Towards a Framework for Educational Robotics

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Abstract

Educational robotics has been considered as a field with a good potential to teach difficult concepts (e.g. friction) in appealing way. As a consequence, the interest in educational robotics has grown in the last decade, which is reflected in increasing number of robotic platforms, kits, and programming interfaces now available. Nevertheless, researches still fail on describe activities that could be used by teachers and other people with no technological fluency, who are scared by the overwhelm amount of information that made them avoid the use of robotics to teach. Moreover, most of the activities developed until now do not consider pedagogical methodologies to inform the design and implementation of them. As a direct consequence of the misinformation about the correct use of pedagogical methodologies and robotics' multidisciplinary, the number of people who master the use of robotics in education is still scant. This paper presents ongoing work on the development of a framework in the European project Educational Robotics for Science, Technology, Engineer, and Mathematics (ER4STEM). The framework aims to make evident the connection between 21st century skills, robotics and pedagogical methodologies to support the creation of pedagogical activities, which is defined in ER4STEM as an activity that has clear learning outcomes and evidence of learning, use of one or more pedagogic methodologies during the activity, and detail description of the activity. This is achieve through the critical use of tools and examples of activities developed ER4STEM.

Keywords

Educational Robotics, Framework for Educational Robotics, Pedagogical Activities, Educational Activities, Educational Robotics for STEM, and Constructionism

Introduction

Robotics is a field where mechanical, electronic and computer engineering converge but it also involves other fields such as mathematics, psychology (e.g. human behaviour and attitudes), biology, arts, and sciences. Therefore, it has been recognized as a technology that could highly impact education (Papert, 1980). Nevertheless, the broad connection with different fields and the constant evolution of technology can make people to focus on the technology aspect without fully consider how pedagogical methodologies should be included, such as best approach or specifying learning outcomes clearly. Despite all these, robotics has been already used to teach diverse topics, such as Geography (Serholt, et al., 2014), Geometry (Walker & Burleson, 2012), Maths (Hussain, Lindh, & Shukur, 2006), Physics (Church, Ford, & Rogers, 2010) among others, with a high predominance in physics and programming. Despite all of these works, most of them are not well documented, which reduce their availability and therefore replication in other educational context.

This does not mean that researchers are not aware of were not aware of these and other weaknesses. For example, the project TERECoP (Alimisis, et al., 2012) presented a constructivist methodology for teacher training in the use of robotics in education. Several training sessions were available across Europe. Nevertheless, this approach focuses on face-to-face training to teachers and it is linked with Lego Mindstorms. Others have come with frameworks to establish precise procedures that have to been followed to create and activity with robotics. This is the case of Roberta initiative (Bredenfel & Leimbach, 2010), which established specific criteria for the activities that could have the brand Roberta and more important the teachers. Although these approaches are beneficial in the long term, it is still required materials that could increase the use of robotics in a critical way that considers benefits of the technology and pedagogical methodologies.

Educational Robotics for Science, Technology, Engineer and Education (ER4STEM) is a European project that aims to realize a creative and critical use of Educational Robotics (ER) to maintain children's curiosity in the world. ER4STEM has adopted constructionism as a foundational approach to designing workshops, robotic solutions and in the development of an integrated framework for inclusive learning and engagement with STEM. The project partners have found fundamental value in designing a variety of approaches, thus each workshop implements activities that foster students to discuss, argue and communicate their ideas about STEM concepts in a meaningful context for them. Consequently, the framework created in ER4STEM aims to make the explicit connection among pedagogical methodologies, knowledge in robotics, and 21st century skills.

Frameworks in Educational Robotics (ER)

There is a limited number of works that offer a clear guideline on the correct use of robotics in education, especially on the connection between technology and pedagogy. Roberta initiative (Bredenfel & Leimbach, 2010) aims to create a gender-balance didactic material and course concept. It specifies several characteristics that teachers and activities must have to be considered as Roberta teacher and activity, respectively. These characteristics could be cluster in four main areas: activity and teacher characteristics, design ideas, and quality criteria. The design ideas for an activity are: selection of interesting topics, provide examples, allow rapid achievements, and strength participants' self-confidence. Once the activity is created, it has to fulfil the following requirements: last from 2 to more than 40 hours, be suitable for mixed groups, be connected to real problems, and be certified by the initiative.

Another framework is created by (Chiou, Lye, Lai, & Wong, 2011), called EARLY. Their framework is based on the work done by (Carroll, 2002), that identifies four critical components in activities that involve technology. These components are: people, activities, context and technology. As a consequence, the EARLY framework describes three basic components: participants (i.e. teachers, learners, developers and experimenters), environment (i.e. computer, material, software and robot) and arena (e.g. problem based arena and soccer). A final element called scope embraces all of them to describe a specific situation or activity. Although the authors present five different case studies, the framework lacks literature support and formal evaluation.

The Educational Robotic Applications (ERA) is a framework created by (Catlin & Blamires, 2010) that postulates ten principles for the correct use of robotics in education. They grouped these principles in three categories. (1) The Technology category where the principles are intelligence, interaction and embodiment. They are related to expect features that robots have and could improve the educational experience. (2) The Student aspect that focuses on engagement, sustainable learning and personalisation. (3) The Teacher category that covers pedagogy, curriculum and assessment, equity and practical. Although these are important aspects to be considered in any educational activity, the authors neither offer information in how they should be implemented nor consider difficulties that may arise in their use. Nevertheless, there is a clear direction on how to use these principles and, as the authors suggest, require supportive testing and evaluation.

ER4STEM Framework

The manner that ER is being presented lacks that guidance that can help people design, develop and implement activities in ER that uses pedagogical methodologies to inform any decision. However, ER involves a huge group of stakeholders. Therefore, the first task in ER4STEM was to determine who the stakeholders in ER are. The stakeholders identified were (Angel-Fernandez, y otros, 2016): young people, young people parents, teachers, school boards, organizations offering educational robotics, educational researchers, robotics researchers, human computer interaction researchers and industry. This group of stakeholders is still too big, if it is to consider that each one of them has a different needs, requirements and objectives. This variety makes it difficult to address all at once. Therefore, it was decided to focus on those stakeholders who have a direct impact on the quality of the activities. This was decided because those stakeholders would provide information that could inform other interested parties to implement ER. Teachers, researchers, organizers of educational activities and industry have been identified as those stakeholders (Angel-Fernandez, y otros, 2017).

Based on their requirements and needs, and ER4STEM's aims, ER4STEM's researchers suggested that workshops and lessons must be treated as similar because the place where the activity is implemented should be transparent for the final users. In order to achieve this, any activity should have a clear learning outcomes and evidence of learning, which could be formal or informal. This has several benefits: (1) the activities designed and implemented as a workshop are easily implemented as lessons. The description of objectives and proof of learning makes it easier for teachers to link the activity with any school's curriculum. (2) The evidence of learning allows people to verify if the activity is reaching the expected results or not. Also it could be used to measure the real impact of ER, which has not been quantified yet (Fabiane & Barreto, 2012) and it would generate arguments towards the use of ER in formal settings. As a consequence all activities done under ER4STEM, and hopefully in all ER, must *be pedagogical activities,* which have the following characteristics: (1) Clear learning outcomes and evidence of learning, which could be formal (e.g. assessment) or informal (e.g. write to a friend about what you have done today). (2) Use of one or more pedagogical methodologies during the activity, which has to be thought during the design of the activity and refine after the implementation of it. (3) Description of the activity using the activity template created in the project (Yiannoutsou, Nikitopoulou, Kynigos, Gueorguiev, & Angel-Fernandez, 2016). This will help other stakeholders to have a clear idea of all considerations taken into account and the assumptions done by the designer.

As a consequence of these all elements already presented, weaknesses of current approaches and industry requirements, ER4STEM's framework is a work on progress that aims to guide any ER's stakeholder on the design or adaptation, implementation and evaluation of pedagogical activities. This is achieved through the explicit connection among pedagogical methodologies, knowledge in robotics, and 21st century skills. To achieve this, the ER4STEM's framework provides four components, such as it is depicted in Figure 1. (1) An ontology of ER. The concept ontology in this case must be understood as it is done in Computer Science. This ontology provides specific definition of each word used in the field and the connection between them. (2) Tools created specifically to be used in ER, such as a web-repository, activity template and activity blocks. The last is a piece of activities that have been proven to be useful to foster specific skills and could be connected with other blocks to create a pedagogical activity. (3) Values or pillar of ER4STEM were selected from the industrial's needs, literature review and project's objectives. These values are: creativity, collaboration, communication, critical thinking, evidence of learning, mixed gender teams, multiple entry points, changing and sustaining attitudes to STEM, and differentiation. (4) Processes for workshops and conferences for young people.

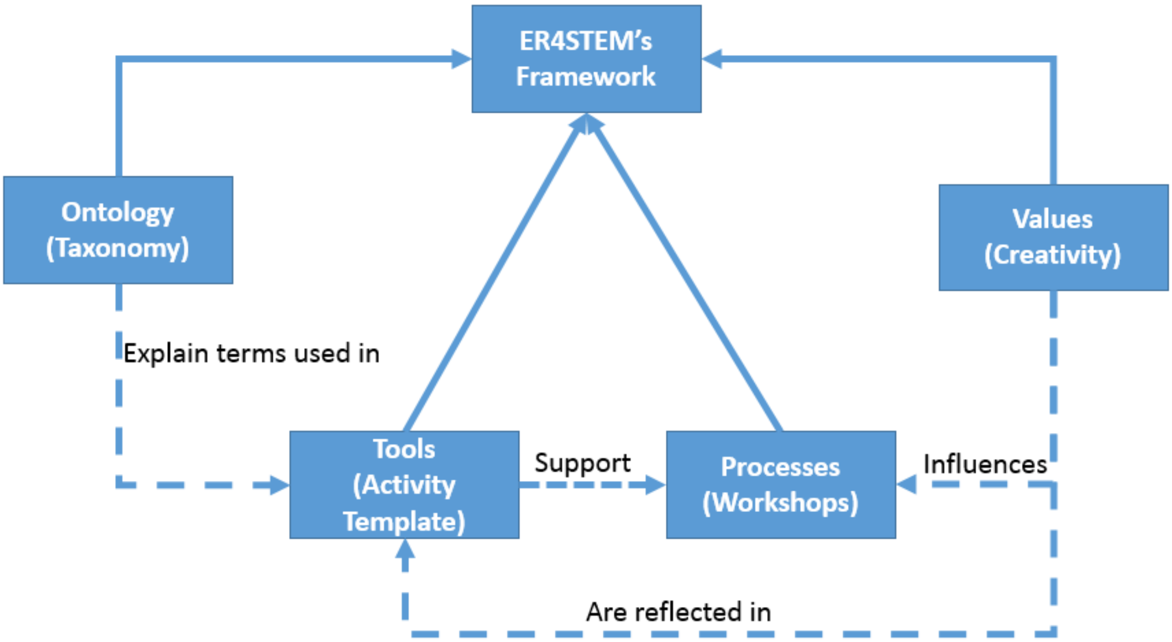

Figure 1 Graphical representation of the elements that compound ER4STEM's framework. The dash arrows represent the connections between elements that constitute the framework. The other lines come from different elements to the framework because they constitute the framework.

Values of ER4STEM

The values of ER4STEM were selected after doing a literature review, analyzing current industry's needs and project objectives. From the *literature review*, several weaknesses on how works in ER were identified (Angel-Fernandez, y otros, 2016). Thus: (1) There is not a clear evidence how pedagogical theories were considered during the design of the activity. (2) Activities reported in many cases are not fully described and therefore limiting their replication. (3) Some of the studies lack rigorous and systematic analysis of the data, which would make it become anecdotal. On the other hand, the *analysis of the industry* revelled that there is a common agreement that STEM is 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). Therefore, the project objectives are four. (1) The provision of multiple entry-points to ER and STEAM. (2) Empowering children to solve real world problem and address all young children. (3) Provide a continuous STEM schedule. (4) Develop an open and conceptual framework. As a result, the values are: creativity, collaboration, communication, critical thinking, evidence of learning, mixed gender teams, multiple entry points, changing and sustaining attitudes to STEM, and differentiation. For each one of these values a literature review is been done to provide stakeholders with suggestions that have been already studied by other researchers.

An example of a value: Creativity

This is one of the skills that most of the people talk but it is difficult to explain in words. An important aspect to foster creativity is to avoid tell children that they are no creative just because the person does not consider that they are doing something new or innovative. Regarding this, it is important to remember that there are diverse level of creativity, for example (Kaufman & Beghetto, 2009) proposed four types of creativity: little-c, big-c, mini-c and pro-c. Little-c is the creative that involves novelty beyond individuals. Pro-c could be positioned between little-c and big-c, and it embedded ideas that are considered with significant valuable in their field but their contribution has not been recognized as big-c. Little-c, which occurs when individuals comes ideas that are new for them and for others but without a significant relevance to their field; and big-c, which occurs when individuals come with ideas that revolutionize their fields. Other important facts to remember are:

- The creation of environments, that promotes creativity, is also possible by
  - Defining clear goals in the activity (Csikszemtmihalyi, 1996)
  - Balancing knowledge and challenge (Lewis, 2015) (Csikszemtmihalyi, 1996). Too difficult or easy will not contribute in the development of creativity.
  - Create a climate where students are not concerned that they may fail (Lewis, 2015) (Csikszemtmihalyi, 1996) (Sefertzi, 2000) (Vassileva, et al., 2012)
  - No creating competitions or providing rewards after finishing the activity (Lewis, 2015)
  - Motivating students to be creative (DeHan, 2009)
- Elements proposed by (Nelson, 2012) to foster creativity in robotics are:
  - Ability to visualize solutions, for example sketching or building prototypes of robots.
  - Thorough knowledge base in the domain, for example building on previous robotic projects
  - Ability to decompose and manipulate partial solutions
  - Ability to take informed risks, which include tasks with no right or wrong answers
  - Flexibility to try alternative techniques
  - Creativity friendly environment
  - Practice
- Failure most not be penalized (Sefertzi, 2000) (Lewis, 2015)
- Use of diverse tools to motivate creativity (Sefertzi, 2000), such us brainstorming, story boarding, lotus blossom, checklist, morphological analysis, and excursion technique.

Educational Robotics Ontology

An ontology as is presented by (Grimm, Abecker, Volker, & Studer, 2011) is a formal explicit specification of a domain of interest that could be executed by a machine and understand by humans. This representation is helpful in two ways. (1) It provides a specific definition of the concepts in the domain of interest. This will avoid misinterpretation of a concept that has different meaning depending of the field. For example, in ER4STEM when the idea of creating an ontology came, there were a misunderstanding between engineers and educational researchers because each one had a different definition of it. Also it will help stakeholders without knowing the concept to understand it. (2) It is the base of a semantic search on the repository, which would let it to provide better results to a query.

Thus in context, the ER4STEM's ontology was created in two steps. (1) Determining requirements and possible queries that should be answers and (2) Describing and formalizing the ontology. During the first step, it was decided to use the activity template as a base to determine concepts that must be in the ontology. On the other hand, the queries were created from diverse meetings between all partners in ER4STEM. This allow the discussion between researchers, practitioners and industry, which contribute to have different perspectives. The final questions are:

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

Based on requirement analysis, it was firstly decided to focus on concepts that are intrinsically embedded in ER, and avoid concepts and terms that unequivocally do be described in other ontologies that could not add any additional value to the base of knowledge. For example robotics or technology ontologies. The second step was initiated with the creation of a beta version of the ontology. This version was discussed with educational experts from University of Athens and Cardiff University, who provided corrections to the educational concepts. Taking into account their comments, a new version of the ontology was created and shared with all partners to have a feedback from them. This feedback lead to the first stable version of the ontology. The taxonomy and its relations are presented in the web-repository.

Tools

In ER4STEM three tools have been created to support stakeholders in ER. (1) *The activity template* is a generic design instrument that identifies critical elements of teaching and learning with robotics based in theory and practice (Yiannoutsou, Nikitopoulou, Kynigos, Gueorguiev, & Angel-Fernandez, 2016). It was designed to be a mediating artefact between pedagogical experts and the ER4STEM partners interested in design activity plans for ER. The template addresses the following aspects: a) the description of the activity, with explicit reference to the domains involved, objectives, duration and necessary materials; b) a level of detail that will demonstrate the influence of a specific approach. (2) *Activity blocks* were designed the outcomes of the first year of the project. They focus on the practical aspect of the activity plan. The activity blocks are adjustable short activities that were selected as good activities that could be used to foster one of the ER4STEM's values. (3) *Repository* is the digital representation of *activity template*, *activity blocks* and *ontology*. The repository's main objective is to support other people in the creation of new activities and inspire them ideas that other users have shared. Figure 2 presents the front page of the repository, which has the option to login in case the user wants to share their activity. Also there is the possibility to visualize diverse activities that already exist in the repository. Also it is also possible to search for specific key words or features, such as age.

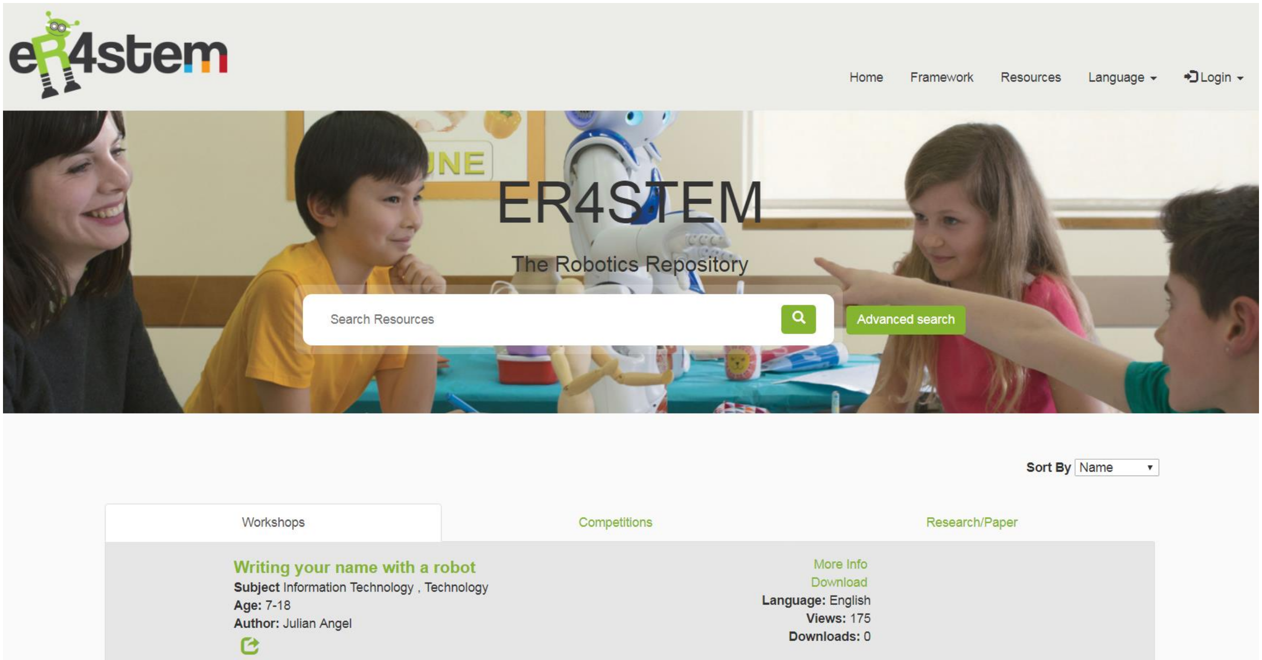

Figure 2 Front page of the ER4STEM's repository.

Processes

A macro process was created base on research cycle and the professional teaching and learning cycle (Laboratory, 2008). The main aim was to conceive a suitable structure that could be used in activities that involves the use of robots. The final result is depicted in Figure 3. As it could be seen this process is composed of four main macro phases: design or adaptation of an activity plan, implementation in real settings, activity's evaluation or assessment, and improvement of the activity plan. The first macro phase is divided in two possible steps, which represents the possibility to design an activity from scratch or adapt one from other existing activities. The second macro phase is implementation, which mainly focuses on considerations involving the settings and the context in which the activity is going to take place. The third phase provides instruments and procedures for evaluating the implementation. The fourth and last macro phase focuses on possible improvements of the activity plan based on information derived from the implementation in real settings, on reflections from the teachers, the students and the designers. Once the activity has been improved, there is the possibility to being implemented again as an activity for future groups.

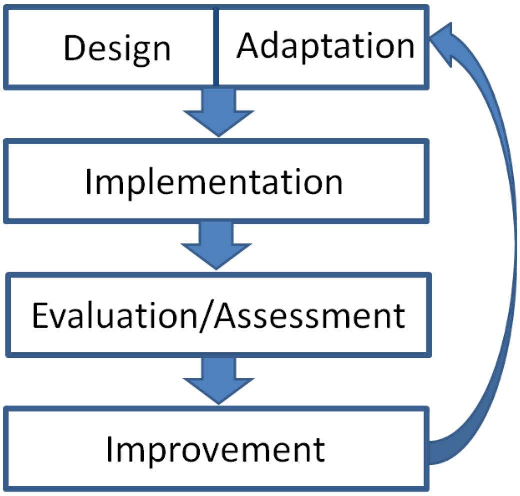

Figure 3 Framework's macro process definition

Using this macro process as reference there has been identified two processes can be created from the project experience: conferences and competitions, and pedagogical activities.

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