STEM Education using Mobile Computing and Internet of Things

Konstantinos Delistavrou[1,3], Ioannis D. Zaharakis[2,3], Achilles D. Kameas[1,3]

[1] Hellenic Open University, School of Science & Technology, Greece
[2] Technological Educational Institute of Western Greece
[3] Computer Technology Institute and Press "Diophantus", Greece
kostas.delistavrou@ac.eap.gr, jzaharak@cti.gr, kameas@eap.gr

Abstract

State of the art technologies, like Ubiquitous Computing, Mobile Computing and the Internet of Things (referred to as UMI) can become educational means and subjects, leveraging innovation and supporting ambitious scientific careers. The UMI-Sci-Ed project investigates the introduction of UMI technologies in education. It exploits them to offer novel educational services, by implementing innovative pedagogies and enhancing creativity, socialisation and scientific citizenship of students and teachers. Inspired by M. Weiser's idea (1993), a tranquil environment for educational activities is provided, where technology assists the process of education. Communities of Practice, including representatives of industry, business and society, are dynamically formed around UMI projects implemented at schools, to further promote Science, Technology, Engineering and Mathematics (STEM) education of high school girls and boys and make attractive the prospect of pursuing a career in UMI domains.

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

1. Introduction

State of the art technologies of Ubiquitous Computing, Mobile Computing and the Internet of Things, (hereafter referred to as UMI), constitute the most recent and explicit attempts towards a pervasive technological support of everyday life, beyond the mere use of tools. Advancements in processing power, broadband networking, software development, databases, visualization tools, and collaboration tools make possible the development of devices, services and applications that permeate all sectors and activities and eventually change the way we live and learn (Kameas, 2010).

In parallel, the economic crisis in Europe imposes the broadening of the political and social support to science and technology. The European society is knowledge based, therefore it should cooperate with the scientific society for the establishment of more responsible scientific practices and the development of citizen-centric policies. This "Responsible Research and Innovation", as it is termed by the European Union, is expected to enable better alignment of research products with the values, needs and

expectations of the European society. New talents should be engaged with science, in order to cultivate it and promote excellence, since science and technology are in great need of ideas and talent. Science should be made charming to youngsters of all genders. Society should be aware of scientific advancements and be involved to innovative activities.

A basic factor for such a reform is education. Adequately educated citizens are able to follow scientific advancements, leverage open access data and contribute to evolution. Under this scope, UMI technologies present themselves both as educational means and subjects, reforming the practices of learning, affecting the practices of teaching and becoming the vehicle for the development of robust careers in science education (Dede, 2008).

In recent years there is an increase of innovative activities, in schools and other communities, promoting Science, Technology, Engineering, and Mathematics (STEM). These activities constitute a stark indication of the rising interest about STEM education. Nevertheless most of them are being run by small groups with narrow focus and limited impact. Even the members of small communities are not aware of their existence and evolution.

In this context the research project "UMI-Sci-Ed: Exploiting Ubiquitous Computing, Mobile Computing and the Internet of Things to promote Science Education" of the Horizon 2020 programme focuses on scientific citizenship, and youngsters' creativity to promote innovative pedagogical approaches on STEM education. Emphasis is given on gender equity and accessibility to activities, in an effort to attract young people in science, providing solutions to the challenges which emerge in the prospect of a career in STEM. The main aim of the project is to develop an integrated, yet open educational environment for 14-16 years old students, based on selected methodological processes and UMI applications. The environment consists of a repository of educational material, media and educational activities, an online social computing platform to support formation and management of Communities of Practice, training, reporting, self-evaluation, and mentoring.

The project is funded by the European Committee under action's "H2020-EU.5.a. - Make scientific and technological careers attractive to young students, and foster sustainable interaction between schools, research institutions, industry and civil society organizations" sector "H2020-EU.5. – Science with and for society". The coordinator is the Computer Technology Institute and Press "Diophantus". Other participants of the project's consortium are: the Cork Institute of Technology from Ireland, the Consortium Ubiquitous Technologies S.c.a.r.l. and the Universita Di Pisa from Italy, the Helsingin Yliopisto from Finland, the Norges Teknisk-Naturvitenskapelige Universitet from Norway, and the Telecentre-Europe AISBL from Belgium. UMI-Sci-Ed project was launched in June of 2016.

The project's main goal is to offer a meta-level of solutions for the interconnection of school, society, business and tertiary initiatives (such as educational visits to companies, conferences, mentoring, sponsorships, etc.). Another goal is the promotion of a model for the multiplication of its impact, from a source group (e.g. students participating in STEM competitions), to the target group (e.g. the entire school population). The most effective way to achieve these goals is to build Communities of Practice, based on active clusters where a part of the knowledge already exists.

2. Methods

Educational projects promoting creativity, competition and innovative educational activities in science, are of key importance for the nurturing of future citizens to actively participate in research and innovation processes, to make choices taking into account available information, and, as a result, to participate in a democratic, knowledge-based society. In this context, it is necessary to turn to innovative and effective methods. UMI-Sci-Ed aims at increasing the attractiveness of science education and the interest of young people in STEM.

The proposed training framework focuses on STEM, using technology as the subject of interest and as an experimentation tool, supported by Communities of Practice. By carefully utilizing state-of-the-art technologies in order to design educational tools and activities, the project offers new educational services with the application of innovative pedagogical methods, for the sake of enhancing creativity, socialization and the identity of "citizen of science". The innovative efforts of UMI-Sci-Ed are based on the following principles:

- Design UMI applications that embody a comprehensive learning environment for 14-16 years old girls and boys.
- Offer knowledge management schemas, such as Communities of Practice for the exploration of domains, practices and information that are important for communities.
- Place emphasis on outcome based learning, social constructivism and educational design principles, as means for the creation of a learning ecosystem.
- Focus on problem solving, scientific citizenship, leadership, learning by doing, communication skills.
- Concentrate on helping students define their personal goals and monitor their progress through activities and milestones.
- Design and develop guidelines for the production of educational material at micro, middle and macro level of educational and technological skills' coverage.

It is very important to ensure that learners become efficient in turning knowledge and skills acquired into professional competences. They should adopt a "culture of creation" to bridge theory with practice. Since new technologies are often abandoned, an approach of co-creating with participants the training toolkit is prioritized. Another important factor is the promotion of pilot activities for the exploration and validation of technical, pedagogical and innovative community based approaches.

To be flexible and effective, the development methodology of UMI-Sci-Ed follows the principles of AGILE instructional design, which, according to Gottfredson & Mosher (2010), is based on the need of modern organizations for adaptability. It involves five areas: Align, Get set, Implement and Iterate, Leverage, Evaluate. Since the students must be prepared to address the requirements of a constantly changing business environment, the design of educational activities and content is evaluated and adjusted dynamically through this iterative process. Field research will be conducted in real educational conditions. High schools in Norway, Finland, Ireland, Italy and Greece will host the workshops and developed activities. The research sample includes five schools from each country and 24 to 30 students per class. There is also the intention that certain meetings of the Communities of Practice be hosted by companies, in order to create a robust link with the market. The business sector has a critical role in shaping technological communities: businesses will participate as experts in CoP schemas to provide information and guidance on addressing complex issues of UMI technologies. This will be the springboard for social networking and the establishment of collective business intelligence.

Educational research includes a mix of quantitative and qualitative methods, in accordance with the assessment carried out in different phases, capturing the effectiveness of tools and activities. Interviews, questionnaires and focus groups will be used to gather data. The pilot testing of the integrated learning environment will be implemented by young participants of the project, their teachers, business executives, academic-experts and designers of educational material.

This approach is carried out through a series of interconnected activities (research, pilot projects, dissemination and initial commercial exploitation) that contribute to the achievement of the main objectives of the project:

1. Novel educational services.
2. Career consultancy services.
3. Supporting software tools.
4. Supporting hardware tools.
5. Dissemination of the project ideas and results.

Research and development activities include the study, design and implementation of the pedagogical-educational approach based on Communities of Practice, as well as on design and development of software and hardware supporting tools.

The UMI-Sci-Ed project focuses on three axes: content knowledge, skills and attitudes.

- Content knowledge involves association with concepts such as the Internet of Things, Ubiquitous Computing, Privacy, Cloud Computing, wired and wireless communications and networking, sensor and actuator networks.
- Skills include hardware assembling, planning, effective literature and web search, teamwork, brainstorming, creative thinking (new ideas based on a set of predefined tools), goal setting, problem recognition and solving, basic project management (project organization, splitting to tasks and task leading, follow ups, evaluation), reporting and presentation skills, etc.
- Attitudes and expertise on learning by doing, peer learning, innovative products and services implementation, UMI application methodology comprehension, creative expansion of the effectiveness of pervasive technologies, increase motivation and self-esteem in the production of technologies or applications from scratch, in an effort to meet the requirements of multidimensional STEM careers.

Educational material is going to be constructed using simplified scientific language. The training is designed and developed with the aspect of popularizing STEM. The endeavor to communicate with young Europeans, regardless of gender, economic or social status is going to be expressed in multiple fashions, even by introducing famous men and women scientists as role models. The project will provide a number of model UMI scenarios to assist teachers in understanding and guiding the educational process, as well as to inspire students create their own applications.

The training framework is supported by a package of hardware components suitable for experimentation, implementation of the proposed pedagogical approach, and intrigue in STEM. This “Swiss Army knife” kit is especially designed for the needs of the project, compatible with similar solutions and infrastructure, with a “Wallet” of exploiting services, available on the internet, on private and public clouds, even being compatible with future infrastructure, since it will respect current standards (Satyanarayanan, 2005). The toolkit consists of a set of components in a metal toolbox that will be distributed to each school. The solution is based on the Internet of Things technology, to provide a solid basis for the development of analogous applications. The main components include:

- Microprocessor UDOO Neo Full (Figure 1), bearing a rich set of ports, interfaces, and sensors. It is compatible with Arduino microcontrollers and supports Android and Linux operating systems.
- UDOO sensor/actuator package of sensors, motors and other electronic components.

- Data Storage Service. A database of topology and network settings of the artifacts that students will develop.
- End-user interface to implement operations such as registering and grouping of the Internet of Things devices, remote access and viewing online data collected by each sensor of networked things. The end user interface will be available for a wide variety of devices.
- Programming environment that gives every student the opportunity to interact and regulate the microprocessor.

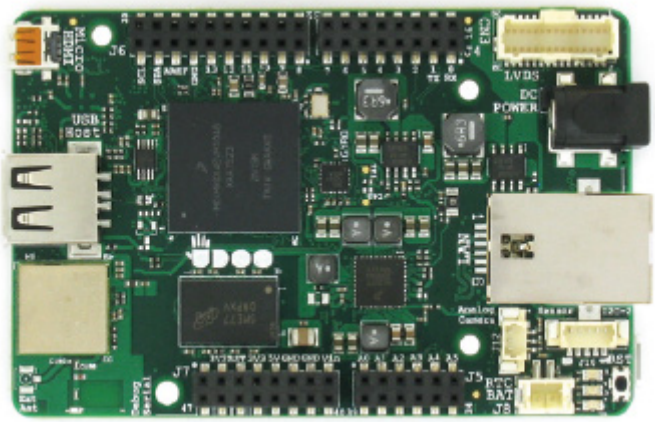

Figure 1. *UDOO Neo Full microprocessor (UDOO, n.d.)*

The supporting software tools are designed in order to support: a) formation and management of Communities of Practice using social networking tools, b) provision of educational material about UMI technologies, c) delivery and support of UMI and entrepreneurship training, d) demonstration of UMI projects and results developed by the students, e) self-evaluation tests regarding the prospects of a UMI career, f) peer learning and mentoring, g) tagging and linking of content and data, h) educational scenarios and artifact analysis, i) information extraction, management and dissemination of the produced knowledge, and j) participatory and instructional design mechanisms.

The supporting hardware and software tools, along with the students' projects form an integrated training framework consisting of: a) an open repository of educational material on UMI technologies, b) means of self-education, training and evaluation, and c) a set of training activities, along with the necessary hardware and software tools, that will allow the education community to implement UMI scenarios in real world conditions.

3. Results

The results of the UMI-Sci-Ed project are expected to substantially contribute to the impact of the Horizon 2020 programme. By leveraging leading innovation the project provides advantages in formal and informal education in STEM and contributes to its integration in society and industry. New methods to promote career planning will be created and validated, while motivating young people through their participation in a technologically and educationally innovative project. UMI-Sci-Ed will create a repository of UMI technologies and knowledge and support their integration in the educational process. The most important achievement is that this will be realized through Communities of Practice, in real educational conditions, so as to create a meta-level of solutions that keep pace with the creativity and ingenuity that pre-exists in schools and other communities.

New career counseling models will be developed. An aim is to produce new knowledge about how counseling models could be viable and sustainable, in environments with many, frequently interchanging participants. UMI-Sci-Ed will produce material relating to students, schools and the local community, giving them the role of co-creator and implementing innovation projects which are based on real needs, defining the role of STEM and ICT in the sector of active solution provisioning.

A knowledge base of the best practices, challenges and shortcomings of UMI technologies, tools and schemes will be built. Particular emphasis will be given on how these approaches could encourage and support training actions. This is expected to contribute to the creation of resistant forms of communities that will have tools to survive in an environment characterized by the high turnover of project participants, such as students, volunteers and other stakeholders.

The development of Communities of Practice creates communication channels between STEM activities and innovation activities, contributing to the development of partnerships between academia, education, society and industry. Communities of Practice will create and maintain knowledge repositories to strengthen cooperation potential. The exploration of the way the industry is involved with Communities of Practice is expected to enable pathways for the co-creation of innovative solutions that may lead to the development of new commercial products.

Nowadays there are many development programs related to social changes at local level. It is also common for students to be engaged to STEM and innovation projects, but with limited impact. UMI-Sci-Ed will try to combine isolated actions in order to create a collective repository based on Communities of Practice. This may gradually become a social knowledge base on UMI and STEM technologies, which will include quantitative and qualitative data on social change, environmental protection, sustainability, cultural heritage, social inclusion, health and well-being. The project will set

the framework for linking communities with the content and the methods to enhance and exploit this "social knowledge base".

4. Discussion

A major advantage of UMI-Sci-Ed project is the exploitation of state-of-the-art however budgetary open hardware and software solutions for the involvement of teenagers in learning UMI technologies in practice. The project's added value is the hand-on utilization of educating by the "learning by doing" and "learning to learn" paradigms, for the deployment of conceptual foundations upon UMI technologies and Communities of Practice Schemes (Wenger, 1998, Wenger et al, 2002). By exploiting the dynamics of Communities of Practice schools and other relevant organizations may form higher-level partnerships.

UMI-Sci-Ed will provide a dynamic framework for using UMI technologies emphasizing their positive and negative points. New career counseling standards are expected to arise via initiatives aimed at the production and preservation of knowledge. Young people will find themselves in the position of the developers of integrated hardware and software solutions, addressing technological challenges and trying to find joint solutions. Thus they will cooperate and socialize in real conditions.

Project partners have an important role to perform. They will provide pedagogical support and guidance for the development of educational material, the composition of educational activities, piloting in schools, evaluation of tools and results, development and establishment of the educational platform. Nevertheless the soul of the project is the youth of Europe. We hope to inspire girls and boys to explore the most recent technologies and exploit their potential. We need young people to be active citizens of science and technology, adopt the culture of learning in practice, cooperation, civic engagement, and pursue STEM careers, contributing their talents to excellence. This is the biggest challenge for the partners of UMI-Sci-Ed.

References

Dede, C. (2008). Theoretical Perspectives Influencing the Use of Information Technology in Teaching and Learning. In J. Voogt & G. Knezek (edit.), *International Handbook of Information Technology in Primary and Secondary Education*, vol. 20 (p 43–62). New York: Springer.

Gottfredson, C., & Mosher, B. (2010). *Innovative Performance Support: Strategies and Practices for Learning in the Workflow* (1st edition). New York: McGraw-Hill Education.

Kameas, A., Towards the Next Generation of Ambient Intelligent Environments. In *Proceedings of 19th IEEE International Workshops on Enabling Technologies: Infrastructures for Collaborative Enterprises (WETICE 2010)*, June 28-30, 2010, Larissa, Greece, 1-6.

Satyanarayanan, M. (2005). Swiss army knife or wallet? *IEEE Pervasive Computing*, (2), 2–3.

UDOO. (n.d.). *All-in-1 ARM Cortex Embedded Development Board | UDOO Neo*. Retrieved from http://www.udoo.org/udoo-neo/

Weiser, M. (1993). Ubiquitous Computing. *Computer*, 26(10), 71–72.

Wenger, E. (1998). Communities of practice: learning as a social system. *The Systems Thinker*, 9(5). Retrieved from http://skat.ihmc.us/rid=1227187866819_1140452997_15052/communities%20of%20practice_wenger.doc

Wenger, E., McDermott, R., and Snyder, W., (2002) *Cultivating communities of practice: a guide to managing knowledge*. Harvard Business School Press.

Περίληψη

Τεχνολογίες αιχμής, όπως ο Διάχυτος Υπολογισμός, ο Κινητός Υπολογισμός και το Διαδίκτυο των Πραγμάτων (UMI) μπορούν να αποτελέσουν εκπαιδευτικά μέσα και αντικείμενα, στηρίζοντας την καινοτομία και φιλόδοξες επαγγελματικές/επιστημονικές σταδιοδρομίες. Το έργο UMI-Sci-Ed ερευνά την εισαγωγή των τεχνολογιών αυτών στην εκπαίδευση. Τις αξιοποιεί για να προσφέρει νέες εκπαιδευτικές υπηρεσίες, εφαρμόζοντας καινοτόμες παιδαγωγικές και ενισχύοντας τη δημιουργικότητα, την κοινωνικοποίηση και την επιστημονική ιθαγένεια μαθητών και καθηγητών. Εμπνευσμένο από την ιδέα του M. Weiser (1993), παρέχει ένα ήπιο περιβάλλον εκπαιδευτικών δραστηριοτήτων, όπου η τεχνολογία απλά επικουρεί τους συμμετέχοντες στην εκπαίδευση. Δημιουργούνται Κοινότητες Πρακτικής για τις ερευνητικές εργασίες UMI που υλοποιούνται σε σχολεία, συμπεριλαμβάνοντας εκπροσώπους της βιομηχανίας, των επιχειρήσεων και της κοινωνίας, για την προώθηση της εκπαίδευσης στις θετικές επιστήμες, την τεχνολογία, τη μηχανική και τα μαθηματικά (STEM), σε κορίτσια και αγόρια γυμνασίων και λυκείων, κάνοντας ελκυστική την προοπτική σταδιοδρομίας στους τομείς των τεχνολογιών UMI.

Λέξεις κλειδιά: Διάχυτος Υπολογισμός, Κινητός Υπολογισμός, Διαδίκτυο των Πραγμάτων, Εκπαίδευση STEM.