a volunteer group of young entrepreneurs, scientists, IT experts and pedagogues from Thessaloniki. Between other projects, eduAct organizes the FIRST LEGO League (FFL) in Greece, a robot competition for children aged from 10 to 16 years old. FIRST® LEGO® League (FLL) is a program that supports children and youngsters in order to introduce them to science and technology in a sporty atmosphere. The basis of FLL is a robotics tournament, where kids and youngsters need to solve a tricky "mission" with the help of a robot. The kids are researching a given topic within a team and they are planning, programming and testing an autonomous robot to solve the mission. The FLL project according to eduAct's website, aims to a national contribution for the teaching of science, mathematics and technology in and out of the school environment, through a game-like academic competition that gives students a chance for innovation and creativity, and at the same time inspires children and young people to think like scientists and engineers. In the last FFL competitions students where working in teams of 3 to 10 children with one coach per team and as material they use on of the Lego Mindstorms sets: RCX, NXT or EV3. Apart from the FFL competition, eduAct also organizes a summer camp for robotics. This was the first "Robotic Camp" in Greece for children around the world. In the Camp, children are cooperating in a team in order to create their robots, with famous robot designers from all over the world giving their support and inspiration. Finally, eduAct organizes a series of workshops for robotics where students from all ages are learning about robots and make their own creative constructions. Every workshop consists of a small group of 10-12 persons and it takes place in 8 meetings of one hour each. The goals of the workshop, as mentioned from eduAct, are:

- To develop a mathematically competent and technological literate workforce
- To influence children to become interested in robotics and related technologies as an area of study and future employment
- To grow future entrepreneurs and employees for the nation
- To enable kids having fun while experimenting with science and technology

In eduAct actions we can see are based on a constructionist approach to educational robotics merged with collaborative and game-based learning.

RobotixLab

RobotixLab (Robotixlab, 2016) applies innovation in the area of creative robotics applications, design and prototype development of an educational robot kit design and production of electronics and making kits for education and more. RobotixLab designs and runs custom made workshops based on the age range of the group (starting from 6-7) with small groups of 15 people working in teams of 2-3 persons. Workshops are organized with a project based approach and the main goal is to help participants acquire an open innovative thinking mindset, learn how to cooperate and be part of a team, take responsibilities, brainstorm and tackle a problem in a lateral thinking way, test, evaluate and redesign their ideas in an iterative optimization design cycle. The main areas of workshops are: Robotics, Electronics, modeling-3D printing, Videography, innovative entrepreneurship and game design. Robotics workshops range from small 3 to 4, 90 minutes sessions to long 25 to 30, 90 minutes sessions and they are based on theme scenarios and challenges like robot recyclers to save the environment, maze solving robots in Theseas and Minotaur adventure and interactive robots that produce art. During a RobotixLab workshop participants build robots based on the theme scenario by either following clear, step by step instructions (for beginners) or brainstorm design and build their very own device (for intermediate to advanced participants). Programming the robots using the computer, testing and evaluating the robot's actions and back to programming or rebuilding a particular part of the robot lead to optimization until the big challenge. Every RobotixLab workshop cycle ends with the challenge competition where in a fun atmosphere teams compete with their robots. RobotixLab applies in its pedagogical agenda the constructionism theory, learning by doing and creative learning theory combined with science, technology and engineering.

RobotiXLab has also supported a two day festival in Thessaloniki in March of 2015, the "Electric Circus" festival. The festival included a robotics competition and other events such as workshops, presentations, conversations and exhibitions. In the robotics contest there were participating 15 teams of 3-4 persons from Greek Elementary schools (ages 9-12).

Robotics Academy

Robotics Academy (Robotics A. o.) is a team of University of Macedonia that organizes workshops for STEM. There are seven different categories of workshops:

1. "Educational Robotics" (Ages 6-16). This workshop is about STEM education based on robotics. The duration of the workshop is 12 sessions within 3 months and the maximum number of participants is 12. The students are working mostly with LEGO Mindstorms sets.
2. "Robotics for children with autism" (Ages 6-16). This workshop aims to engage autistic students with robotic in order to improve their social abilities through collaborative and team-based activities. The duration of the workshop is 12 sessions within 3 months and the maximum number of participants is 12.

3. “STEM - Play & Understand” (Ages 9-16). In this workshop students follow a course about STEM in a playful, interactive and experiential environment. At the end of the course they create their own artefact. The duration of the workshop is 12 sessions within 3 months and the maximum number of participants is 12.
4. “Robotics and automatism technologies” (ages 16-60). In this workshop participants are engaged in hands on training through examples and activities with Arduino and Rasberry Pi. The workshop is divided in 3 cycles: In the first cycle the students learn about Arduino and other sensors. In the second cycle students are engaged with more advance functions of Arduino and its coding. Finally in the third cycle students combine their Arduino knowledge with programming in order to create complex constructions. The duration of the workshop is 12 sessions within 3 months and the maximum number of participants is 10.
5. “Open Lab – Free Creation” (ages 5 – 55). These are open monthly workshops where people can play and create with robotics and take part in mini competitions.
6. “Teacher Training” (ages 22-55). The aim of this workshop is to train computer science teachers in the subject of educational robotics. Teachers are trained how to use Lego Mindstorms in their classrooms. The duration of the workshop is 12 sessions within 3 months and the maximum number of participants is 10.
7. “Parents and kids becoming friends with robots” (age 6-12). In this workshop young children are working as a team with their parents and they learn together about robotics. The duration of the workshop is 14 sessions within 4 months and the maximum number of participants is 6 teams of children-parents.

3.4 CONFERENCES AND COMPETITIONS

Unfortunately conferences for school aged children in the field of robotics are not yet widespread. An Internet search has only brought up WEROB (see below in conjunction with RoboCup Junior) apart from ECER that integrates conference-styled activities besides robotic competitions. Consequently, a few major robotic competitions are described in the following.

By now, many robotic competitions exist in the world for different age and peer groups. The used technologies greatly vary as well as the settings of these competitions. The fact of being a competition is often mentioned as a motivation factor as the children and adolescents are eager to show their skills. However, such an environment is not necessarily ideal for all children. Nevertheless, most large robotics activities and events for young people are based on competitions. In order to add other skills besides constructing and programming robots, many competitions demand activities such as written documentation of their development or being interviewed by a judge.

RobotChallenge

The RobotChallenge (Challenge, 2015) takes place annually in Vienna. It has seen teams from 56 countries with more than 200 robots since its installation in 2004. Thus, it is stated to be one of the biggest competitions for self-made, autonomous and mobile robots worldwide. It encompasses fourteen different competitions with classic tasks such as line-following with LEGO controllers up to sprints or sumo with humanoid robots and air races. Therefore, beginners as well as experienced robot designers of all age groups can take part. Due to its size, it has good media coverage with articles regularly published in important Austrian newspapers. It is supported by the Austrian Federal Ministry of Science, Research and Economy.

FIRST LEGO League

The FIRST LEGO League (FLL) (League, 2015) is an international competition organized by FIRST in cooperation with LEGO for school students aged nine to fourteen (or sixteen in countries outside USA and Canada). The competition is split into three judged sections and a live robot run. The first judging session, Core Values, is designed to detect how the team works together. Teams are also asked to perform a teamwork exercise (usually timed). Secondly, in the Robot Design, the team explains how they designed their robot and demonstrates their programs to the judges. Thirdly, in the Project, the students must research a topic related to the current challenge and create an innovative solution. The teams have five minutes to present their ideas, and the judges have another five minutes to ask questions. Finally, the students must use the robots they designed and built to autonomously complete a set of tasks on the challenge mat. Teams in different parts of the world have different times allotted to complete the construction of the robot, due to the varying date of qualifying tournaments, and then go on to compete in FLL tournaments. The only competition run by FIRST itself is the FIRST World Festival. Worldwide a very high number of students participate in any form at the FLL, reaching more than 230.000 participants, 2900 teams from eighty countries in 2015.

By integrating problem-solving and discovery learning pedagogical approaches, children further develop skills and abilities such as critical thinking and team working and team leading skills and basic STEM applications. As all the participants have to present their solutions with a dash of creativity to the judges, the initiative encourages a concentrated work on the personal presentation and communication skills of each child. First Lego League is a valuable resource in the sense that it shares great experience on how a robotics competition can impact a large number of children all around the world and encourage them to pursue higher education in STEM fields.

RoboCup Junior

RoboCup (Junior, 2015) is a division of RoboCup styled for school aged children. The international competition was installed first in 2000 in Australia during the regular RoboCup competition. Each year, an international competition is run around the same time, and at the same location, as the RoboCup competition. Besides the international competition there are national and regional competitions around the world. Often teams have to qualify at their local competition to be admitted to the world championship. The participants compete in one of three main leagues: Soccer, Rescue or Dance.

Since 2010, the international RoboCup Junior competition has been accompanied by the RoboCup Junior Annual Workshop (also entitled as Workshop on Educational Robotics, WEROB). WEROB encompasses papers by researchers but also students can submit papers to this workshop and hold presentations accordingly.

Robo League

The Robo League Bulgaria is an open competition aimed to create a perfect scenario for robotic enthusiasts of different ages. The competition is divided into the following categories: mini sumo, line trace, super line, maze, 3D maze, and freestyle. The categories and the teams are formed based on participants' interest and individual level of experience. The participants have to design their robots on their own before the actual competition, tailored to the category in which they will compete.

Simultaneously to the competition, Robo League provides to secondary schools and universities the opportunity to show their robotics projects. The initiative also includes hands-on sessions with leading professionals in the field invited to present topics of interest. For a third consecutive year, in 2015, the Robo League Bulgaria has been once again organized and sponsored by the robotics community of Bulgaria. It is a good example of a self-organized technical community and its ability to achieve sustainable results without or with a minimal amount of external funding.

Robotics Week School Robot Challenge

The Robotics Week School Robot Challenge is a national competition in England. Its primary goal is to inspire students to design and assemble a robo-bug using as an educational approach the biomimicry. It is organized as a gender-balanced competition open for UK school students within the age ranging from four to seventeen years old. The initiative aims to promote STEM concepts among students and to challenge the participants to interrelate fundamental concepts of educational robotics to their various practical applications in different STEM fields such as biology and ecology.

World Robot Olympiad WRO Hellas

One of the most famous competitions for educational robotics in Greece is the WRO (World Robot Olympiad) Hellas, which is a membership of the World Robot Olympiad organization. WRO Hellas organizes yearly a national competition for robotics, since 2009. The competition involves students from any Greek school or university, with the age range being between 6 to 25 years. Every competition has a number of challenges for different age groups: one for Elementary school students (6 – 12 years old), one for Middle School students (13-15 years old) years old, one for High School students (16-19 years old) and one for University students (17 – 25 years old). There is also one extra special challenge with the age group usually being between 10 and 19 years old. Every challenge has a theme (e.g. Bowling Game, Treasure Hunt) and the students are called to assemble and program a robot in order to do a specific action (e.g. cross walk on a coloured path). The basic material that is used from the students (based on the last competition) includes Lego Mindstorms sets (NXT or EV3) and some high tech colour sensors. Sometimes there are also Arduino and Rasberry microprocessors in some categories. The competition consists of a number of rounds: assembly time, programming and testing time, in total 150 minutes. Also, all the challenges are team-based and every team consists of one coach (minimum age 20) and two or three team members. From pedagogical point of view, we could say that the students are engaged with educational robotics in a project based and collaborative learning context.

3.5 EDUCATIONAL TECHNOLOGIES AND RESOURCES

Several educational technologies have been mentioned in the previous section. There is one website that offers a nice overview on educational technologies for robotics, the Educational Robots repository (Roboter, 2016). It offers a dictionary in order to classify activities, materials and other resources related to Educational Robotics. The website is divided in seven categories, related to STEM and Robotics:

- Out of the box: This category includes toys, robots and websites for young children such as Fisher-Price Think & Learn Codepillar, Bee-bot, etc.
- Assembly Kits: In this category there are listed several links of selected Educational Robotics Kits such as Lego Mindstorms, Tinkerbots etc.
- Crowd funded robots. This category includes external links to crowd funded robot projects such as DIY Robots for Kids.
- Self-build and Microboards: In this category one can find external links to self-build materials for robotics such as Arduino, Nibo etc.
- 3D printed robots: This category includes robots made by a 3D printer device
- Humanoid: In this category are listed famous humanoid robots
- Programming: In this category are included websites and software's for programming a robot like Scratch, ROBOTC and Arduino software.

This is a very useful repository as it has categorized all the main domains of Robotics and by using it students may be motivated to get involved with robotics and STEM. Although, diverse educational technologies for educational robotics are identified, they have not been analysed in depth for this deliverable. The stakeholder requirements (section 4) show that the issues will not be solved by creating more tools, but by supporting the design and evaluation of activities with existing tools (also elaborated in section 6).

Aside from the Educational Robots repository, several portals exist that focus on either one kind of educational technology (or platform) with different materials or on materials on educational activities for diverse contexts. In our research, we analysed four of the most popular educational portals that are usually known to European educators: Scientix, Open Education Europa, OER Commons and Consumer Classroom. The features that were analysed for each one of these repositories were: target audience, user-friendly, searching parameters, content, and robot related content.

Scientix

In this portal (Scientix, 2015), users can find teaching materials, report libraries, training courses and LRE materials, although the focus is not only Science, most of the material is related to STEM education.

Target Audience: This community is focused on science related material and aimed to reach national teachers.

User-friendliness: As a portal, navigation is very easy, and it has a very clean layout to avoid any confusion. Further to this, users can request free translation of the learning resources.

Searching Parameters: Users can search by one or more of the following fields: subject, minimum and maximum age, type of resource and language.

Content: Currently, it could be found over 1.739 resources in different subjects and fields. Each resource contains tags, age range, resource type, author and a description.

Robot related Content: Content related to robots is of approximately five resources.

OpenEducationEuropa

In this portal (Europa), users can find or share information with others. Users can find MOOC's, Courses, Resources and even institutions.

Target Audience: The portal is aimed at teachers, researchers and educators across different areas of knowledge.

User-friendliness: The search feature is very visible, with a slightly less visible "*Advanced Search*". Overall, the website main page is always updated with new information, and this might confuse where one should press to proceed.

Searching Parameters: After introducing a keyword, the user will be able to filter the content and obtain a more refined search. Content can be refined by type, institution, language, features, subject, licenses and education level.

Content: Over 66.000 results from different content types (although over 44.000 are user profiles) could be found. The content for each resource varies according to the type, however for learning resources this includes educational level, languages, licenses, tags and type. The portal also allows users to comment within the resources with an account. Further to this, sharing via email, twitter and Facebook is also available.

Robot related Content: Content related to robots is of approximately over 200 resources.

OERCommons

The OER Commons portal (Commons, 2015) is very welcoming upon landing on the site. It is very well structured with an easy to use tool for users to search for materials. The portal can also be used to create and connect with others.

Target Audience: The portal is aimed at individuals or organizations that would like to share or else find resources to reuse with their colleagues or students. Most of these resources follow a Creative Commons or GNU License. This will allow the material to be used, reused, adapted and shared according to the author rights.

User-friendliness: As previously mentioned, it has a very clean and modern design. A very useful tool is the Learner Options. This feature allows the user browser to change the text size, the text style, line spacing and the colour and contrast.

Searching Parameters: Users can search by free text, subject, education level and standard. Upon searching one can refine the search by education standard, subject area, education level, material type, conditions of use, content source, primary user, media format and educational use.

Content: Over 64.000 resources can be found in this portal. For each resource, further information such as provider, level, grades and abstract can be found. Comments can also be left for each resource without the need to log in. Any resources found can be saved by the user once an account is created.

Robot related Content: Over 280 resources are available related to Robotics.

Consumer Classroom

This portal (Classroom C.) is rather a tool that is to be used by the teachers, including also the searching of resources.

Target Audience: This tool is aimed at teachers to showcase an extensive library of consumer education resources from across the EU.

User-friendliness: The website is very user-friendly with specific banners for different tools and features available. An interesting feature is the Lesson Builder, where users can create their own lessons for the classroom.

Searching Parameters: Starting with a free text search, then the user can narrow their results by theme, subject, language, age, rating, format and country.

Content: This portal seems to be a rather new one, as it currently features around 1000 resources.

Robot related Content: No direct robotic content is available.

Platform based Repositories

Some robotic platform vendors offer repositories where people can share their activities with the platform. Beside Lego (Lego) and Arduino (Arduino) there are two interesting repositories to mention:

- *Dash and Dot* (Dot, 2015) offers a number of lesson plans for teachers, also with the possibility of allowing teachers to upload their own lesson plan. Each lesson plan is tagged with the subject domain and the grade it can be used with. Some of the lesson plans are free of charge, with others being accessible with a subscription.
- *Sphero* (Sphero, 2015) includes a "lightning lab" which is a growing community of makers, students, and instructors. Lightning Lab is your hub to create, contribute, and learn with Sphero robots. Further to this, one can download classic lesson plans in PDF format, which include student, teacher guide and worksheets.

3.6 CONCLUSIONS

This section has presented several initiatives in educational robotics, which were grouped in research in educational robotics, educational robotics projects, workshops and curricula, conferences and competitions, and educational technologies and resources to convey a better panorama of the current situation. Our main findings are:

- Although there is a wide range of *workshops* using robots with and without *curricula*, there is a need to define criteria to identify best practices in curricula and the need for a process that guides teachers or workshop organizers in the creation of new activities that are pedagogically informed.
- There are many different successful robot *competitions* worldwide, but these mostly address young people already interested in STEM and use the concept of competition for motivation, there is a need to have more different learning contexts like robot art exhibitions or *conferences* to address more young learners.
- Research in educational robotics lacks detailed and structured descriptions of activities or experiment design for being comparable among them or replicable. There is a need to describe *educational robotics activities* analytically to become more explicit and elaborate about pedagogical design and also have activities that can be shared and compared. Parameters and criteria need to be defined to be able to identify best practices and innovations in pedagogical activities.
- The many existing *educational resources* regarding robotics are based on the *technology* they use. There is a need for a user- and activity-centered repository. This can only be achieved by a better understanding of the stakeholders engaged in educational robotics.

These findings necessitate the modification of the identification process for the best practices in educational robotics. As a first step, in the next section, we follow the identified requirement to analyse stakeholders of educational robotics closer and offer a first overview and selection of main stakeholders.

4 STAKEHOLDERS

For the analysis of the main stakeholders of ER4STEM, following process was used:

- Identify all stakeholders impacted by educational robotics activities and having impact on educational robotics activities and outcomes based on the extensive best practice research, and knowledge body and experience in the consortium
- Select up to three main stakeholders that will be mostly affected by the ER4STEM project outcome, the framework and repository
- List the requirements of the main stakeholders to ER4STEM

In the first step all stakeholders of ER4STEM were identified and briefly reviewed:

Young people who will be involved in educational robotics activities by schools or other organizations. They are directly targeted by these activities to learn about robotics or "STBEAM" fields (Science, Technology, Business, Engineering, Arts, Maths) or to "maintain their curiosity in the world". So they will be directly impacted by our project outcome (the framework and repository) and we will measure this impact, yet they do not have as much influence on shaping educational robotics activities as other stakeholders.

Young people parents may encourage their offspring to participate in educational robotics activities or they may not. Although having a lot of influence on their children's choices, in most cases they will not have enough pedagogical or scientific background to design educational robotics activities with their children. Thus, they are not main stakeholders of the ER4STEM project, yet they should be considered together with *Young people* as important stakeholders that can also benefit from the outcome of the project.

Schools have two different stakeholders: *teachers* with their main responsibility to teach through different methodologies; and *school boards* or *senior management*, who decides over budget and established standards. The influence of the role of the teacher over the same activity with the same materials is widely known and acknowledged. Therefore, ER4STEM project will focus on teachers as main stakeholders in order to support them in their teaching by providing them a framework and repository that allows them to use educational robotics in their classrooms in an informed and structured way.

Organizations offering educational robotics: There are non-profit organizations offering educational robotics activities, organizations based on profit or mixed versions. These can be clubs, projects, initiatives, universities, science and technology institutes, etc. They all have in common that they offer educational robotics activities, to encourage young people to follow STEM careers in most cases. The activities offered by these organizations reach a wide audience and can create a big impact. Therefore, ER4STEM considers *educational* *robotics activities organizers* as main stakeholders who will profit from the outcome of the project and also contribute to the impact by using the framework and repository.

Inside *Universities* there are several stakeholders relevant for ER4STEM: educational researchers, teacher educators, engineering scientists and people involved in outreach programs with educational robotics. Especially, *educational researchers* have an impact on the analytical description of activities and their scientifically sound evaluation. By considering them as main stakeholders for the project and involving them in the framework and repository, we will complete the educational robotics picture from a different perspective.

Industry is directly affected by people's skill sets and education. The demand in high quality knowledge workers in STEM fields is increasing worldwide, but young people choosing STEM fields are not matching these numbers in demand. There are even initiatives started by industry to counter these developments. The outcome of the project will impact the industry as much as it will impact young people's lives, maybe in a broader context. Therefore, it makes sense to consider industry as a valuable stakeholder that can monitor ER4STEM project goals and activities from the perspective of human resource needs regarding skills and knowledge of future employees.

Educational *Policy makers* are governmental organizations established with the purpose to lead the future of education. Although the project realizes the importance of these stakeholders, addressing them would go beyond the scope of ER4STEM. The project aims to influence them indirectly via its main stakeholders and dissemination through Scientix.

Having identified the ER4STEM stakeholders, in the second step, three main stakeholders that will be mostly affected by the ER4STEM project outcome, the framework and repository were selected: *teachers, organizers of educational robotics activities* and *educational researchers*. Additionally, industry was selected as a secondary stakeholder because it brings a different perspective on the required skills and knowledge that can be transmitted by educational robotics.

In the third step, the requirements from the main stakeholders are analysed to correctly reflect stakeholders concerns and needs through the project.

4.1 TEACHERS

Teachers are generally interested in educational robotics activities as they represent an interesting and exciting alternative to regular teaching lessons. Consequently, they welcome the opportunity of having somebody carrying out such activities in the frame of their lessons as long as they have enough freedom on designing their semester schedule. However, especially regarding primary school teachers but also regarding those of schools with older children, the will and ability to hold such workshops without any external assistance is low. Lack of technical knowledge represents a major hindering factor for the success of train-the-trainer workshops, as the teachers don't reach real confidence in what they learned.

Such as the *Teaching Profession in Europe* (Commission/EACEA/Eurydice, 2015) report compiles about teachers' needs: "*They are specially concerned with needs under the headings of 'teaching students with special need', 'ICT skills for teaching', 'new technologies in the workplace', 'approaches to individualized learning' and 'teaching cross-curricular skills.*" This shows that teachers' main concern is related to how to acquire the skills to use technology rather than the required knowledge to teach their subjects.

For the design of the framework and the repository, these needs will have to be taken into consideration. The stakeholder group *teachers* will need to be involved in the design process of both to ensure the impact and sustainability of the project outcome.

4.2 EDUCATIONAL ROBOTICS ACTIVITIES ORGANIZERS

Educational robotics activities organizers are a heterogeneous group from different backgrounds and contexts, and thus difficult to analyse from one perspective. Nevertheless, they all have three main concerns in common:

1. Educational robotics activities design
2. Sustainability of activities
3. Accessibility

Regarding the design of educational robotics activities, the requirements are:

- Clear educational objectives related not only to robotics but also linked to other knowledge domains; this means to identify if a course has robotics as an object or as a tool and if a course emphasizes learning processes or the understanding of specific concepts or skills or both
- Promotion of cloud and mobile technologies instead of desktop software
- Integration of educational robots as teachers, peers, and companions and not only as tools
- Promotion of multi-platform and multi (technical) language environments
- Clear structure or process to develop educational robotics activities

Considering the sustainability of the activities, the requirements are:

- Standardized and clear structure for the reporting and sharing of activities
- Tools for the integration of educational workshops within the curricula in learning spaces
- Guidelines for educational activities to have a clear and sustainable model for continuous improvement (based on new educational research findings, technologies, trends, etc.)
- Environments for the exchange of good practices and the establishment of educational robotics communities (e.g. in open portals such as Scientix)

Considering accessibility, the requirements are:

- Activities that cover a wide range of age groups and furthermore serve as an entry point for each of those groups; likewise, the activities promoted should foster the smooth transition between groups
- Provide open content for use in educational activities, presented through various media (video, visual guides, schemes, downloadable written descriptions and walkthroughs, etc.)
- Provide solutions regarding affordable and cost-effective platforms in order to encourage the sustainable integration of the technologies applied within the educational activities (an example of a relatively cost-effective technology with good cost-to-quality ratio is the LEGO technology and as for a relevantly low initial investment - the Arduino technology)

For the design of the framework and the repository, these requirements will have to be taken into consideration. All project partners who will organize educational robotics workshops and conferences belong to this stakeholder group *educational robotics activities organizers* and will be constantly reporting back on the needs and requirements as well as monitoring the implementations in the framework and repository.

4.3 EDUCATIONAL RESEARCHERS

Educational researchers are also a widely heterogeneous group, and only a small part is involved in educational robotics. The common requirements from this stakeholder are:

- Pedagogically informed description of activities
- Evaluation with clear study set up and hypotheses, evaluation criteria and instruments
- Comparability of activities and results
- Standardized approaches

For the design of the framework and the repository, these requirements will have to be taken into consideration. All project partners who will organize educational robotics workshops and conferences will also be taking a role in evaluating these and thus gather valuable experiences on the research side of their educational robotics activities. Some of the project partners are *educational researchers* and will be constantly reporting back on the needs and requirements as well as monitoring the implementations in the framework and repository.

4.4 INDUSTRY

The industry has a different perspective on STEM education or any activities that lead to more future employees with the necessary skill sets and knowledge to shape the 21st century. In the following, we present a brief report on the industry requirements:

STEM skills are those skills expected to be held by people with a tertiary-education level degree in the subjects of science, technology, engineering and math. For the purposes of this report, the STEM fields include natural sciences (physics, biology or chemistry), mathematics, engineering (general, civil, electrical, electronics, communications, mechanical, and chemical), computer science, and architecture. Other fields such as medicine or social sciences are not included. This study includes both STEM professionals encompassing a wide range of knowledge-intensive occupations including scientists (i.e. physicists, mathematicians and biologists), engineers and architects, and the STEM associate professionals encompassing technical occupations connected with research and operational methods in science and engineering, including technicians in physics, life science and engineering; supervisors and process control technicians in industry, ship and aircraft and ICT technicians.

STEM graduates in EU

In 2012, 23% of all EU-28 graduates held STEM qualifications. By comparison, the respective figures for the USA and Japan were 16% and 22%. The highest percentage of STEM graduates has Finland (27.6%), Germany (27.3%) and Sweden (26.7%), whilst Poland, Belgium, and Netherlands have the lowes, with 16.9%, 16.9%, and 14.5% respectively (Panorama, 2015).

Demand for STEM skills

With global economic growth expected to be driven by the life sciences, alternative energy, aging populations and consumption in emerging markets, the demand for STEM talent is set to explode in the next decade.

In 2013, the employment of science and engineering professionals and associate professionals constituted 7% of total EU-28 employment. In the period between 2003 and 2013 the demand for STEM skilled labour has increased by 12% in spite of the economic crisis. For the period between 2013 and 2025 the employment for all occupations is expected to grow by 3%, whilst the demand for STEM professionals is anticipated to grow by 6.5% (Policies, 2015). This means that there is one million and twenty five thousand additional jobs expected in STEM fields between 2013 and 2025 and that by 2025 there will be 7.7 million STEM professionals in total. Slovenia, Malta, Austria, Hungary, Finland and Luxembourg are the countries in which the share of STEM professionals in total jobs openings by country is expected to be highest - ranging from 9 % to 5 %.

There are however huge differences across STEM-related sectors - the demand is expected to rise in professional services (by 15%) and computing (by 8%), whilst zero growth is forecasted in the pharmaceutical sector. In parallel, high numbers of STEM workers are approaching the retirement age. It is estimated that around two-thirds of the job opportunities for STEM-related professions will replace retiring workers.

Employment in STEM is male-dominated. Women account for just 24 % of science and engineering professionals and 15% of science and engineering associate professionals. Current demand for STEM skills requires both upper-secondary and higher education graduates. Currently, 48% of the STEM-related occupations require medium level qualifications, which are mostly acquired via upper-secondary level VET. However, while the level of STEM higher education graduates has increased since the mid-2000s, the number of STEM qualifications achieved through upper-secondary level education is steadily declining with the estimate of 46% by 2025 (Panorama, 2015).

The growing demand for STEM skills is not limited to Europe only. In the United States for example, employment in STEM occupations is estimated to grow almost twice as fast between 2008 and 2018 than employment in other occupations. Companies that rely on STEM skills are already hectically searching for talents. In the United States, tech companies like Facebook, Amazon, Cognizant and Apple will need to fill upwards of 650,000 new jobs by 2018 to meet their growth projections. Not only high-tech companies are searching for STEM talents. Many of the skills are needed for instance in the financial services, utilities industry, insurance industry, or chemical companies.

Supply of STEM skills

The average EU share of the STEM university graduates has remained stable between 2006 and 2012 in relation to the total number of university graduates: 22.3% and 22.8%, respectively (Policies, 2015). There are of course variations across countries - the share in Netherlands and Luxembourg is below 15% while in Sweden, Finland, Greece and Germany is higher than 27%. The persisting trend is the underrepresentation of women among the STEM graduates: in 2012 there were 12.6% female graduates in STEM-related subjects compared to 37.5% share of male graduates.

The average EU share of the STEM VET graduates has slightly decreased from 32% in 2006 to 29.4% in 2012. There are again significant variations across countries - they account for more than 40% in Bulgaria, Estonia and Cyprus, in comparison to less than 20% in Belgium, Denmark and the Netherlands. The percentage of women among STEM VET graduates is even lower than for university graduates.

In total, the number of STEM university graduates in EU28 increased by 37% between 2003 and 2012, whilst the number of STEM VET graduates decreased by 11% from 2006 and 2010, followed by a slight increase since then. The recent rise can be attributed to the fact that more people are staying in education due to the weak employment demand caused be the economic crisis.

Comparable figures for the United States are 13% of all university graduates awarded in STEM. Consider that the US graduated 88.000 visual and performance arts majors in 2008 but only 69.000 engineers. The number of STEM graduates in the US would need to increase by 20 to 30 percent between 2006 and 2016 to meet the country's projected growth in science and engineering employment alone. In a global view however, the STEM talent situation looks very different. China, India and Brazil are producing more and more of the world's STEM graduates. In China for example, 41% of all university degrees are awarded in STEM subjects (see Figure 1). There are on-going debates how STEM graduates from developing countries are really qualified for employment in domestic firms. But if only one in five STEM graduates in China will be suitable for global employment, China will produce approx. 720.000 candidates a year, which is far more than 460.000 graduates produced in the United States.

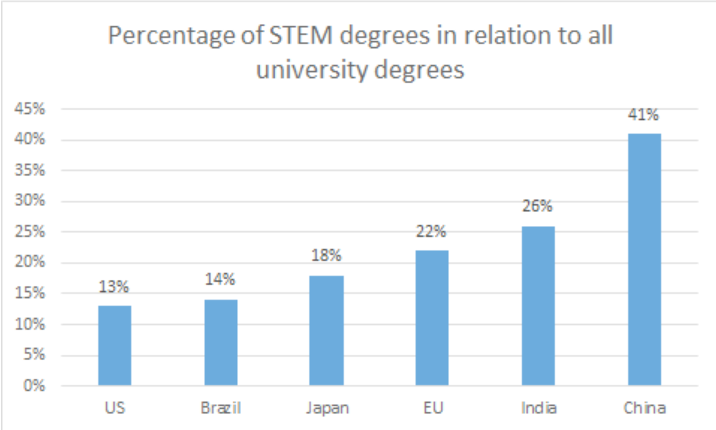

Figure 1: Percentage of STEM graduates compared to all university graduates in 2012

STEM skill shortages

There is a common agreement that the scientist, technologists, engineers and mathematicians are critical to the future economic growth. However, there are different views on whether the supply of STEM-skilled labour will be sufficient or not in the near future. According to Business Europe the lack of STEM-skilled labour will be one of the main obstacles to economic growth in the coming years (Europe, 2011). Their concerns are based on two facts: the proportion of students going into STEM is not increasing at the EU level and there is a persisting trend of insufficient representation of women among the STEM graduates. The European Commission report "*Mapping and analysing bottleneck vacancies in EU labour markets*" also reveals that a large majority of EU28 countries have experienced recent recruitment difficulties in relation to STEM skills.

On the contrary, there are studies such as the Accenture report (Craig, Thomas, Hou, & Mathur, 2011) claiming that the problem is not in a shortage but rather in location mismatch: talented people are available but not always in the places where they are needed. For employers relying most on STEM talent, location mismatch is already a bigger problem than shortage. Accenture's 2010 High Performance Workforce Study (Accenture, 2010) revealed that in companies where STEM skills represent critical workforce, 24% of executives said that STEM skills were located in countries other than those in which they are needed and 21% said that the supply of skilled talent they need is extremely small or non-existent. The study concludes that location mismatch is already a bigger problem than shortage and that there is a real opportunity for establishing a new, truly global labour market for STEM talents.

The current skill shortages related to STEM have been identified in the majority of the EU countries: 21 countries report difficulties for science and engineering professionals, 20 for ICT professionals and 14 for science and engineering associate professionals. The current shortages are reported mainly in technological fields such as mechanical engineering, electrical engineering, electronics engineering, civil engineering, and industrial and production engineering (Policies, 2015), (Commission, 2014). Manufacturing is the main sector where science and engineering professionals are sought after. In particular, the demand is for mechanical and electronics engineers mainly in the manufacture of computer, electronic and optical products, and furthermore in the electricity, gas, steam and air-conditioning sector.

The main reason for current STEM labour shortages is the insufficient number of graduates due to negative perceptions of STEM occupations and the lack of work experience and high-level expertise. Another issue identified is that despite the achieved STEM qualification the graduates are considered under skilled in terms of personal and behavioural competences. The missing "*soft*" skills include: team-working, communication, time management, organizational skills, as well as the more commercially-related skills including product development, customer service and business acumen. In general, the concerns about current and future skill shortages are widespread among EU employers. The shortages in Europe are not only due to insufficient supply of home-grown talent, but also related to difficulties in attracting talent from other parts of the world.

STEM unemployment

The unemployment rate among the STEM workers has been very low since the beginning of 2000 at the EU level. The STEM unemployment rate in 2013 was as low as 2% in EU 28, what is far below the total unemployment rate of 11%. In the countries most affected by the economic crisis - Greece, Portugal and Spain, the rates were above 4%, but otherwise the rates were consistently low across EU. In fact, the STEM unemployment is related just to workers that are moving or changing jobs (POLICIES, 2015).

Conclusion

For the design of the framework and the repository, these requirements will have to be taken into consideration. Some of the project partners are companies or related to *industry* and will be constantly reporting back on the needs and requirements. One industry partner will be monitoring the implementations in the framework and repository from this perspective.

4.5 CONCLUSIONS

In this section we have analysed ER4STEM stakeholders and requirements. For the design of the framework and the repository, all these requirements will have to be taken into consideration. Stakeholder requirements will be addressed with following action plan:

- The stakeholder group *teachers* will need to be involved in the design process of the framework and repository to ensure the impact and sustainability of the project outcome. Teacher panels and workshops (also in cooperation with Scientix) as well as feedback from teachers participating with their classes in ER4STEM workshops will ensure the continuous involvement of this stakeholder group.

- All project partners who will organize educational robotics workshops and conferences belong to the stakeholder group *educational robotics activities organizers* and will be constantly reporting back on the needs and requirements as well as monitoring the implementations in the framework and repository. Additionally, organizers outside the project will be involved by ER4STEM project partners during national networking events and encouraged to cooperate with the project.
- All project partners who will organize educational robotics workshops and conferences will also be taking a role in evaluating these and thus gather valuable experiences on the research side of their educational robotics activities. Some of the project partners are *educational researchers* and will be constantly reporting back on the needs and requirements as well as monitoring the implementations in the framework and repository.
- Some of the project partners are companies or related to *industry* and will be constantly reporting back on the needs and requirements. One industry partner will be monitoring the implementations in the framework and repository from this perspective.

The ER4STEM stakeholders are summarized in Figure 2.

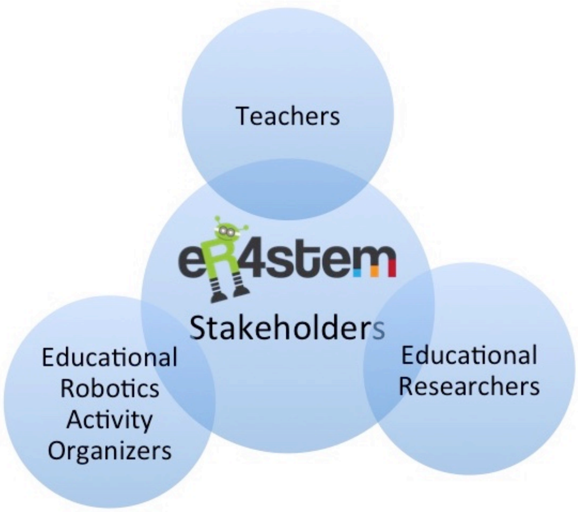

Figure 2: ER4STEM stakeholders overview

5 PARAMETERS AND CRITERIA TO IDENTIFY GOOD PRACTICES

The best practice research findings, elaborated in section 3, suggest that stakeholder requirements need to be studied closer, which we do in section 4 by identifying ER4STEM main stakeholders and their requirements. Another finding of the research is the need for recognized and accepted parameters and criteria to identify best practices in educational robotics. In order to achieve this, following bottom-up empirical process was followed:

- Our academic partner responsible for pedagogical activities and innovations has developed an activity plan customized for educational robotics; each partner has filled the activity plan with their latest or planned activities (examples in the Annex of this document) and has reported feedback on the process
- At the same time, researchers from the different teams have carried out an extensive best practice research and selected a set of good practices researching robotics conferences, competitions, seminars and workshops organized by the different institutions etc.; this was the first phase of the selection process, done in a semi-structured way, and is presented as an overview in section 3
- The second phase of the selection process has included analysis and reflection on phase one; specifically, the criteria have been shaped by an analysis of the content of five examples of good practices already selected and by an elaboration of the criteria that researchers had implicitly applied during the selection of the specific good practices
- Next, the items that - from the analytic and the reflective process – have been identified to be part of what could be considered best practice in the field of educational robotics have been synthesized in one structure: parameters and criteria to identify good practices (it is important to notice that the word “best” was replaced by “good”; the main reason for this is that the criteria have not been empirically validated and accepted by the community)

In the next sub-section, we will provide theoretical background for the activity plans. Then we introduce our structure of parameters to identify good practices and finally we present criteria to choose good practices among the identified.

5.1 ACTIVITY PLANS AS INSTRUMENTS TO PROMOTE INNOVATION AND SUPPORT THE PEDAGOGICAL DESIGN

The activity plan template is a construct that aims to support the pedagogical design of the project and promote the pedagogical innovation in the domain of Educational Robotics. It draws on previous research and theoretical experience of ETL-UoA (i.e. MC-squared project, Metafora Project, ESCALATE, ReMath) which has studied and researched following:

a) the characteristics of activity plans that integrate digital technologies to enhance the learning and teaching process
b) the teachers as designers of such activity plans (and how these plans relate to professional development)
c) the students not only as recipients but also as active agents that contribute to the re-shaping of activity plans

Specifically, the activity plan template first offers a structure to support the design aspect of the practitioners that organize workshops for educational robotics. This is related to the concept of Documentational Genesis (Pepin, Gueudet, & Trouche, 2013), which highlights that design is an integral part of the teaching profession and addresses activity plans in the following ways:

a) instruments supporting the teaching and learning process
b) evolving or live documents - in the sense that they are continuously renewed, changed and adapted - through which teachers express their beliefs, their knowledge and their practices
c) as tools that depict and facilitate teacher professional development

The other property of the activity plan is that it is an instrument for sharing, communicating, negotiating and expanding ideas within interdisciplinary environments. This property of activity plans is linked to the concept of boundary objects and boundary crossing (Kynigos & Kalogeria, 2012). The focus here is on the artefact (in our case activity plan) that mediates a co-design process by helping members of different disciplines to gain understanding of each other's perspectives and knowledge. Educational Robotics for ST(B)E(A)M is such an interdisciplinary environment which involves an understanding of related but different domains (i.e. Science, Technology, Business, Engineering, Arts, Mathematics) and involves players from industry, academia and organizers of educational activities.

By equipping professionals with a structured means (activity plan template) to describe and share their practices, we contribute to capturing in a unified way current European approaches to STEM education. On the other hand, the activity plan template also draws attention to issues important for promoting innovation in the domain of Educational Robotics and this way we expect that activity plans will contribute to enhancing and enriching current approaches.

5.2 PARAMETERS TO IDENTIFY GOOD PRACTICES

Following the previously described process, we suggest following structure to identify good practices for educational robotic activities:

Context: general information about the educational robotics activity environment where it will take place

- *Place*: gives information about the space where the educational robotic activity takes place, e.g. classroom, room, etc.
- *Participants' description*: such as age, culture, background, which gives understanding how to create the activity
- *Theoretical framework*: the pedagogical approach used in the educational activity; e.g. Do It Yourself (DIY), Do It With Others (DIWO), constructionism, etc.

Educational Activity: describes how the activity is going to be done

- *Connection with a curriculum*: gives information if the current activity is part of school's curriculum or not.

- *Motivation of the activity*: gives an understanding why the activity is going to be done.
- *Description of the activity*: gives information about the duration, tasks, orchestration, grouping, kind of interaction during the activity, and teacher's role.

Tools: diverse artefacts that are used in the educational robotic activity

- *Technology used*: describes all the artefacts used during the activity, such as robotics' platforms and software
- *Type of artefacts produced*: at the end of the educational activity
- *Why the specific technology was selected?* This question helps to reflect why the technology is used in the activity

Activity's Evaluation: process that should be done to assess if the activity has achieved the desire results

- *Students*: give feedback to the teacher to consider possible pitfalls that were not considered during the activity's preparation
- *Teacher*: reflect about the activity and spot possible ways of improvement

Sustainability: an important factor in educational robotic activities

- *Cost of the activity*: the costs to first produce and the costs to maintain the educational robotic activity for longer time periods
- *How is the activity financed?*
- *Is the activity maintained over long periods?*

Accessibility: focus on how the educational robotic activity is shared with others, which could be researchers or teachers among others.

- *Is the activity possible to replicate?*
- *How is the information shared?*

5.3 CRITERIA

Given the structure from section 5.2, here we present the process to select good practices in educational robotics:

First, we have to define which of the robotic workshops or seminars cover the basic prerequisites for an "educational robotic event" in order to be considered as a good practice:

- Topic is about Science-Technology-Business-Engineering-Art-Mathematics or something from another discipline but related to robotics
- To have constructionist elements (not just a presentation of tools or predefined guidelines)
- Innovative, related to student or citizen interests
- To include technology related to educational robotics

In case that the “educational robotic event” is assessed as relevant according to the aforementioned basic pre-requisites, then the process continues with the assessment of the parameters (defined in 5.2). Below are the good practice criteria for these parameters:

Context

- *Place*: it is considered as good practice for the event to be placed in a school or museum or science institutions or other educational scientific organizations
- *Participants' description*: it is considered as good practice if the event is aligned to the age of the participants, the number, the prior knowledge of the participants on the subject and others
- *Theoretical framework*: it is considered as good practice if the event is explicitly aligned to a theoretical framework for instance DIY (Do It Yourself), DIWO (Do It With Others), Constructionism, STEM education, Design

Educational Activity

- *Connection with a curriculum*: it is considered as good practice if the educational robotic event contributes to the enhancement of the curriculum for other disciplines
- *Motivation of the activity*: it is considered as good practice if the educational robotic event contributes to motivation of young people to learn STEM disciplines
- *Description of the activity*: it is considered as good practice if the educational robotic event contains information about the duration, tasks, orchestration, grouping, kinds of interaction during the activity (where is the emphasis concerning the action, the relationships, the roles in the group and the teacher's role)

Tools

- *Technology used*: it is considered as good practice if the educational robotic event is based on technology that follows the latest trends and is similar to what young people are using in their everyday life e.g. mobile and cloud solutions
- *Type of artefacts produced*: it is considered as good practice if the artefacts produced during the educational robotic event are interesting and engaging; participants are interested to use the artefacts and to apply them in different domains of their lives
- *Why the specific technology was selected?* It is considered as good practice if the educational robotic event's specific technology is well aligned with the educational objectives of the workshop and is presented in a way that is easily understandable by the specific target group in the workshops.

Activity's Evaluation

It is considered as good practice if during the educational robotic event it is known whether the workshop or the seminar has embedded the process of evaluation from the students' perspective with questionnaires, interviews etc. and from the teacher's perspective to indicate that they care to improve their work.

Sustainability

- *Cost of the activity*: The activity requires materials or tools that are reasonably priced compared to other related activities. An example of a relatively cost-effective technology with good cost-to-quality ratio is the LEGO technology and as for a relevantly low initial investment the Arduino technology.

- *How is the activity financed?* The educational robotics events have a sustainable model for financing in mid-term period, e.g. self-financing through fees, wide voluntary base, partnership with public organizations such as municipalities, schools or long term sponsorship partners.
- *Is the activity maintained over long periods?* The educational robotics events are performed sustainably for at least three subsequent periods in close cooperation with schools or other educational organizations.

Accessibility

The activity is open for participation for new classes or individuals, information such as lessons, materials and guidelines are shared and publically available in a structured way so that other educational institutions can replicate them.

5.4 CONCLUSIONS

In this section we have addressed the need of the educational robotics community to identify best or good practices among the vast landscape of activities taking place all over Europe and also worldwide. A new perspective is used to analytically deduct a set of parameters that will lead to the identification of good practices and their evaluation as such. This set of parameters has been selected after an analysis on the stakeholders that will have an impact in educational robotics activities, the best practice research, previous knowledge in activities pedagogical design and experience in the consortium of teaching, researching or conducting educational robotics activities.

The parameters and criteria to identify good practices are designed to feed into the activity plans (and not map directly into them) by providing interesting and new ideas for:

a) concepts, objectives, artefacts;
b) orchestration;
c) teaching interventions and learning process;
d) implementation process;
e) evaluation process

6 FIRST IDEAS ON THE ER4STEM FRAMEWORK

The best practice research, mapping activities with the activity plans customized for educational robotics, reporting feedback on the process, developing parameters and criteria and team reflections have led to first ideas on the ER4STEM framework. The project vision "*we will realize a creative and critical use of educational robotics to maintain children's curiosity in the world*" is built on strong goals, one of which is the development of an open and conceptual framework. The goal of the framework development rests on three main goals of the project:

- Provide multiple entry-points into educational robotics and creative STEM
- Empower children to solve real-world problems and address all young learners
- Provide a continuous STEM schedule

In Figure 3 the project vision and goals are summarized.

Figure 3: ER4STEM project vision and goals overview

In order to achieve the overall goals, the framework is informed from different perspectives, i.e. workshops and curricula, conferences, pedagogical activities and innovations, and educational technologies, and will undergo a rigorous evaluation. Figure 4 depicts the dependencies of the different perspectives (work packages in the project).

Each of these perspectives has own goals, first deducted from the vision and overall goals of the project and then aligned with the best practice and requirements process described in the first part of the deliverable. The ER4STEM framework follows two main objectives:

- Create processes, tools and artefacts that allow the use of robots in learning spaces
- Be the catalyst to improve young people's learning experience through the use of robotics in formal and informal spaces.

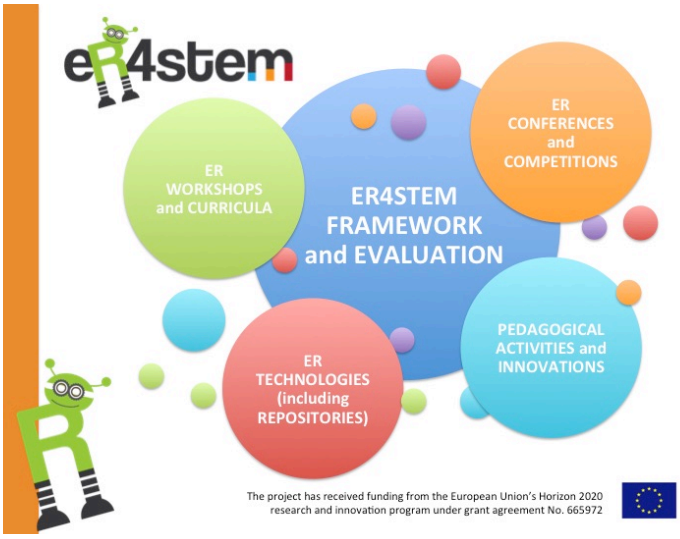

Figure 4: ER4STEM framework and dependencies

The framework is informed from different perspectives with their own objectives:

- Workshops and Curricula
  - Design a generic process for development of workshops and curricula that empower children
  - Organize workshops that provide multiple-entry points and facilitate a continuous STEM schedule
- Conferences
  - Young people show what they have been empowered to do at ECER conference
- Pedagogical activities and innovations
  - Develop tools to help become more explicit and elaborate about pedagogical design
- Educational technologies
  - Create and maintain a repository that addresses different stakeholders and is sustainable after the end of the project
  - Development and improvement of educational technologies (HedgeHog and Slurtles Prototypes)

The framework and the different perspectives undergo a rigorous evaluation that has following objective:

Evaluate the impact of the framework tools and activities on young people

For the creative process of developing first ideas on the framework based on the goals of "*creating processes, tools and artefacts that allow the use of robots in learning spaces*" and "*being the catalyst to improve young people's learning experience through the use of robotics in formal and informal spaces*" a wood workshop metaphor is used.

The wood workshop spaces and tools are not enough per se to produce good quality wood artefacts. Although the tools have been created to help the production of wood artefacts, if someone does not know how to use the tools and combine them in a correct way, the results are not going to be satisfactory. For example, an inexpert can have a chisel but cannot produce the same quality wood artefact as someone with experience can. As a consequence, the existence of tools and well-equipped spaces do not ensure artefacts of good quality. Therefore some people have to create techniques to use these tools in a creative way to have the desired output.

These techniques are created by master woodworkers who have specialized on the creation of better and new wood artefacts. This objective drives them to look for new tools and techniques that could improve the artefacts' quality and the creation of new wood artefacts, which is seen by others as wood project ideas. Some of these master woodworkers explain these techniques to people who are not interested in producing techniques or tools but rather are aspired to teach others without woodwork knowledge. The people who receive this knowledge could be seen as teachers.

Teachers take the responsibility to teach their wood knowledge to people who are eager to learn all wood techniques, the apprentices. The teacher can use different teaching approaches but one important factor in the apprentice's learning process is to work with real projects. One approach could be to let the apprentice at the beginning watch the teacher working. Later the teacher starts giving the apprentice simple tasks to teach and explain techniques and the use of specific tools. When the teacher sees that the apprentice has learned the necessary *skills* of one level, she introduces new techniques and tools that can or cannot be based on previous techniques. How the techniques are explained and the exact time to introduce new techniques is part of the *teaching process*.

Some teachers may not be interested in receiving apprentices but rather prefer teaching people who are only interested in creating wood artefacts without becoming woodworkers. Therefore, these teachers create events around specific projects that focus on the creation of wood artefacts. These events are spread over one or several months and they can vary depending on the wood artefact's difficulty level, which also determines who enrols in the event. During these events, teachers explain techniques and tools' uses through some teaching process. Due to time limitation and the heterogeneous previous knowledge level of the participants, the teaching process in these events can be different in respect to the one used with apprentices.

The principal components of this metaphor can be seen in the Figure 5.

When transferring the wood workshop metaphor to the ER4STEM framework, four different topics emerge: Framework stakeholders, tools, artefacts and processes. The first ideas on the framework are presented under these topics below:

Framework Stakeholders

The framework's design will address the three main stakeholders – teachers, researchers, and organizations offering educational robotics – to bring them tools and processes that are aligned to their needs by taking the requirements mentioned in section 4 into account. The framework will not provide all tools and processes, rather a basic set of tools and processes along with the structure where more can be created and added over time. Also, the framework needs to be presented to the different stakeholders in different shapes.

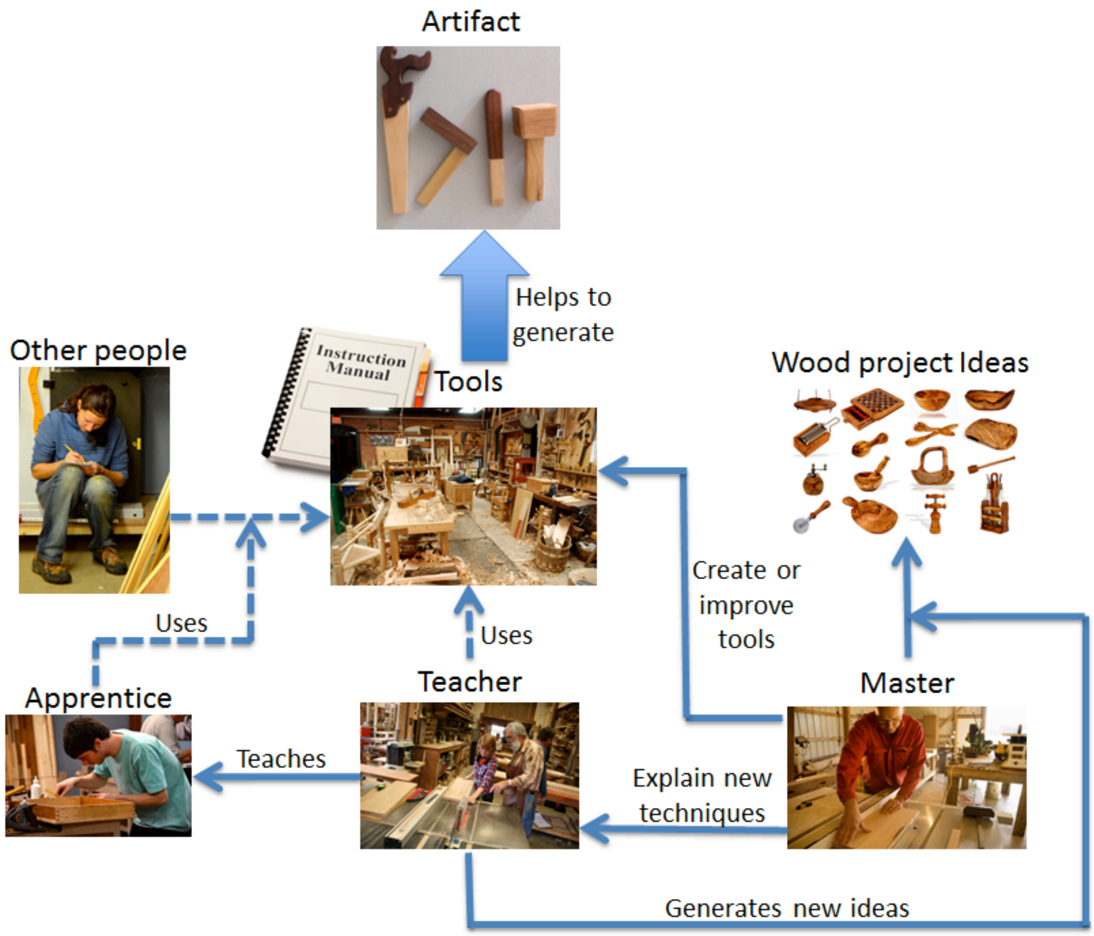

Figure 5 Wood workshop example used to explain frameworks' objectives

Framework Tools

Robotic platforms, educational kits, programming software, and non-tech materials such as handicraft materials are also considered as tools in the framework. The framework does not have any preference towards any kind of tool, because the real impact is in *how* these tools are used to produce the desired artefacts.

Framework Artefacts

From one perspective, framework artefacts are the final output of activities. In the metaphor, the artefacts are something tangible and easily evaluable. In educational robotics activities, the output can be something manual as building a real or virtual robot or it can be something completely different as long as the educational goals are achieved. This huge spectrum of possibilities generates a challenge in the framework conception, which is how to correctly map tools with artefacts to let people obtain the desired skills during the "construction" process. Consequently, from the other perspective, framework artefacts are the obtained skills (techniques to use the tools) and inspiration of the trainees to become scientists, experts, managers or entrepreneurs in STEM and related fields. This is also one outcome to be evaluated in the end.

Framework Processes

Given the selected stakeholders, different processes generated in the framework are needed. Organizers of educational robotics activities need a process to design pedagogically informed workshops or conferences or curricula. Teachers need a process to create educational robotic activities that fulfil their teaching subject needs. Researchers need a process to analyse and evaluate existing tools, techniques or processes as well as contribute new ones. All these processes should promote activities that are replicable by others, sustainable over time, comparable and consider participants' context.

ER4STEM Framework

Combining the ideas on all four topics mentioned before, three main components are considered as the framework's corner stones: skills, domain and context. Skills are envisioned as skill trees that are interconnected among them. For example, basic mathematics skills are needed to explain basic physics skills. The importance of these trees is that they allow a mapping between activities done and the exams that participants could have. The domains are mathematics, arts, engineering, business, technology or science. Trees and domains are related in a way that some skills are predominant in some domains, and selecting the correct combination will have better results. Finally, the context gives an understanding of participants' background, preferences, culture, and age. This gives additional input to address the activity in a way that could be encouraging for the participants.

Concluding the first ideas, the ER4STEM open and conceptual framework will be the catalyst to improve young people's learning experience through the use of robotics in formal and informal spaces. To achieve this, the framework will create processes, tools and artefacts that allow the use of robots in learning spaces by addressing the different needs of the three main stakeholders of the framework. The user-centred repository will reflect the framework and focus on mapping the processes needed by its stakeholders to achieve sustainability after the end of the project.

7 CONCLUSION / OUTLOOK

For this deliverable, first, current approaches and best practices in educational robotics workshops, curricula, conferences, competitions, pedagogical activities design, and educational technologies have been researched and gaps have been identified. The educational robotics community needs a common solution that addresses these gaps. The ER4STEM framework and repository can offer this solution by addressing the main stakeholders in educational robotics and providing them processes, tools and artefacts as well as a place to connect.

Thus, different stakeholders who are either affected by educational robotics or have an impact on educational robotics were identified and the main stakeholder requirements analysed by concluding that young people are impacted by the outcome of the project (and this impact will be evaluated), however, the main stakeholders of the framework and repository are teachers. This stakeholder group will need to be involved in the design process of the framework and repository to ensure the impact and sustainability of the project outcome. Two other main stakeholders for the framework and repository were also identified: educational robotics activities organizers and educational researchers. Both these stakeholders are represented in the consortium and will be constantly reporting back on the needs and requirements as well as monitoring the implementations in the framework and repository. Additionally, one industry partner will be monitoring the implementations in the framework and repository in order to give guidance on whether the project is going on good track towards addressing the issues related to the expected STEM skills shortages on labour market. This partner will try to match the accomplishments of ER4STEM with its own needs concerning the skills required from persons hired on junior positions and thus will monitor the efforts. The evaluation of the project will be complemented from this perspective.

Consequently, as a result of the best practice research gap of missing identification for best practices, parameters and criteria to identify and establish good practices for generating educational robotics activities that impact learning experiences and foster children's curiosity have been developed combining the rigorous research on existing approaches with the consortium partners' experience in educational robotics including first-hand knowledge about pedagogical methodologies and main stakeholders' requirements. Each partner in the consortium who organizes workshops has filled the activity plan to describe previous or recent workshop activities. Examples can be found in the Annex of the deliverable.

Finally, the first ideas on the ER4STEM open and conceptual framework have been presented. The ER4STEM open and conceptual framework will be the catalyst to improve young people's learning experience through the use of robotics in formal and informal spaces. To achieve this, the framework will create processes, tools and artefacts that allow the use of robots in learning spaces by addressing the different needs of the three main stakeholders of the framework. The user-centred repository will reflect the framework and focus on mapping the processes needed by its stakeholders to achieve sustainability after the end of the project.

8 GLOSSARY / ABBREVIATIONS

EC	European Commission
ER4STEM	Educational Robotics for STEM
REA	Research Executive Agency
STEM	Science, Technology, Engineering, and Mathematics
DIY	Do It Yourself

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10 ANNEX

TITLE: Practical Educational Robotics Workshop

Author:

ESI CEE Team: Ivaylo Gueorguiev with the support and direct contribution of Pavel Varbanova, Petar Sharkov, Prof. Galina Momcheva, Dr. George Sharkov, Prof. Maria Nisheva, Christina Todorova and Georgi Georgiev.

1. Description of the scenario

1.1. Domain

1.1.1. *Primary domain:* Robotic Product Development (Technology Design)

1.1.1.1. Science ()

1.1.1.2. Technology (x)

1.1.1.3. Business ()

1.1.1.4. Engineering ()

1.1.1.5. Arts ()

1.1.1.6. Mathematics ()

1.1.2. _Contextual (peripheral) domain:_ STBEAM

1.1.2.1. Science (5)

1.1.2.2. Technology (10)

1.1.2.3. Business (3)

1.1.2.4. Engineering (8)

1.1.2.5. Arts (2)

1.1.2.6. Mathematics (8)

1.2. Objectives

1.2.1. _Subject related:_ Learn the key robotics elements (technology); construct a robot (technology & engineering) , develop a visual program to control the robot and to execute tasks (technology and maths); develop the creative thinking skills needed to find different applications of robotics in other fields (science, arts & business)

1.2.2. _Technology use related:_ Arduino controllers; motor drivers; ultrasonic sensors; scratch or snap visual programing.

1.2.3. _Social and action related:_ teamwork skills in a groups of 3-4 students; creative thinking of the whole class; ideas generation by individuals and achieving consensus in a team and in a class; and presenting results by the teams.

1.2.4. _Argumentation and fostering of maker culture:_ formulate and express ideas; listening skills; decision-making within a team, etc

1.2.5.

1.3. Time

1.3.1. _Duration:_ 2-6 weeks

1.3.2. _Schedule:_ 2 or 3 workshops 4 hour each; 4 – 6 workshops 2 hours each.

1.4. Materials and Artifacts

1.4.1. _Digital artifact:_ students will work with Scratch or Snap; Arduino IDE; python s2a_fm and pymata program are used to connect the robot to a computer and to control it with visual interfaces. Optional hummingbird server could be used if Finch robot is used for the programming classes and Choreograph could be used to demonstrate the NAO humanoid robot

1.4.2. _Robotic artifact:_ custom set developed by ESI CEE: gearbox; chassis; chains and wheels; Arduino controller; motors driver; breadboard; jump wires; ultrasonic module; Bluetooth module or USB cable; batteries and batteries holders. NAO and Finch robots for demonstration are optional.

1.1.1. _Student's workbook and manual:_ Visual Guide how to construct the robot; tasks and illustrations

1.1.2. _Teacher's instruction book and manual:_ Manuals How to connect and program the robot

2. Space and Students Info

2.1. Students Info (Target Audience)

2.1.1. *Sex and Age:* boys & girls, 8-12 years

2.1.2. *Required Prior knowledge:* No prior knowledge required

2.1.3. Nationality and cultural background: Bulgarian, cultural background diverse, capital city and other cities

2.1.4. Social status and social environment: mainstream public schools and private schools

2.1.5. *Special needs and abilities:* no special needs and abilities are required

2.2. Space Info

2.2.1. Organizational and cultural context: Workshops in school, either in classroom or computer room during regular school time

2.2.2. Physical characteristics: indoors;

3. Social Orchestration

3.1. Population

3.1.1. Students: 20-40 students in a class

3.1.2. Tutors: 1 or 2 researchers + 1 or 2 assistants

3.2. Grouping

3.2.1. *Setting:* one table and one PC per team of 3-4 students

3.2.2. Grouping criteria: no specific criteria

3.3. Kinds of Interaction during the activity (emphasis)

3.3.1. *Actions*: learn the basics of robotics through demonstrations and games; construct an Arduino robot using visual instructions and guidance by the instructor, if needed; 2-hour creative workshop based on Tony Buzan's mind-mapping concept; programming and controlling Arduino robots or Finch robots through visual programming to complete simple tasks (task could be closely related to maths, algebra or geometry)

3.3.2. Relationships: collaborative

3.3.3. *Roles in the group:* the roles are not predefined as we encourage the students to shift their roles between team leader, programmer, robot developer, presenter

3.3.4. Support by the tutor(s): facilitator and consultant for robot construction; teacher and instructor for teaching of basics of robotics and creative thinking

4. Teaching and Learning Procedures

4.1. Teacher's role

4.1.1. *Teacher' function:* facilitator and consultant for robot construction; teacher and instructor for teaching the basics of robotics and creative thinking

4.2. Teaching methods

4.2.1. *Teacher's approaches:* constructionist with elements of instructionism,

4.3. Student activity processes

4.3.1. *Students' function:* learning; analysing, creating, discussing, observing

4.4. Student learning processes

4.4.1. *Designed Conflicts and misconceptions:* competing is the main goal

4.4.2. *Learning processes emphasised:* all students in the team work together and construct the robot. They are confident and know that building a simple robot is not difficult.

4.4.3. *Expected relevance of alternative knowledge (which):* alternative knowledge will be encouraged to be demonstrated during the creativity session in which the students will have to associate the robot with other domains.

5. Student productions

5.1 Artifacts - robots

5.1.1 *assignment:* defined engineering and programing tasks; open exercises and creative tasks

5.2.2 *interaction:* Visual through schemes, mind maps, drawings and pictures and verbal through instructions, presentations and discusisons.

5.2.3 *morphology:* Mostly anthropomorphic

5.2.4 *behavior:* Mostly friendly and cooperative

5.2.3 *parts:*

5.2 Programs - code

5.2.1 Structure of code-commands: visual programing following patterns that are typical for C and C++ programing

5.2.2 Elements (e.g. iteration, selection, variables): variables, constants, simple cycles and logical functions such as if, and, or.-

5.2.3 Conditionals (e.g. event handling): -using the ultrasonic sensor to detect and avoid obstacles or to direct the robot to objects.

5.3 Discussions – arguments (describe the activity emphasis on one or more of the following types of discussion)

Discussions and reflections were left to the teachers in the classroom

5.3.1 descriptive - explanatory: description of base robotics elements such as sensors, processors, drivers, actuators; description of the general tasks and purpose.

5.3.2 alternative: provision of alternatives if a dead end is reached;

5.3.3 critical - objection: critical thinking about problems and possible solutions;

5.3.4 contributory - extending: discussions about alternative design or additions to the construction; software and purpose .

6. Sequence and description of activities

Total duration of the activities will be in the range of 6-12 hours. The session in which the student will develop code and will animate the robots will be used as a buffer to compensate the time.

Orchestration: team of 3-4 students per table; enough free space in the center of the room for demonstrations; demo robots such as NAO; omnidirectional models or mobile telepresence robot + full set per a team.

Description:

Module 1 Introduction and pre-evaluation (1/2 hour)

The researchers introduce themselves as robot enthusiasts and explain that in this workshop they will play and work together with the student teams in order to build together a real robot. It is important to provide feedback and contribute to the that will be used to design even more interesting educational workshops. The rules and safety instructions are explained:

Rules

- Everybody listen to the others and respect their ideas
- No direct competition, lets cooperate and have fun
- Questions and strange ideas are highly encouraged
- The researchers are facilitators and friends – everybody can argue with them regarding the content but not regarding the discipline

Safety instructions:

- Do not put small parts in the mouth – can have serious injury
- Do not connect batteries before the instructors check the model for short circuits – the robot can cause fire.
- Be careful when using jump wires and pins – you can feel pain.

Kids fill out pre-workshop evaluation form.

Module 2 What is a robot (1/2 – 1 hour)

The researchers discuss with student the key elements of the robots such as processors, drivers actuators and sensors. The researcher is using the available demo robots to show the elements. Children guess different types of robots such as industrial robots; home robots; humanoids; drones; toys and others.

Module 3 Construction (1-2 hours)

Students build a robot using visual guides on printed cards or slideshow on computers. The instructor do not directly contribute during the building but help them to discover the right approach.

Module 4 Robot's touch (1-2hours)

Ones the models are built the researchers demonstrate in action different type of robots such as Nao, vGo, omnidirectional robots or other and facilitate Q&A session. During that time technical assistant or another researcher verifies the models to be sure that they are operational and no significant mistakes e.g. short circuits are present.

Student play with their models using predefined control program and PC keyboards. They pass through different obstacles and experiment with the physical characteristics of the models.

Module 5 Let's imagine… (2 hours)

Researchers facilitate creativity session trough brain storming and mind mapping on how the robots can support people in their life and what is the importance of robot for our civilization.

Module 6 Programming (2-3 hours)

Students learn how to control the robots with Scratch or Snap and they try to fulfil missions that were included in the brain storming by developing simplified code. The students are using proportions, arithmetic operations, geometry and other math domains in order to achieve their missions. The students could use paper, glue and other materials to decorate the robots

Module 7 Evaluation (1 hour)

Evaluation session is held for students to present their achievements and evaluate their experience.

Group and/or individual interviews are conducted and students fill out post-workshops questionnaires.

TITLE: ECER-Botball-Preparation-Workshop

Author: Lisa Vittori

1. Description of the scenario

1. **Domain**

1. *Primary domain:* Software engineering
    1. Science
    2. Technology
    3. Business
    4. Engineering (X)
    5. Arts
    6. Mathematics
2. *Contextual (peripheral) domain: e.g.* Robotics
    1. Science (7)
    2. Technology (10)
    3. Business (4)
    4. Engineering (10)
    5. Arts (0)
    6. Mathematics (2)

2. **Objectives**

1. *Subject related:* Identify and study key elements of a robot as well as the essential programming concepts to build and program a robot, which is capable of competing in the ECER tournament
2. *Technology use related:* Programming of the botball controller in C
3. *Social and action related:* working in a team, assuming different roles, overcoming of difficulties

4. *Argumentation and fostering of maker culture:* Expression of ideas, exchange of solutions to mutual problems, ...

3. **Time**

    1. *Duration:* 16 h
    2. *Schedule:* 2 consecutive days with 8 hours each

4. **Materials and Artifacts**

    1. *Digital artifact:* programming language C
    2. *Robotic artifact:* Botball robotic kit, the form must be developed by the students, usually it is a kind of vehicle
    3. *Student's workbook and manual:* manual for the controller, the sensors and the motors, step-by-step instructions for building a first drivable robot as a basis for the workshop, workshop slides
    4. *Teacher's instruction book and manual:* workshop slides

2. Space and Students Info

1. **Students Info (Target Audience)**
    1. *Sex and Age:* boy & girls, 15 - 18 years old
    2. *Required Prior knowledge:* no prior knowledge required
    3. *Nationality and cultural background:* mainly Austrian students with some participants from other countries which don't do a separate Botball workshop (e.g. Poland, Belgium, Egypt, …)
    4. *Social status and social environment:* mixed environment, a large part from public technical high schools
    5. *Special needs and abilities:* -
2. **Space Info**
    1. *Organizational and cultural context:* A large room for the workshop event, which is a special event occupying school and free time, participation is voluntary
    2. *Physical characteristics:* indoors with table-space for placing laptops and building the first robot and space for letting the robot move a bit

3. Social Orchestration

1. **Population**
    1. *Students:* up to 100
    2. *Tutors:* 1 lecturer, 3 assistant tutors
2. **Grouping**

    1. *Setting:* students around tables, looking at the projection screen, in small groups
    2. *Grouping criteria:* self chosen
3. **Kinds of Interaction during the activity (emphasis)**
    1. *Actions:* building together a robot, exchange ideas, dialogue, negotiation, debate, ..
    2. *Relationships:* collaborative
    3. *Roles in the group:* emergent roles
    4. *Support by the tutor(s):* support, intervene, self-regulatory

4. Teaching and Learning Procedures

1. **Teacher's role**
    1. *Teacher' function:* lecturer, trouble shooter
2. **Teaching methods**
    1. *Teacher's approaches:* constructionism combined with instruction-element
3. **Student activity processes**
    1. *Students' function:* observing, creating, discussing, ..
4. **Student learning processes**
    1. *Designed Conflicts and misconceptions:* -
    2. *learning processes emphasised:* emphasis on empowering students to control their robot as a result of the program the students gave
    3. *Expected relevance of alternative knowledge (which):*

5. Student productions

1. **Artifacts - robots**
    1. *assignment:* defined engineering and programming tasks
    2. *interaction:* (How to communicate with the robot?) speech, gesture, mind control, app,...
    3. *morphology:* vehicle like
    4. *behavior:* friendly, butler
    5. *parts:* parts of the Botball robotic set
2. **Programs - code**
    1. *Structure of code-commands*: function calls
    2. *Elements* (e.g. iteration, selection, variables): iteration, selection, variables, function definition

   3. *Conditionals* (e.g. event handling): waiting for sensor-events

3. **Discussions – arguments (describe the activity emphasis on one or more of the following types of discussion)**

Discussions and reflections were left to the teachers in the classroom

   1. *descriptive - explanatory*: description of a situation, a construct or an idea for others to understand and /or to implement
   2. *alternative:* provision of solutions to problems, provision of alternatives if a dead end is reached
   3. *critical - objection*: revision of other's constructs and ideas, identification of problems, challenge of ideas
   4. *contributory - extending*: sharing of resources, provision of ideas towards improving an existing construct or initial idea

6. Sequence and description of activities

Workshop Day 1

Pre-Phase : Introduction

Duration: 30 min

Orchestration: assembly discussion

Description: The tutors and lecturers introduce themselves as robot experts and explain that in this workshop, the children will learn how to design and program a robot from their robotic set, that is capable of competing in the tournament. The tournament basic set up is explained.

Phase 1: First Prototype

Duration: 90 min

Orchestration: group work

Description: All groups are encouraged to build a first robot, which can drive using two motors and carry the controller. Students who use the set for the first time are encouraged to build their robot according to a step-by-step guide to make them familiar with the basic parts for this simple robot like motors, wheels and the basic metal parts

Phase 2: Programming principles - simple movements

Duration: 120 minutes

Orchestration: group work with short lecture parts

Description: The students are briefly introduced to basic programming principles, like structure of a program, statements. Afterwards basic movement functions are discussed by means of simple tasks, like driving a specific path or pattern.

Phase 3: Complex programming structures - using sensors

Duration: 220 minutes

Orchestration: group work with short lecture parts

Description: The students experience the usage of sensors, loops, selections through small examples and simple tasks.

Phase 4: Discussion and Outlook for the next day

Duration: 30 min

Orchestration: assembly discussion

Description: The tutors discuss the main parts of the workshop day and present an outlook for the next day

Workshop Day 2

Phase 5: Competition setup discussion and short planning phase

Duration: 90 min

Orchestration: assembly discussion

Description: The tutors and lecturers explain the competition task for the actual year and discuss points which are unclear for the students. The students are encouraged to think about a strategy for the game and needed parts

Phase 6: Gather experience with different robotic parts

Duration: 360 min

Orchestration: group work with short lecture parts

Description: The students experience the usage of different parts of the Botball robotic set and their possible relevance for the competition through small examples and simple tasks.

Phase 7: Workshop evaluation

Duration: 30 min

Orchestration: individual work

Description: The students have the possibility to express their feedback for the workshop through questionnaires and personal discussion

7. Assessment Procedures (for teacher reflection or student feedback)

1. **Formative assessment**
    1. *Pupil voice activities (Interviews with students, Questionnaire)*
    2. *Observation notes*
    3. *Peer assessment*
2. **Summative assessment**
    1. *Essays*
    2. *Tests*
    3. *Student productions (code-robots-textual discussions)*
    4. *Mark sheet*

TITLE: A ROBOTIC INSECT (ZOOMORPHIC)

Author: UoA

1. Description of the scenario

1.1. Content

1.1.1. *Primary domain:* e.g. Electrical engineering

1.1.1.1. Science

1.1.1.2. Technology ×

1.1.1.3. Business

1.1.1.4. Engineering ×

1.1.1.5. Arts

1.1.1.6. Mathematics ×

1.1.2. *Contextual (peripheral) domain: e.g.* Art, Biology & Mathematics

1.1.2.1. Science (0)

1.1.2.2. Technology (4)

1.1.2.3. Business (0)

1.1.2.4. Engineering (10)

1.1.2.5. Arts (0)

1.1.2.6. Mathematics (10)

1.2. Objectives

1.2.1. *Subject related:* Study the angle and position of all materials (servo motors, circuits, sensors), as well as the construction of the legs in order for the insect to be autonomous and move correctly.

1.2.2. *Technology use related:* Programming of Arduino

1.2.3. Social and action related: Improve collaborative skills, take roles within groups

1.2.4. Argumentation and fostering of maker culture: practice making conjectures about how the robot will react to external stimuli based on the program given

1.3. Time

1.3.1. Duration: 2 weeks

1.3.2. Schedule: 6 hours per week

1.4. Materials and Artifacts

1.4.1. Digital artifact: programming language

1.4.2. Robotic artifact: an insect

1.4.3. *Student's workbook and manual:* use a manual with step-by-step instructions for the construction, electronic and programming parts

1.4.4. *Teacher's instruction book and manual:* three incisive stages and five steps for the first two stages using workshop's slides.

2. Space and Students Info

2.1. Students Info (Target Audience)

2.1.1. *Sex and Age:* boys & girls, 15-17 years old

2.1.2. *Prior knowledge:* little if any knowledge of Arduino but 10 pupils out of 20 are experts on the electronic part of it.

2.1.3. Nationality and cultural background: 5 pupils are from Albania, 2 from Bulgaria, 1 from Poland and 12 from Greece.

2.1.4. Social status and social environment: underpriviledged area

2.1.5. *Special needs and abilities:* 2 pupils suffer from ADD (Attention Deficit Disorder)

2.2. Space Info

2.2.1. *Organizational and cultural context:* in school at the technology laboratory

2.2.2. *Physical characteristics:* indoors

3. Social Orchestration

3.1. Population

3.1.1. *Students:* 20 (2 groups)

3.1.2. *Tutors:* 2 (1 tutor for each group)

3.2. Grouping

3.2.1. *Setting:* students in a normal classroom, around light mobile tables, looking at the blackboard, in small groups of 3

3.2.2. *Grouping criteria:* mixed ability, mixed gender

3.3. Kinds of Interaction during the activity (emphasis)

3.3.1. *Actions:* exchange ideas, dialogue, negotiation, debate

3.3.2. *Relationships:* collaborative, competitive

3.3.3. *Roles in the group:* emergent roles

3.3.4. *Support by the tutor(s):* support, intervene

4. Teaching and Learning Procedures

4.1. Teacher's role

4.1.1. *Teacher' function:* (what is the teacher doing?) mentor, researcher, lecturer

4.2. Teaching methods

4.2.1. *Teacher's approaches:* demonstrate

4.3. Student activity processes

4.3.1. *Students' function:* action, writing, observing, creating

4.4. Student learning processes

4.4.1. *Designed Conflicts and misconceptions:* that biology is irrelevant to mathematics

4.4.2. *learning processes emphasised:* emphasis on studying robot behaviour as a result of the usage of sensors and the program the students gave (i.e. use behaviour as feedback on programming).

4.4.3. *Expected relevance of alternative knowledge (which):* Emphasis on mathematical thinking (i.e. the construction of the insect's legs depends on a specific geometry pattern in order for the zoomorphic robot to move).

5. Student productions

5.1 Artefacts - robots

5.1.1 *assignment:* entertain, company

5.2.2 *interaction:* gesture

5.2.3 *morphology:* zoomorphic

5.2.4 *behavior:* pet

5.2.3 *parts:* electronics, software, mechanics, materials like wood and paper clips

5.2 Programs - code

5.2.1 Structure of code-commands: It was divided in a number of different procedures, Sub-procedures were used, it was all one main procedure, it was plain text etc.

5.2.2 Elements (e.g. iteration, selection, variables): Iteration: for loop, while loop etc., selection: if, ifelse, if not etc., arithmetic variables, recursion etc.

5.2.3 Conditionals (e.g. event handling): Event handling of the sensors, of the programming environment etc.

5.3 Discussions – arguments (describe the activity emphasis on one or more of the following types of discussion)

5.3.1 descriptive - explanatory: description of a situation, a construct or an idea for others to understand and /or to implement

5.3.2 alternative: provision of solutions to problems, provision of alternatives if a dead end is reached

5.3.3 critical - objection: N/A

5.3.4 contributory - extending: sharing of resources, provision of ideas towards improving an existing construct or initial idea

6. Sequence and description of activities

Pre-Phase : introduction

Duration: 20 min

Orchestration: assembly discussion

Description: The teachers explain that will happen in this workshop and the children will learn how to design robots. We expect that children broaden their view of technology as "*something that we build to make our lives easier-happier*" and as *"true robots act autonomously"*. From then on, children start thinking critically about it.

Phase 1: Group formulation – "What is going to occur concerning the construction?"

Duration: 3 hours

Orchestration: group work

Description: Children are introduced to the idea that "*Real robots are highly complex and designed by a team of experts from different disciplines (designers, human-robot-interaction experts, programmers, engineers, etc.)".*

The children are guided step by step through five important topics, eventually they design a specific robot a zoomorphic insect.

Step 1 – Robot Task ("assignment").
The children are asked to imagine a robot for themselves that does anything they want. Every idea is valuable in this phase and not discarded as useless or undoable.

Step 2 – Robot Interaction.
Known and not yet invented applications are both encouraged equally. Children learn that some of their ideas need scientists who invent new things that are then built into the robots by engineers. *How would you tell your robot what to do? Would you talk to it in a secret language or with signs? Would the robot understand your thoughts? Or would you use an app to control it?*

Step 3 – Robot Morphology ("looks and materials").
We divide the third step, robot morphology, into "looks" and "materials". First, we introduce the robot morphology "*Robots have to look like animal (zoomorphic)".* Second, we talk about different materials robots can be made of, and describe some properties: *They can feel smooth, hard, furry, etc. How would your robot feel like?*

Step 4 – Robot Behavior.
In the fourth step, the abstract concept of autonomous behavior needs to be explained in a manner that children understand. We use two paths: In order to make the abstract word "behavior" more concrete, we describe roles (or personas) with which children identify. *Would you like your robot to be rather like a protector, a pet or a friend?* We also explain that robots have rules to obey.

Step 5 – Robot Parts.
This last step brings the previous steps together. The teachers-researchers show pictures of mechanic and electronic parts: some are used in every robot; others depend on what the robot does, how it looks like or how it should behave. In the beginning of the design process, the focus is on the holistic view of a product developer who needs to know what parts are needed but is not concerned with the details.

Phase 2: "What is going to occur concerning the programming?"

Duration: 2 hours

Orchestration: group work

Description: The groups of children will deal with the programming part of the robot.

Phase 3: Evaluation

Duration: 40 minutes

Orchestration: group work

Description: We collect all the data (questionnaires, interviews, etc)

7. Assessment Procedures (for teacher reflection or student feedback)

7.1. Formative assessment

7.1.1. *Pupil voice activities (Interviews with students, Questionnaire)*

7.1.2. *Observation notes*

7.1.3. *Peer assessment*

7.2. Summative assessment

7.2.1. *Essays*

7.2.2. *Tests*

7.2.3. *Student productions (code-robots-textual discussions)*

7.2.4. *Mark sheet*

TITLE: Crazy robots – Robotic Product Development

Author: Lara Lammer

1. Description of the scenario

1.1. Domain

1.1.1. *Primary domain:* Robotic Product Development (Technology Design)

1.1.1.1. Science ()

1.1.1.2. Technology (x)

1.1.1.3. Business ()

1.1.1.4. Engineering ()

1.1.1.5. Arts ()

1.1.1.6. Mathematics ()

1.1.2. *Contextual (peripheral) domain:* STBEAM

1.1.2.1. Science (8)

1.1.2.2. Technology (10)

1.1.2.3. Business (8)

1.1.2.4. Engineering (8)

1.1.2.5. Arts (8)

1.1.2.6. Mathematics (1)

1.2. Objectives

1.2.1. *Subject related:* Design a robotic product from scratch (technology design); design, execute and present a user study (science); develop a marketing and sales strategy (business); basic understanding of circuits and sensors (engineering); design the robot's morphology and interaction (art, science); basic mathematics during testing (s=v*t or Pythagoras)

1.2.2. *Technology use related:* Mattie robot, programming of Arduino (also possible)

1.2.3. Social and action related: Whole class decides on one robot concept, sales and marketing group often takes the role of coordinator, children learn about different areas in robotics (e.g. also psychology), different personality types (introvert, feeling type, …), in real-life you may team members that you don't like and still they can contribute valuable ideas and work to the team.

1.2.4. Argumentation and fostering of maker culture: Testing of the prototype from two perspectives: engineering and user perspective

1.3. Time

1.3.1. Duration: one semester

1.3.2. Schedule: 3 workshops each two school hours, +1/2 hour visit of lab and Romeo robot demo after second workshop

1.4. Materials and Artifacts

1.4.1. Digital artifact: robot sound files

1.4.2. Robotic artifact: Mattie robot in very different shapes, e.g. bee, fish, trash bin, toilet, Wall-E, …

1.4.3. *Student's workbook and manual:* 5-step plan for the design process, different instructions and circuit plans

1.4.4. *Teacher's instruction book and manual:* -

2. Space and Students Info

2.1. Students Info (Target Audience)

2.1.1. *Sex and Age:* boys & girls, 10-14 years (mainly 10-12)

2.1.2. *Required Prior knowledge:* No prior knowledge required

2.1.3. Nationality and cultural background: Mostly Austrian, cultural background diverse, capital city and surrounding

2.1.4. Social status and social environment: mainstream public school

2.1.5. *Special needs and abilities:* -

2.2. Space Info

2.2.1. Organizational and cultural context: Two workshops in school, either in classroom or handicraft room, and one workshop at the university. During regular school time

2.2.2. Physical characteristics: indoors

3. Social Orchestration

3.1. Population

3.1.1. *Students:* 10-27 (big groups require more tutors, are more chaotic and demanding, but it works)

3.1.2. *Tutors:* 2 (+teacher and more tutors when necessary)

3.2. Grouping

3.2.1. *Setting:* Can be adapted to different indoor settings. Students need to watch beamer presentation but also work in groups afterwards

3.2.2. *Grouping criteria:* preference of subject (engineering, science, human-robot interaction, design or sales&marketing)

3.3. Kinds of Interaction during the activity (emphasis)

3.3.1. *Actions*: result-oriented, solution-oriented

3.3.2. *Relationships:* collaborative

3.3.3. *Roles in the group:* emergent roles

3.3.4. *Support by the tutor(s):* support where needed, the students solve the problem and present it as theirs

4. Teaching and Learning Procedures

4.1. Teacher's role

4.1.1. *Teacher' function:* frontal presentation with discussion, during group work mentoring or watching

4.2. Teaching methods

4.2.1. *Teacher's approaches:* partly instructionist, mostly constructionist

4.3. Student activity processes

4.3.1. *Students' function:* action, writing, observing, creating, presenting

4.4. Student learning processes

4.4.1. *Designed Conflicts and misconceptions:* all five different teams work on the same robot. If they do not communicate, the things they do will not come together, they need to communicate and align through the whole process, but the activity is designed that they learn this by experience

4.4.2. *learning processes emphasised:* holistic concept to show students that different talents and interests can all work in robotics

4.4.3. *Expected relevance of alternative knowledge (which):* Depending on what robot they design, e.g. one group did a robot for children with down-syndrome and one student from the class (with a sibling having down-syndrome) was their expert and they learned about this

5. Student productions

5.1 Artifacts - robots

5.1.1 *assignment:* Mostly needs from the students and their families, like cooking and serving food, helping with homework, protecting, being a friend, entertaining, transporting from A to B, etc.

5.2.2 *interaction:* Mostly via speech

5.2.3 *morphology:* Mostly anthropomorphic, then zoomorphic or cartoon-like

5.2.4 *behavior:* Mostly friendly; either butler or friend or both

5.2.3 *parts:* This is the most difficult part where kids perform better if the five steps are iterated: “do you think the robot can help you cooking, when it does not have an arm?”

5.2 Programs - code

5.2.1 Structure of code-commands: -

5.2.2 Elements (e.g. iteration, selection, variables): -

5.2.3 Conditionals (e.g. event handling): -

5.3 Discussions – arguments (describe the activity emphasis on one or more of the following types of discussion)

Discussions and reflections were left to the teachers in the classroom

5.3.1 descriptive - explanatory: description of a situation, a construct or an idea for others to understand and /or to implement

5.3.2 alternative: provision of solutions to problems, provision of alternatives if a dead end is reached

5.3.3 critical - objection: revision of other’s constructs and ideas, identification of problems, challenge of ideas

5.3.4 contributory - extending: sharing of resources, provision of ideas towards improving an existing construct or initial idea

6. Sequence and description of activities

Workshop 1: Ideation

Duration: 100 min (= two school hours)

Orchestration: presentation, assembly discussion, each student works on clay model

Description: The researchers introduce themselves as robot experts and explain that in this workshop, the children will learn how to design robots while the researchers will learn from their ideas how to build better robots in the future. We expect that children broaden their view of technology as “*something that we build to make our lives easier*” and as *“true robots act autonomously”.* From then on, children start thinking critically about it. Children are also introduced to the idea that “*Real robots are highly complex and designed by a team of experts from different disciplines (designers, human-robot-interaction experts, programmers, engineers, etc.)”.* They are also encouraged to think as product designers during “ideation” phase and offered a simple structure to conceptualize a robot from scratch, using materials like clay, stones, feathers, plush wire, etc. Furthermore, children are not constrained by the limits of technology: there are no limits for their robots’ capabilities when they start brainstorming. The teacher on the other hand, records students ideas in a power point or in the blog of the class or in a template.

When all the aforementioned are actualized and children are guided step by step through five important topics, eventually they design a robot like a product designer.

Step 1 – Robot Task (“assignment”).
The children are asked to imagine a robot for themselves that does anything they want. Every idea is valuable in this phase and not discarded as useless or undoable. Children are rather encouraged to think about a helper and adapt their ideas to this concept.

Step 2 – Robot Interaction.
Known and not yet invented applications are both encouraged equally. Children learn that some of their ideas need scientists who invent new things that are then built into the robots by engineers. *How would you tell your robot what to do? Would you talk to it in a secret language or with signs? Would the robot understand your thoughts? Or would you use an app to control it?*

Step 3 – Robot Morphology ("looks and materials").
We divide the third step, robot morphology, into "looks" and "materials". First, we introduce four different categories of robot morphology "*Robots can look like machines, like cartoon characters, like animals (zoomorphic) or similar to humans with a head and body (anthropomorphic)"*. Second, we talk about different materials robots can be made of, and describe some properties: *They can feel smooth, hard, furry, etc. How would your robot feel like?*

Step 4 – Robot Behavior.
In the fourth step, the abstract concept of autonomous behavior needs to be explained in a manner that children understand. We use two paths: In order to make the abstract word "behavior" more concrete, we describe roles (or personas) with which children identify. *Would you like your robot to be rather like a butler, a teacher, a protector, a pet or a friend?* We also explain that robots have rules to obey and introduce the Three Laws of Robotics.

Step 5 – Robot Parts.
This last step brings the previous steps together. The researchers show pictures of mechanic and electronic parts: some are used in every robot; others depend on what the robot does, how it looks like or how it should behave. In the beginning of the design process (ideation), the focus is on the holistic view of a product developer who needs to know what parts are needed but is not concerned with the details.
After this introduction children immediately start building a prototype with modeling clay that they can take home to show family and peers. In an expanded 5-step plan concept with follow-up workshops that move from ideation to prototyping, Step 5 is a starting point to go into more detail by using simple technology (e.g. maker electronics) to work out technically feasible solutions.

Workshop 2: Prototyping

Duration: 100 minutes + approx. 30 min lab visit

Orchestration: presentation, assembly discussion, group work

Description: Before we start the second workshop, the class visits the Vision for Robotics Lab at the Vienna University of Technology and are shown a demonstration of the Romeo robot from the company Aldebaran (http://projetromeo.com/) where we introduce them to the robot's different capabilities and sensors including 3D cameras and computer vision. In the workshop after the demonstration, we start the theory session by repeating definitions from the first workshop: what is technology; what is a robot; how do robot experts translate their ideas into a product (i.e. the three incisive stages "ideation", "prototyping", and evaluation). We also repeat the five steps and underlin our next focus on prototyping and getting deeper into different robot parts.

It is also an important topic of this workshop to introduce children to robot experts: "What kind of people are they? What do they know?" We explain children important areas in robotics such as mechatronics and coding but also sociology, psychology, design, or ethics. We tell them about three different personality traits to consider when collaborating: thinking and feeling types, generalist and specialist thinkers, and extrovert and introvert types. We also introduce them to multiple intelligences (Howard Gardner) underlining that each of them is unique with their interests and talents, and can contribute different aspects to a team. We also talk about what robotics experts all have in common: curiosity, creativity, persistence and the ability to collaborate.

Finally, the "CEO of Crazy Robots Company" (one researcher) charges the "Mattie robot project manager" (the other researcher) with the project assignment to build a robot for children with a budget of 300 Euros. The project manager explains the concept of the Mattie robot, and then divides the students in groups. Each group has different tasks that are described in the following:

Sales & Marketing: In this task, students define a target customer group (e.g., children at a specific age or with special needs as users and their parents, grandparents or other relatives as buyers) and the tasks of the robot along with its design and behavior. They have to coordinate their ideas with all other groups. They discuss with the design group which materials are available, with the engineering and research groups the capabilities of the existing technology and with the human-robot interaction groups the best way of interaction with the target group. They learn about the 4 Ps of marketing (product, price, place, promotion) and think of a strategy for their product.

Engineering: This is a typical task for children interested in STEM and robotics. The students connect the electronic parts using jumper wires, a breadboard and step-by-step instructions. They need to figure out how the motors need to turn for the robot to drive straight or turn left or right. We programmed the microcontroller beforehand because of time constraints; in an expanded workshop, students can also code. This is a classic technical assignment with a predetermined goal that has to be achieved.

Human-Robot Interaction (HRI): The children in this group need to define the types of sound files the robot will play and design an interface for the interaction. They need to coordinate with the sales & marketing and design groups so that their sound files and buttons match the overall concept and design of the robot. When all agree, this group records the sound files and assists the design team that creates the buttons.

Research & Development: This group is like the research & development department of a company or researchers at a research institution who develop new sensors. For this task we let students get acquainted with real sensors and teach them what to do with sensor readings – a number which represents a voltage. In a wooden box six sensors are connected to a display that shows the current sensor readings. First, students have to identify the different sensors by stressing them. Then, they help the engineering team choose the right sensors for the Mattie robot to follow light. They discuss how to use the other sensors on the robot and what additional sensors can be developed. For groups who finish quickly there is an optional task: the students connect a tilt sensor with an LED and test it as a possible anti-theft solution.

Design: The task of this group is the design of the robot, especially the body or hull – the transparent bucket, cut on top and bottom – with decoration materials. Before the group can start crafting, they need to decide with the other groups what the robot is for and for whom. The design needs to fit the robot concept and the customer (user) group. The designers also help the HRI group to finalize their buttons on the robot with conductive paint or tin foil.

Phase 3: Evaluation

Duration: 100 minutes (in some cases + 50 minutes when teacher could organize next class hour)

Orchestration: group work

Description: In the third workshop, groups can complete tasks from the second workshop, especially the design team needs the time for e.g. finishing buttons or other parts of the robot. The theory part is kept very short, again repeating definitions and shortly explaining what evaluation is. Then, some students are given the unfinished tasks from the second workshop. The rest of the class is divided into two teams: technical evaluation and product (or user) evaluation.

The technical group evaluates the chassis, e.g. average speed of robot, maximum distance of infrared receiver, reliability of the ultrasound sensor for detecting objects, or average deviation on a straight line. The user group is again divided into user study experts and marketing experts. While the user study experts design the study and prepare questionnaires and interview guidelines, the marketing experts design a product poster. When design and buttons are finished, the whole robot is put together and the user study is conducted either with classmates or students recruited from other classes. Then, the presentations follow: Product presentation, robot demonstration and presentation of evaluation results.

7. Assessment Procedures (for teacher reflection or student feedback)

7.1. Formative assessment

7.1.1. *Pupil voice activities (Interviews with students, Questionnaire):* Questionnaire after second workshop and feedback round after third workshop

7.1.2. *Observation notes*

7.1.3. *Peer assessment*

7.2. Summative assessment

7.2.1. *Essays*

7.2.2. *Tests*

7.2.3. *Student productions (code-robots-textual discussions)* 5 step plan template filled, in one version of the concept a storyboard “one day with my robot”, robot clay model, Mattie robot concept, exterior design and human-robot interaction buttons and sound files

7.2.4. *Mark sheet*

TITLE: Introducing programming structures using LEGO NXT

Author: UoA

1. Description of the scenario

1.1. Content

1.1.1. *Primary domain:* Computer Programming

1.1.1.1. Science

1.1.1.2. Technology ×

1.1.1.3. Business

1.1.1.4. Engineering

1.1.1.5. Arts

1.1.1.6. Mathematics

1.1.2. *Contextual (peripheral) domain: e.g.* Art, Biology & Mathematics

1.1.2.1. Science (0)

1.1.2.2. Technology (0)

1.1.2.3. Business (0)

1.1.2.4. Engineering (10)

1.1.2.5. Arts (0)

1.1.2.6. Mathematics (10)

1.2. Objectives

1.2.1. *Subject related:* Introducing basic programming structures and use them to give a vehicle autonomous behavior.

1.2.2. *Technology use related:* Programming in LEGO NXT programming environment

1.2.3. Social and action related: Taking and exchanging roles in a group. Communicate with other groups to find solutions

1.2.4. Argumentation and fostering of maker culture: indentifying an authentic problem, make assumptions, test possible solutions, choose the best solution, communicate with other "makers"

1.3. Time

1.3.1. Duration: 4 weeks

1.3.2. Schedule: 2 hours per week

1.4. Materials and Artifacts

1.4.1. Digital artifact: Lego Nxt programming environment

1.4.2. Robotic artifact: a simple vehicle

1.4.3. *Student's workbook and manual:* activity sheets, Lego electronic manual, evaluation sheet

1.4.4. *Teacher's instruction book and manual:* teacher's note on each of 4 stages totally

2. Space and Students Info

2.1. Students Info (Target Audience)

2.1.1. *Sex and Age:* boys & girls, 12-15 years old

2.1.2. *Prior knowledge:* No knowledge of Lego technology. No or little knowledge of programming concepts

2.1.3. Nationality and cultural background: 9 pupils from Greece.

2.1.4. Social status and social environment:

2.1.5. *Special needs and abilities:* Lego programming environment is in English. English is not native language for participants

2.2. Space Info

2.2.1. *Organizational and cultural context:* after school activity in Computer Lab

2.2.2. *Physical characteristics:* indoors

3. Social Orchestration

3.1. Population

3.1.1. *Students:* 9

3.1.2. *Tutors:* 2

3.2. Grouping

3.2.1. *Setting:* students in front of computers with one lego nxt kit available for each group

3.2.2. *Grouping criteria:* mixed ability, mixed gender

3.3. Kinds of Interaction during the activity (emphasis)

3.3.1. *Actions:* exchange ideas, dialogue, negotiation, debate

3.3.2. *Relationships:* collaborative, competitive

3.3.3. *Roles in the group:* pre-defined roles, emergent roles

3.3.4. *Support by the tutor(s):* facilitate, support, intervene

4. Teaching and Learning Procedures

4.1. Teacher's role

4.1.1. *Teacher' function:* (what is the teacher doing?)facilitator, mentor, co-researcher,

4.2. Teaching methods

4.2.1. *Teacher's approaches:* introducing simple examples, setting initial program status

4.3. Student activity processes

4.3.1. *Students' function:* action, writing, observing, creating

4.4. Student learning processes

4.4.1. *Designed Conflicts and misconceptions:* misconceptions about programming structures conditions

4.4.2. *learning processes emphasised:* emphasis on how different programming structures and conditions affect the robot behaviour

4.4.3. *Expected relevance of alternative knowledge (which):* Physics laws can affect the result of robot behaviour

5. Student productions

5.1 Artifacts - robots

5.1.1 *assignment:* Robot will perform programmable movements for educational reason

5.2.2 *interaction:* gesture

5.2.3 *morphology:* machine-like

5.2.4 *behavior:* autonomous vehicle

5.2.3 *parts:* Lego Mindostorm NXT parts

5.2 Programs - code

5.2.1 Structure of code-commands: One “scenario” in Lego programming environment with nested structures.

5.2.2 Elements (e.g. iteration, selection, variables): Iteration, selection, nested structures, optionally variable usage.

5.2.3 Conditionals (e.g. event handling): Non-event programming. Conditions are embedded into structures.

5.3 Discussions – arguments (describe the activity emphasis on one or more of the following types of discussion)

5.3.1 descriptive - explanatory: Discussion and make assumptions about the cause of a problem

5.3.2 alternative: giving alternative solution to the same programming problem

5.3.3 critical - objection: N/A

5.3.4 contributory - extending: extending a successful program to enhance the robot behavior

6. Sequence and description of activities

Phase 1: Introduction and experimentation

Duration: 2 hours

Orchestration: group work

Description: Children are engaged in discussion about robotic behaviors and how the creator-programmer can give the desired functionalities and characteristics to a robotic device. Students are introduced to available parts, sensors, motors. They experiment with different values and settings and observe the results on the class floor.

Phase 2: Sequential programming

Duration: 2 hours

Orchestration: group work

Description: Students implement their first programs that have programming blocks in a row. No loops or selection structures are needed. The first program should move the robot on a predefined path on the floor. The robotic vehicle is pre-assembled so students have to focus on programming and debugging their own programs. After a successful first program, they are asked to enhance the program by repeating the movements on the floor and ensuring that the robot returns to the initial position.

Phase 3: Using loops

Duration: 2 hours

Orchestration: group work

Description: Students try to find a way to simplify their programs by avoiding using the same sequence of blocks many times in the same program. Almost spontaneously they try to use loop programming blocks. With teacher assistance, they recognize the usage, the conditions and the characteristics of the new programming structure and also the role of the sensors in executing a loop block.

Phase 4: Giving "smart" behavior: the usage of selection/switch blocks

Duration: 2 hours

Orchestration: group work

Description: A robot in order to be "smart" (autonomous) has to avoid any obstacle that could be in its path. Students discuss the new problem and are introduced with a new programming block:"switch block". Firstly they use the new block once to avoid one obstacle. Very soon they realize that this is not a very "smart" behavior and of course this is not a real-life solution. So, they are encouraged to combine the "switch block" with the "loop block" to have a permanent solution. Students experiment with the position of the two blocks in the program as well as with the various settings that read and control the sensors and motors.

Phase 5: Feedback and evaluation

Duration: 30 minutes

Orchestration: individual and class work

In addition with the activity sheets that students complete during activity phases, finally they discuss in classroom the difficulties, the different solutions, the limitations that may have found in every step. They also fill in an evaluation questionnaire and teacher gets short informal open interviews from students that want to share their experience.

7. Assessment Procedures (for teacher reflection or student feedback)

7.1. Formative assessment

7.1.1. Pupil voice activities (Interviews with students, Questionnaire)

7.1.2. Observation notes

7.1.3. Peer assessment

7.2. Summative assessment

7.2.1. Essays: N/A

7.2.2. Tests: N/A

7.2.3. Student productions (programs, activity sheets)

7.2.4. Mark sheet: N/A

TITLE: Bee-Sequential Programming: Advance Level (15 – 18 years old)

Author: Julian Mauricio Angel-Fernandez

1. Description of the scenario

1.1. Domain

1.1.1. *Primary domain:* Programming

1.1.1.1. Science

1.1.1.2. Technology

1.1.1.3. Business

1.1.1.4. Engineering (x)

1.1.1.5. Arts

1.1.1.6. Mathematics

1.1.2. *Contextual (peripheral) domain:* Sequential thinking

1.1.2.1. Science (0)

1.1.2.2. Technology (0)

1.1.2.3. Business (0)

1.1.2.4. Engineering (10)

1.1.2.5. Arts (0)

1.1.2.6. Mathematics (0)

1.2. Objectives

1.2.1. *Subject related:* Give instructions to the robot to go from point A to point B. This task is done incrementally to allow the learner to get use to the idea of sequential programming.

1.2.2. *Technology use related:* Arduino programmed with Scratch for Arduino. Use of the platform DFRobot 2WD Mobile Platform for Arduino, with three line sensors and six push buttons.

1.2.3. Social and action related: None

1.2.4. Argumentation and fostering of maker culture:

1.3. Time

1.3.1. Duration: 1 weeks

1.3.2. Schedule: 2 hours

1.4. Materials and Artefacts

1.4.1. Digital artefact: Robotic platform with push buttons and Scratch for Arduino programming environment

1.4.2. Robotic artefact: Car with all the circuits visible

1.4.3. *Student's workbook and manual:* A manual with step-by-step instructions of the different challenges and tutor presentation.

1.4.4. *Teacher's instruction book and manual:* None

2. Space and Students Info

2.1. Students Info (Target Audience)

2.1.1. *Sex and Age:* Boys and girls, 15-18 years

2.1.2. *Required Prior knowledge:* None

2.1.3. Nationality and cultural background: None

2.1.4. Social status and social environment: To be define

2.1.5. *Special needs and abilities:* None

2.2. Space Info

2.2.1. Organizational and cultural context: For example: in school at the technology laboratory, during project time in after school established voluntary club activity

2.2.2. Physical characteristics: indoors, floor, and a mat with a black line grid.

3. Social Orchestration

3.1. Population

3.1.1. Students: 24

3.1.2. Tutors: 2

3.2. Grouping

3.2.1. *Setting:* The groups are composed of two students. To each group is given a robot platform, a mat with the black line grid, one computer and one USB cable to program the Arduino.

3.2.2. Grouping criteria: None

3.3. Kinds of Interaction during the activity (emphasis)

3.3.1. *Actions:* solution-oriented

3.3.2. Relationships: collaborative

3.3.3. *Roles in the group:* None

3.3.4. *Support by the tutor(s):* support

4. Teaching and Learning Procedures

4.1. Teacher's role

4.1.1. *Teacher' functions:* mentor, the teacher helps the young learners when they show difficulty to achieve their task.

4.2. Teaching methods

4.2.1. *Teacher's approaches:* constructionist, the teacher orients students when they need help asking them to do something with the robot and then making them reflect about it.

4.3. Student activity processes

4.3.1. *Students' function:* action, they program the robot to "help" it to go from point A to point B

4.4. Student learning processes

4.4.1. *Designed Conflicts and misconceptions:* Both students should communicate to decide who program the robot or how they should proceed

4.4.2. *learning processes emphasised:* Sequential thinking

4.4.3. *Expected relevance of alternative knowledge (which):* None

5. Student productions

5.1 Artifacts - robots

5.1.1 *Assignment:* The young learners should tell the robot how to go from point A to point B.

5.2.2 *Interaction:* Push buttons and Scratch for Arduino

5.2.3 *Morphology:* Car like

5.2.4 *Behavior:* the robot executes young learners' commands as best as it can.

5.2.3 *Parts:* DFRobot 2WD Mobile Platform for Arduino assembled. Note: Especial attention should be taken when the push buttons are assembled due to the noise that could be generated. A guide to debouncing (http://www.eng.utah.edu/~cs5780/debouncing.pdf) explains the different alternatives to solve this problem. Additional it is needed Scratch for Arduino, and a self-made library to hide the line detection process.

5.2 Programs - code

5.2.1 Structure of code-commands: if-else and while

5.2.2 Elements (e.g. iteration, selection, variables): iteration, conditionals and variables

5.2.3 Conditionals (e.g. event handling): None

5.3 Discussions – arguments (describe the activity emphasis on one or more of the following types of discussion)

5.3.1 Contributory - extending: sharing of resources, there is just one robot for every two young learners

6. Sequence and description of activities

Pre-Phase

Introduction and Organization (15 min)

The host (Teacher/Researcher) present their self and welcome the participants to the workshop. Next, the host explain the participants that they are going to work in groups of two using a robotic platform, a mat and a computer. After that, the host ask the participants to pick a partner. Once they have formed the groups, it is given to each group a platform, a mat and a computer.

Phase 1: Understanding

Show the robot and explain robot's characteristics (10 min)

The host ask the participant to observe their robots and tell about the components that they can identify in the robot. Also, the host ask the participants how they think that the robot could be program.

The main components to identify are:

- Line sensors -> eyes of the robot
- Arduino -> brain of the robot
- Push buttons -> ears of the robot
- Cables ->
- Batteries->

It is possible to use any metaphor as human body or animal body to explain how these parts are connected with them to make easer their understanding.

Show how to Program the Robot (5 min)

The host show the participants where to open the program, and how a code is send to the robot without making explicit how to write a program. The participants should open a simple example (Move forward one tile) to give them an idea how to proceed with the next steps. It is important to show them where they have to connect the robot. This procedure should be included in the guide, so they can use it or ask to the host.

Show an example how to use the robot (one or two examples on how to make it work) (10 min)

The participants are asked about how they think that the robot starts to execute the instructions. After some dialogue among them, the host ask if opening a new file is enough to make the robot move. The participants have to realize that some instruction should make the robot move. With this introduction, then is explained conditional and it is shown to them an example of the robot moving forward one tile and turning 90 degrees.

In this first introduction is not given any information about cycles.

Phase 2: Exploration

Forward movement exploration (5 min)

The participants are asked to return to their work station and program the robot to move forward three tiles. It is expected that they copy and paste the example three times.

Forward and backward movement without turning (10 min)

The participants are asked to make the robot to move forward three tiles and then make it move backwards to its original position without making it turn.

Forward and return movement (10 min)

At this point, the participants have understood some basic idea on sequential programming. In this task, they have to make the robot move forward four tiles. Then make the robot turn looking at its initial position. Next, make the robot return to its initial position and finally make it turn 180 degrees.

Phase 3: Conceptualization

Trajectory design (5 min)

It is asked to the participants to come with a trajectory for the robot with a least ten tiles and at least five turns. Each group has to show their trajectory to the host before they can start the implementation.

Discovery (10 min)

Each group is asked to implement their trajectory. After five minutes that they have started the implementation, the host ask them if it has been easy. Due to big amount of steps that they should program, the participants may and may not come with the necessity to way describe and remember in what part of the sequence they are. The host introduces visual mechanisms to describe these long sequences, in this case arrows.

Analysis (15-20 min)

The host ask the participants:

What could the problems if they address the problem as they have done so far?

What happen if the sequences are longer?

What are the patterns that they have noticed in their trajectory?

The expected result of this analysis is that they realized that long trajectories are very difficult to code just using conditionals. Therefore it is introduced the concept of cycles and variables. Then they are asked to code their same trajectory using these to concepts.

Implementation (10 min)

After the introduction of cycles and variables, it is asked the participants to continue with the implementation. If some of them finish before the time, they are asked to implement a new sequence following the same procedure.

Phase 4: Conclusions

Reflection (15 min)

In this last part, the following questions are asked to the participants:

What were the problems found during the use of the robot?

Why the robot does not behave always in the same way? Ask if they notice that the robot did not follow a straight line.

7. Assessment Procedures (for teacher reflection or student feedback)

7.1. Formative assessment

7.1.1. Pupil voice activities (Interviews with students, Questionnaire)

7.1.2. Observation notes

The platform used in this workshop is the DFRobot 2WD Mobile Platform for Arduino. The kit does not come with all the necessary tools to make the robot move, and moreover their assemble instructions are vague and can confuse teachers that have not previous knowledge in electronic.

To correctly assemble the robot is necessary to buy:

- Arduino Uno
- Arduino Motor Shield, to control the motors direction and velocity. Depending on the activity's objective this could be replace with H-Bridges to make participants to build the system.
- 6 push buttons
- 12 resistances and 6 capacitors, to implement the debouncing system in hardware (http://www.eng.utah.edu/~cs5780/debouncing.pdf)
- Cables to interconnect all the parts
- Breadboard to implement the debouncing system. Depending on the activity's objective, this could be eliminated and make the participants to analyse this problem.

To make the robot robust enough for long periods of interactions, some components should be solder, which will include the necessary tools to do it.

7.1.3. Peer assessment

7.2. Summative assessment

7.2.1. Essays

7.2.2. Tests

7.2.3. Student productions (code-robots-textual discussions)

7.2.4. Mark sheet

8. Assessment Procedures (for teacher reflection or student feedback)

8.1. Formative assessment

8.1.1. Pupil voice activities (Interviews with students, Questionnaire): Questionnaire before and after the workshop and interviews at end of the workshop

8.1.2. *Observation notes:* Observation notes will be taken during the workshops and video audio recordings will be produced if written consent by parents and students is obtained.

8.1.3. *Peer assessment*: peer reviews will be done by researchers at certain workshops

8.2. Summative assessment

8.2.1. *Essays: Students could be asked to write essays about the workshop*

8.2.2. *Tests:* no formalised test are envisaged.

8.2.3. *Student productions (code-robots-textual discussions)* standardised robots; standardised and custom commands; creative mindmaps and ideas.

8.2.4. *Mark sheet*