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Promoting STEM via UMI: an Ecological Framing of CoPs in Networking and Networked Robotics

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Abstract

Ubiquitous Computing, Mobile Computing and Internet of Things (UMI) technologies, are widely diffused in the everyday life. In addition to their primary usage (e.g., supporting the implementation of the future 5G network), these technologies can be used in the context of Science Education. According to this perspective, the innovative psycho-pedagogical approach here presented has been ad-hoc developed for the Horizon 2020 Project "Exploiting Ubiquitous Computing, Mobile Computing and the Internet of Things to promote Science Education" (Umi-Sci-Ed). The aim of the project is to enhance knowledge and skills of Science, Technology, Engineering and Mathematics (STEM) and to promote positive attitudes towards these disciplines. In order to reach this goal, the UMI technologies, framed in the Community of Practices (CoPs) paradigm, will be introduced in the learning process of secondary schools' students (i.e., 9th and 10th grade). Specifically, the students will attend to innovative learning activities, such as hands-on activities, concerning with Networking and networked Robotics. In the present contribution, the theoretical framework that constitutes the rationale for the Umi-Sci-Ed project will be described. In particular, the "bottom-up" socio-constructionist perspective will be presented, as well as the main technological tools (e.g., UDOO) that would be used to implement an integrated STEM learning environment. The expected results of the project will be discussed.

1. Introduction

STEM education researchers largely focused their attention to promote change in instructional practices for undergraduates' education [1]. The search for "best practices" in teaching approaches is due to the well-documented need to increase pupils' knowledge of STEM [2] and their interest in pursuing Science careers [3]. It has been observed that many students are losing their potential competitiveness for the high-tech knowledge-based economies because of their low performances and their dislike of STEM subjects [4]; this is particularly true for women [5]. As a result, educational reform has become a topic of discussion among several countries. The call for improved STEM education is accentuated by the awareness that evolutionary STEM field constitutes the fastest-growing area of the worldwide economy [6]. The present contribution, stemmed from Umi-Sci-Ed Project [7], aims to offer a better understanding of the most recent learning approaches that have been demonstrated to be particularly effective in improving STEM's knowledge and enhancing positive attitudes towards STEM among high-school students. In this vein, networking and networked robotics activities, as well as a social-constructionist approach, are considered to be a valid learning approach that can contribute to enhance positive outcomes among students (i.e., interest, positive attitudes towards STEM, creative thinking, and problem-solving).

2. The State of Art of STEM Education in the High School: a focus on Networking and Networked Robotics

An innovative pedagogical approach to STEM education would take advance from networking and networked robotic applications in the classroom lessons or specific laboratory's settings [8]. Thanks to their capability to facilitate the development of abstract thinking and collaborative problem-solving abilities, robots are frequently used as educational tools [9]. In a typical educational robotics laboratory, students are involved in the bottom-up construction process of a robotic system and they

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face with a number of challenges: they have to predict outcome of their construction and to plan a sequence of instructions to achieve the desired objective. These challenges enhance their abstract thinking and problem solving ability. In line with this perspective, several robotics tools and embedded systems has been developed with the aim of supporting new learning approaches to scientific disciplines (e.g., NAO, Lego Mindstorms, Arduino) [10,11,12].

3. Innovative Learning Approaches

An important change in undergraduate education paradigm during the last ten years concerns with the shift from instruction- "teacher centered" approach to learning- "student-centered" approach [13]. This sort of *Copernican revolution* is referred not only to the STEM education realm, but, more in general, to all undergraduate instruction processes and programs in several fields [14]. The principal assumption is that promoting positive attitudes and enhancing motivation towards STEM affect positively complex learning processes with long-run effects on student persistence and interest in STEM study [15]. In this perspective, several pedagogical approaches have been developed [16]:

- *Context-Based Approach* (CBA) (the focus is on the use of contexts and applications of scientific/technological/engineering and mathematics issues; students can experience the relevance and the applicability of the science contents);
- *Inquiry Based Learning* (IBL) (i.e., presentation of questions or problems); *Computer-Based Learning* (ICT) (i.e., computer-based instruction, games, simulation);
- *Collaborative Learning* (COLL) (e.g., a project-based work or a discussion on a specific object);
- *Extra-Curricular Activities* (EXT) (i.e., all activities outside the classroom, yet linked to the school program; e.g., field trips, guest lectures).

However, previous research didn't provide evidence for one approach being more effective than others; it seems that innovation represents a line way to follow, but only one innovative approach, *per se*, is not enough to raise students' performance, positive attitudes and interest towards STEM [16]. We suggest that a keystone should be an innovative theoretical framework aimed to integrate different approaches and to support the main characters of the learning process (i.e., students, teachers, and stakeholders). This theoretical framework constituted the basis for the European Project Umi-Sci-Ed that is presented in the next section.

4. Umi-Sci-Ed Project: Exploiting Ubiquitous Computing, Mobile Computing and the Internet of Things to promote STEM Education

The Umi-Sci-Ed is a project within European Union's Horizon 2020, work program: "Innovative ways to make science education and scientific careers attractive to young people". The aim of Umi-Sci-Ed is to introduce the Ubiquitous Computing, Mobile Computing and Internet of Things (UMI) technologies in STEM education, in order to promote innovative practices for the excellence among 14-16 aged youngsters. The chance offered by Umi-Sci-Ed is to empower youngsters' creative thinking, problem-solving, and ability to compete in a highly demanding working environment. To reach this goal, UMI will constitute a means to deepen scientific knowledge and dwell with its practical applications. Even more important, innovative activity within schools should made science and scientific careers more attractive to youngsters [17].

4.1 The Psycho-Pedagogical Model: Ecological Framing, CoPs, and Robotics

The Psycho-Pedagogical Model here presented constitutes the rationale of the Umi-Sci-Ed. The main idea stemmed from Bronfrenbrenner's ecological model [18], the Social-Constructionism and the CoPs constructs. The use of UMI represents the operative expression of the hands-on learning. The Ecological Model explains the interconnected and complex interactions that occur across multiple systems (e.g., schools, industry, teachers, and students). Bronfrebrenner's lens could help to interpret STEM education as the result of the complex relationship among four systems: macrosystem (i.e., cultural, economic, social and political beliefs about STEM; e.g., "STEM are important to society"); exosystem (i.e., interconnected systems such as the community and region that affect students indirectly); mesosystem (i.e., all the interconnected systems that directly influence the student; e.g., home, school, work); microsystem (i.e., the student and her interactions with peers and teacher). The Umi-Sci-Ed aims to affect at all these levels. Furthermore, the project is based on the concept of CoPs: "people who share a concern or a passion for something do and learn how to do it better as they interact regularly" [19]. In CoPs, the learning process is guided from collaborative practice and, accordingly to a social-constructionist perspective, the knowledge is constructed by interactions and

communications between people [20]. The assumption is that “the best way to construct knowledge or understanding is through the construction of something shareable, outside of a student’s head” [21].

4.2 Learning Through Robotics: The use of the Udoo-Neo Kit

In Umi-Sci-Ed, the students will be invited to explore Networking and Networked robotics through hands-on activities. The principal tool that will be used is an advanced System on Chip: UDOO Neo board [22]. This tool can be used as a ARM development board for realizing and deep-understanding a general network component as well as a robotic system. In the laboratory activities, the students will be presented with Internet in a different perspective of the everyday life one, it will be “anatomized” in its inner components. Network functions and protocols will be presented starting from the idea of the observability of network components. With respect to the Networked robotics concepts, the Umi-Sci-Ed purpose is to introduce the students in the general domain of Cyber Physical System (CPS) that will be also able to communicate with the network to provide a specific service.

5. Conclusions

Several educational improvements have been conducted in order to implement good practices in the STEM education. Different national educational programs incorporate technology and engineering within science and mathematics lessons as means of scientific applications. However, the role of technology and engineering in STEM education remains in most cases somehow ambiguous [23]. The present contribution aims to offer a review on the various innovative learning approaches; presenting an integrated theoretical framework consistent with the most recent theories on learning, which constitutes a central concern of the rationale for the Umi-Sci-Ed project. Nevertheless, Umi-Sci-Ed has a more ambitious goal. The project’s idea is being already disseminated and the results will be reported across all over Europe. This will be created a virtuous chain, where technological institutions (CTI, CIT, CUBIT), academic organizations (University of Helsinki, Norwegian University of Science and Technology and University of Pisa) and stakeholders (e.g., industry) offer new technology to the students of high schools. In turn, the results that will be obtained from the application of the innovative methodological approach across the European schools will enhance youngsters’ competitiveness. The foresee result will stress the UMI relevance for STEM education giving a contribution to the study approaches to the "knowledge-based" society.

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