Exploring Ubiquitous and Mobile Computing to Leverage STEM Education: A Second Educational Scenario

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Abstract

Our everyday life is affected by technologies like Mobile Computing, Ubiquitous Computing and the Internet of Things. Ongoing research at the Hellenic Open University aims to leverage STEM education by providing an educational framework that exploits such technologies. For this reason, a novel educational methodology is being developed. It is going to include a set of educational scenarios backed by a platform of proper software and hardware configurations. Development of the methodology continues with a second pilot scenario. Its rationale, steps and expected results are described and discussed here. The next steps of the research are defined.

Keywords: Ubiquitous Computing, Mobile Computing, Internet of Things, STEM Education

Introduction

As Computer Science evolves, new devices, services and applications appear on the market and affect our everyday life. Supporting technologies improve and constitute the basis for further development. A set of state of the art technologies with impact on our everyday life are the UMI technologies, i.e. Ubiquitous Computing, Mobile Computing, and the Internet of Things (IoT) (Kameas, 2010). The spread of UMI technologies might lead to unprecedented, currently unexplored, learning opportunities. These technologies can advance student engagement and supply opportunities for novel and creative interactions within STEM subjects (Science, Technology, Engineering, and Mathematics). In parallel, there is an expanding need in the market for jobs in the professional domain of ubiquitous, open-source, affordable, software and hardware products (Mavroudi, Giannakos, & Divitini, 2016).

Our research aims to influence STEM subjects by utilizing UMI technologies. We plan to introduce these modern Computer Science technologies as educational means for STEM education. A parallel goal is to utilize them as topics of Computer Science curricula at the secondary and tertiary level, synthesizing all three dimensions of UMI. This concerns the pedagogical part of our research that aims to define a valid methodology based upon present-day educational strategies. A repository of educational scenarios is going to complement the educational methodology to provide the required material and a pool of ideas for further development. The application of educational scenarios will be supported by a platform of verified software and hardware tools. These tools will guarantee the smooth implementation of the scenarios in the classroom, with the minimum educational noise regarding infrastructure.

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From a theoretical point of view this work is based on essential features of contemporary educational theories. Constructionism is a student-centered educational theory where new knowledge is discovered by heartening students to interact with actual objects and exploit their prior knowledge (Harel & Papert, 1991). Constructionism is based on Piaget's theory of constructivism, which is suitable for the Science and Mathematics subjects of STEM. Despite that the epistemology of Computer Science is different than physics, the core idea of constructivism and hence constructionism, that knowledge is constructed by the student, is valid for Computer Science as well. We intend to test and prove that Technology and Engineering subjects of STEM comply with this idea, like Computer Science subjects do (Ben-Ari, 2001), and that UMI technologies can be used as both learning tools and learning objects for a next generation of educational applications, as nowadays robotics are considered learning tools and objects in modern school settings (Alimisis & Kynigos, 2009).

Connectivism, on the other hand, is a theory that concerns the way the Internet has created potential for learning using the World Wide Web. By exploiting peer and social networking through blogs, wikis, online discussion fora, Massive Open Online Courses (MOOC), anyone can share and learn, sometimes resulting to communities associated with the common educational materials (Siemens, 2005; Downes, 2010). Regardless of being a valid theory, connectivism is also considered a tool to be used for reflection of the learning process through modern media (Duke, Harper, & Johnston, 2013). Novel techniques and instructional methods derive from new technologies, like these of UMI. New methodologies are entitled to analysis about their contribution towards more effective STEM education. Diversity of population and technologies dictates an analogous set of instructional techniques. We plan our educational methodology to comply with connectivism, since it allows such a diversity through different networks that support collaboration of students.

A bibliographic survey about the use of UMI technologies in secondary and tertiary education, showed that they are mostly used as learning tools. By now, only a few cases concern the teaching of UMI technologies as learning objects (Delistavrou & Kameas, 2016). After setting up a first pilot educational scenario, the definition of a second scenario is described in this paper, as an extra contribution towards a repository of UMI educational scenarios that combine hardware, software and social tools, providing an alternative testing configuration. This scenario is part of a cycle of training, evaluation and dissemination activities involving teachers, students and other stakeholders. In subsequent phases, technology agnostic scenario templates will be designed, allowing interested parties to design their own scenarios grounded on real life needs and to implement them with the technological infrastructure at-hand. Our ambition is that these scenarios will inspire school communities, leading to the development of transversal skills in addition to the UMI related skills, thus enhancing the career prospects of students and supporting the professional development of teachers. In the following pages the methodology under development is presented in brief. Next the second pilot educational scenario is described. Finally, there is a short discussion and the description of the next steps of this research.

Methodology

In the proposed training framework, UMI technologies are used as both educational materials and in parallel as learning objects, backed with the support of an integration and socialization platform. The proposed methodology is based on three principles. The first is the development of UMI applications by high school students of all genders, so that they adopt a "culture of creation", to bridge theory with practice. The second is the exploitation of social platforms for exchanging information and good practices, dissemination of results, socialization of peers, and sharing other information important to the community. The third is the application of modern pedagogies, as means for the creation of a learning ecosystem that focuses on problem solving, "learning by doing", transversal skills and scientific citizenship.

The educational materials are being constructed using simplified scientific language to popularize STEM and reach youngsters, regardless of gender, economic, or social status. Communication with teenagers is attempted using multiple fashions of scenarios for producing fancy technological artifacts. These are expected to motivate students to create their own constructs, but also aim to assist teachers to guide the educational process on STEM subjects.

The educational research planned combines quantitative and qualitative methods. Assessment performed during different phases will capture the effectiveness of activities and tools. Data is going to be gathered using questionnaires, analysis of artifacts and focus groups on social media. The pilot testing of the integrated learning environment is going to be applied by students, their teachers, academics, and community stakeholders. The activities of the research contribute to the achievement of the main objectives of research, about the provision of novel educational services; selection and development of supporting software tools; proposal of adequate hardware tools; and publication of results.

The training framework uses a set of hardware and software components suitable for experimentation, together with an open repository of educational material based on the implementation of the proposed pedagogical approach. There are many open hardware platforms that could support the training framework, providing a solid basis for the development of analogous applications (e.g. Intel Edison, Raspberry Pi, Arduino Yún). The software tools are based on open source software solutions.

The second educational scenario

During the first pilot scenario (Delistavrou & Kameas, 2016) students develop an IoT terminal that recognizes wired or infrared wireless Morse code signals. The received signals are interpreted to text messages that are distributed to the web using popular messaging services, like Twitter, Viber and Skype. In the second educational scenario presented here, students realize a more complicated IoT application. The aim is to develop a mobile IoT solution that will help them browse the school library, providing them with useful information, in sound format, about book categories and books. This mobile IoT narrator is carried by its user and recognizes color tags that lay on library corridors and books. Based on the recognized color it reproduces aural tunes to inform its user. Each color code is scanned by an RGB color sensor connected to a microprocessor (Figure 1), which is powered by a power bank and has a Wi-Fi interface to communicate with local network infrastructure. Once a color tag is scanned the code of the color is sent to the school's web server via the local wireless network. There, the code is interpreted and the reply is sent to the mobile microprocessor for reproduction. There the information is read by a screen reader or played back. The user hears the message through the connected to the microprocessor headphones. In parallel a script that runs on the server collects data about books' and categories' popularity. Information that derives from collected data is visualized and presented at the school's web site.

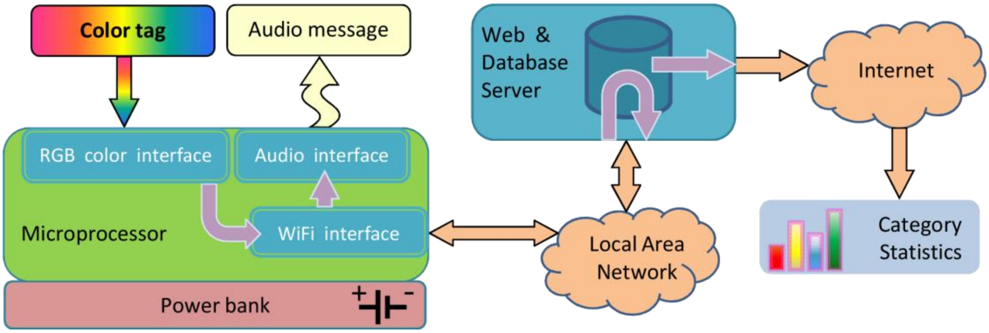

Figure 1. Block diagram of the IoT artifact developed by the educational scenario

The educational scenario refers to the subject "Informatics' Applications" of the 1st grade of the Greek General or Vocational Upper Secondary Schools. Subject's curriculum is defined in ("Government Gazette of The Greek Republic," 2014), and teaching guidelines for school year 2016-17 are set in ("Guidelines for Teaching the Subject Applications of Informatics of the 1st Grade of General Upper Secondary Schools During School Year 2016-2017," 2016). The activities of the educational scenario can be performed during the sections: Applications programming for mobile devices (Activities 1, 2, 4); Internet and Communication (Activity 3); Internet Collaboration and Security (Activity 5).

Students are already familiar with UMI technologies from the first scenario, so they are exposed to more advanced topics. Teachers facilitate learning by introducing activities, encouraging active participation, and leveraging students' motivation. The school community test-drives scenario's digital artifacts. Other stakeholders of local community participate through social media. They are introduced to UMI technologies through presentations provided by an online platform. Its materials help them realize technologies, understand the produced artifact and maximize the scenario's impact. The educational scenario aims to help students construct new knowledge, cultivate their skills and competences, as well as change their attitude towards technology. A representative subset of the learning objectives follows:

- Describe UMI technologies (Knowledge, Introductory activity).
- List UMI applications and digital artifacts (Knowledge, Introductory activity).
- Select sensors per required use (Knowledge, First activity).
- Explain the basic electricity quantities (Knowledge, Second activity).
- Label elements of your school's computer network (Knowledge, Second activity).
- Illustrate the basic structure of a static web page (Knowledge, Third activity).
- Interpret the basic structure of a dynamic web page (Knowledge, Third activity).
- Express the procedure for building an application (Knowledge, Forth activity).
- Name some rules to help you avoid plagiarism (Knowledge, Fifth activity).
- Recognize netiquette rules of good behavior (Knowledge, Fifth activity).
- Construct a circuit to drive an RGB color sensor (Skills, First activity).
- Connect a microprocessor to school's LAN or WLAN (Skills, Second activity).
- Compose a web page to accept data using an HTML form (Skills, Third activity).
- Create a simple server side script (Skills, Third activity).
- Draw circuits by using prototyping software (Skills, Forth activity).

- Prepare an SD card and install an operating system image (Skills, Forth activity).
- Develop an application using graphical code blocks (Skills, Forth activity).
- Debug an application (Skills, Forth activity).
- Summarize benefits of using databases to organize data (Attitudes, Third activity).
- Consider the potential of UMI applications (Attitudes, Forth activity).
- Dissect a greater problem into small solvable chunks (Attitudes, Forth activity).
- Utilize collaborative tools to enhance teamwork (Attitudes, Forth activity).
- Exploit media to disseminate a project or cause (Attitudes, Fifth activity).

Next, the activities and worksheets are described, along with an indicative time allocation:

Introductory activity (1h): <u>UMI technologies.</u> Students extend their knowledge of the niche technologies of Ubiquitous Computing, Mobile Computing and the Internet of Things, with an update after the first scenario.

a) WS 1: "UMIght" Cool projects made by young girls and boys like you!

First activity (3h): <u>Light sensors.</u> Students get familiar with light and color sensors. They explore their everyday use on circuits. They set up and operate an RGB color sensor connected to the used microprocessor platform.

a) WS 1: "Rea-light" The use of light and color sensors on UMI configurations.
b) WS 2: "Attach" Features of a specific RGB color sensor.
c) WS 3: "Operation" Operate the RGB color sensor and realize its data output.

Second activity (3h): <u>Mobility.</u> Students explore ways to put their configuration on the move, by using power banks and exploit wireless communications.

a) WS 1: "Power banking" Resources of energy for computing mobility.
b) WS 2: "Unplugged connectivity" Wireless communications.
c) WS 3: "WLAN" Exploiting school's local area network wirelessly.

Third activity (4h): <u>Servers.</u> Students realize the use of a web and database server as a back-end for their artefact.

a) WS 1: "Serve" The role of servers in web applications.
b) WS 2: "I would like a page, please" Requesting a page from a web server.
c) WS 3: "Databases" Organizing data using plain tables and records.
d) WS 4: "Pages a la carte" Web-serving data upon request.

Forth activity (8h): <u>IoT narrator.</u> Students put everything together to develop a trivial IoT narrator which will help them choose navigate in school library to choose books.

a) WS 1: "Think" Analysis and design of the IoT narrator solution.
b) WS 2: "Content" Create the content to be served.
c) WS 3: "Boot" Set up the microprocessor.
d) WS 4: "Cable in" Cabling and interconnection of devices.
e) WS 5: "Codename" Develop the code that runs on the microprocessor.
f) WS 6: "Construct" Work out the database.
g) WS 7: "Service" Cultivate the code of the web server.
h) WS 8: "Stress" Test and debug the application.

Fifth activity (3h): <u>Publicity.</u> Students disseminate their work with the use of web media, by blog and social posts.

a) WS 1: "News" Write a press release.
b) WS 2: "Web" Publish web pages.
c) WS 3: "Socialize" Post to blogs and social media.

Results

The participation of the students, teachers and the school community members is expected to produce several outputs. These quantitative and qualitative feedback elements are going to be analyzed to construct knowledge about the whole process. Periodical assessment measures the effectiveness of tools and activities. Data is gathered via multiple sources. Students' diagrams are analyzed about their quality, applicability, relation to the provided hardware solution. Produced source code is inspected for errors and its effectiveness. Web pages and social media posts provide input about students' involvement and commitment. Factors that reveal such attitudes are the language used, the expression of positive feelings, the number of reactions and messages. Furthermore, students reply to questionnaires before the beginning of the scenario, periodically after each worksheet or activity, and after the completion of the scenario. These are divided into two categories: self-evaluation quizzes and questionnaires for the assessment of the process, the pace, the quality of materials, and difficulties they face. The responses provide feedback on whether UMI technologies motivate them to continue their participation.

Teachers reply to assessment questionnaires and write short reports describing their experience facilitating the scenario. Their input and suggestions are an invaluable resource of feedback about the scenario and the proposed tools and technologies. Their experience is going to help us establish the good practices and strengthen methodology's weaknesses. Community's involvement is measured via its involvement and engagement to the social networking facilities of the scenario, the number of visits to the web pages, the number of posts, and the number of reactions to posts. An extra questionnaire is addressed to the school community members for feedback and suggestions. The community members assess the produced artifact; its usability, viability and propose alterations and ways of exploitation. They are asked to respond to a short questionnaire on their opinion about the project and possible ideas for its exploitation in school classes and other activities.

Discussion

A major advantage of the methodology under development is the exploitation of modern open hardware and software solutions to assist students in learning about UMI technologies. Its added value is the hands-on approach of education, following the "learning by doing" and "learning to learn" paradigms. A dynamic framework for exploring UMI technologies is provided, emphasizing positive and negative aspects. Youngsters will play the role of solution designers and developers, addressing technological challenges and trying to find joint solutions through collaboration and socialization. They have a first-class opportunity to delve into the most recent Computer Science technologies.

The research provides advantages in formal and informal education in STEM. It establishes a repository of UMI technologies and know-how, supporting their integration in the educational process. An important achievement is that it concerns field research, realized in real educational environments. It produces materials relating to students and schools, with possible extensions to local community. Implementing innovative projects based on real needs points the active role of STEM and Information and Communication Technologies in society.

Next steps of the research include various actions. A set of research question has risen by the initial bibliographical survey. To answer them a comparison of European secondary Computer Science curricula is performed to help us define the topics that could be enhanced using UMI technologies, and construct a pilot curriculum for introducing UMI technologies as learning objects. A similar investigation for tertiary institutes will follow. The contribution of UMI technologies on the improvement of learning strategies is planned as well.

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