The UMI-Sci-Ed Platform: Integrating UMI Technologies to Promote Science Education

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Abstract: Currently, there is a growing research interest on emerging technologies, such as, ubiquitous computing, mobile computing and the Internet of Things (IoT), collectively mentioned as UMI technologies. The proliferation of UMI technologies will not only change the way we live but can also offer new learning opportunities. At the same time, there is an increasing need for skills that are associated with the UMI domain in the labour market. The Umi-Sci-Ed is an EU project which explores ways to shed new light into this training aspect by introducing several model educational scenarios that incorporate UMI technologies, in order to cultivate relevant competences on high school students. This paper reports initial results achieved in this context. In particular, we give an overview of the key components of the UMI-Sci-Ed platform that aims to support the activities of Communities of Practice involved in STEM education. Students through a mentoring mechanism are provided with training material, IoT hardware kits and software tools to explore UMI technologies through hands-on activities. In this framework, example educational scenarios and the corresponding UMI applications developed are presented. The hypothesis is that the learning process can be empowered by using such UMI applications as students are provided with meaningful opportunities to participate in the learning process such as in terms of building applications that are relevant to the subject they like and having active interactions within student groups in a way that practical experiences can provide them a rich context to grasp scientific knowledge. Finally, the results of a preliminary evaluation of the proposed approach in the context of an educational workshop are discussed.

1 INTRODUCTION

As the quality of school education in science and mathematics has become an important asset, the society is actively communicating and cooperating with the scientific community for the establishment of responsible scientific practices in order to enable the structuring of citizen-centric policies (Cavas, 2015). The ultimate aim is to recruit new talents for science, technology, engineering and mathematics (STEM) domains as well as to fertilize and further promote excellence. On the other hand, Ubiquitous Computing, Mobile Computing and Internet of Things (UMI) are state-of-the art technologies that emerge both as educational means and as support mechanism for developing powerful careers in STEM domains (Delistavrou & Kameas, 2017).

In the meantime analysis of Eurostat data on STEM employment indicates that in the next ten years, there will be 8 million new STEM jobs in the EU (Brzozowy et al., 2017). Consequently there is an urgent need to establish new learning and training programs in a more interdisciplinary form which embraces transversal competences and career consultancy (Mavroudi & Divitini, 2017).

The Horizon 2020 UMI-Sci-Ed project (http://umi-sci-ed.eu/) focuses on the investigation of the introduction of UMI technologies in education, putting these state-of-the-art technologies in practice, so as to make attractive the prospect of

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pursuing a career in domains pervaded by UMI. In order to realise this aim, UMI-Sci-Ed provides a collaborative environment for educational activities, where technology itself will not star but support the stakeholders of education, including, the educational community, the industry, career consultants and educational authorities and policy makers. To this end, Communities of Practice (CoPs) will be formed dynamically around UMI projects implemented at schools, including representatives of all necessary stakeholders. UMI-Sci-Ed aims to deliver:

- A set of educational services in the context of a training mechanism for young students, containing guidelines for UMI learning under the CoPs format, roles and structures.
- A set of career consultancy services by conducting piloting UMI-Sci-Ed activities and scenarios using CoPs and UMI and linking the market needs to the project stakeholders through the UMI-Sci-Ed software platform.
- An open-source software based learning environment as a facilitating mechanism for UMI learning in the science education in order to support all stakeholders to form CoPs.
- A range of hardware supporting tools that includes low cost modular hardware kit and several peripherals, packaged in handy suitcases that will be delivered to selected schools for the fast prototyping of new artefacts and for the teaching and promoting the UMI technologies.

All the above are aligned with the open access to scientific publications and to research data EU policy and conformed to ethical principles and data protection legislation based on EU guidance on responsible research innovation.

The remainder of the paper is organised as follows. In the next section we present the key components the UMI-Sci-Ed platform in terms of the CoPs model adopted, the hardware and software tools integrated, the on-line services provided and the portal navigation design. A justification of the services integrated based on the CoPs theory is attempted. Next we discuss the approach we followed to create model UMI educational scenarios and give example scenarios and UMI applications. The advantages of the proposed approach are laid out, especially in the setting of a secondary education system via a preliminary evaluation of the approach in the context of a local school. A discussion on related work is also provided.

2 UMI-SCI-ED PLATFORM

2.1 Communities of Practice (CoPs)

Social networking and its power in shaping a new dynamic educational landscape of 21st century has become a key factor for emerging teaching and learning modalities, based on collaborative features. Closely linked to organizational learning and Knowledge Management schemata is the framework provided by Wenger et al. (2002) on CoPs, as "groups of people that cohere to through sustained mutual engagement on an indigenous enterprise, and creating a common repertoire". The term is based on *legitimate peripheral participation* (Wenger et al., 2002) which emphasizes the informality of learning through social interaction rather than by a planned, rather mechanistic process of cognitive transmission. The message conveyed by the CoPs theory is that even in apparently routine or unskilled work, there is a large amount of interaction and sense making in completing the task(s) involved.

There is an extensive literature on the benefits and the impacts of establishing and maintaining CoPs (McDermott, 2000; Wenger et al., 2002; Snyder & Brigg, 2003), however their value could be summarized in: a) providing access to new knowledge; b) fostering trust and a sense of common purpose; c) generate knowledge and encourage skills development; d) disseminate valuable information and transfer best practice; e) initiate new lines of business including new products and services; f) decrease the learning curve for new practitioners or employees; and g) help companies recruit and retain talent.

CoPs continue to be explored as ways to build capacity in schools to impact student achievement as well as organizational practitioners. The model by Wenger et al. (2002) in this context is based on social learning; participation is voluntary, membership can be self-selected or assigned, based on the expertise or a passion of the topics. Leadership comes from both formal and informal leaders while organisation values innovation and knowledge sharing; knowledge sharing occurs mainly within the community. Under this model the designed and developed learning environment had to incorporate the basic array of CoPs framework tools to achieve, knowledge presentation, communication and collaboration; however in our approach, the strategic decision has been to design a simple but robust structure supporting CoPs avoiding to finally structure the educational environment before taking into consideration members' interaction and launching of pilot activities. For that reason, knowledge management and collaboration tools are incorporated in the UMI-Sci-Ed platform.

In UMI-Sci-Ed CoPs case, a major part is to inventory existing processes and then refine those processes through collaboration among UMI-Sci-Ed stakeholders. The collaborative practices that practitioners, as CoPs members, learn to use will enable them to share knowledge and disseminate best practices within their organisation and other agencies; UMI-Sci-Ed CoPs are expected to create, develop and disseminate new tools, systems, resources based on applications developed via UMI technologies. For creating and supporting the UMI-Sci-Ed CoPs we have selected the model by Snyder & Brigg (2003), as composed by the following phases: a) discovering the potential, b) coalescing, c) maturity/growth, d) advocacy/stewaderhip, and e) transformation. Each stage has a number of associated goals and activities or tasks. Identifying issues that the CoPs will address, identifying the target population, defining the roles and processes of involving key stakeholders, recruiting participants and identifying key content for CoPs are important actions on following the aforementioned stages.

The UMI-Sci-Ed platform, therefore, is intrinsically grounded on the concept of CoPs. For the educational scenarios and the corresponding applications developed using UMI technologies and discussed in this paper the CoPs model is demonstrated by the participation of students, their teachers and mentoring UMI domain experts.

Exchanging of practices and experience, problem solving activities regarding the design and development of open software applications based on IoT toolkits, reflection on current practices and problems arising throughout the European teachers' teaching practices, establishing liaisons between the school and corporate sector through involvement in projects around UMI technologies have been defined as basic goals of the recently launched UMI-Sci-Ed platform to support CoPs activities. High school students also are going to be involved as future engineers in designing and developing projects based on specific educational scenarios; the structure and format of educational scenarios has been selected as the springboard for further leveraging CoPs, triggering interaction among practitioners of academia, corporate and school sector.

2.2 IoT Toolkit

To support training in the UMI domain a low-cost hardware toolkit is used. It includes a Single Board Computer (SBC) with an integrated microcontroller and several peripherals such as sensors and actuators. The hardware kit is accompanied by a programming environment that enables young students to realize their ideas, putting theory into practice. Provided hardware kits, packed into proper suitcases, will be donated to, selected schools for teaching, educational experts for the development of educational scenarios, and other stakeholders for dissemination.

The final hardware kit is composed by: (a) UDOO Neo Full SBC (https://www.udoo.org/udoo-neo/), (b) a micro SD card with GNU/Linux OS pre-loaded, (c) USB Kit for UDOO Neo, (d) a micro-HDMI to HDMI cable, (e) a breadboard, (f) jumper cables, (g) push-buttons, (h) a monochrome LED matrix module, (i) a micro servo motor, (j) a mini PIR motion sensor, (k) a set of blue, red, yellow, green, RGB LEDs, (l) a set of resistors, (m) a potentiometer, (n) an Infrared (IR) LED, (o) an IR phototransistor, (p) a sensor of temperature and humidity, (q) a light sensor (LDR), (r) an ultrasonic ranging module, and (s) a gas sensor module.

The programming environment complements the hardware toolkit and is going to be used to perform the activities of the educational scenarios developed by UMI-Sci-Ed research community. The UDOO Neo Full SBC is able of operating by either the GNU/Linux, or the Android operating systems. Its official operating system is UDOObuntu, a GNU/Linux distribution based on Ubuntu 14.04 LTS, equipped with some added software components, like the Web Control Panel (WCP). The WCP utility is accessible via a web browser. It is designed to help users configure the SBC, develop basic projects, and explore provided documentation. WCP supports Ardublockly, a visual programming editor for Arduino sketches. Students can develop microcontroller applications by dragging and dropping visual blocks, instead of typing statements. Environment's blocks collection is being enhanced with extra blocks representing specific components used in UMI-Sci-Ed educational scenarios.

2.3 Software Platform

In the context of the defined characteristics of the CoPs framework discussed above such as domain, community and practice, UMI-Sci-Ed platform tools had to be aligned with these characteristics so as to cater for an array of members' and community's needs: e.g., content management, communication and collaboration. Identifying the body of knowledge in such an important field as UMI has been important in the sense of incorporating a variety of content presentation and sharing tools, in the repository of UMI-Sci-Ed platform. Coaching and mentoring processes are also quite important in the sense of building these through simple but flexible tools such as collaboration and teleconferencing tools. The first version of the UMI-Sc-Ed platform strategically involves simple and practical IT tools; however, the actual use of the UMI-Sci-Ed platform environment during the launched pilot activities is expected to lead to the environment's expansion based on already selected and more sophisticated tools; as time evolves, new information will be introduced as well as new ideas and techniques that could be incorporated into the practice.

Therefore, the software platform[1] offers a number of services which effectively support the formation and management of CoPs using collaboration tools such as forums, blogs, wikis and access to social media. The platform repository includes various forms of content such as UMI projects and results developed by the students, research results on educational approaches and methodologies, links to tools for information extraction, management and diffusion of the produced knowledge.

The portal is the front-end of the platform providing an interaction space for all stakeholders. The approach of a user's dashboard is followed (Figure 1) where user's information is clearly provided and is associated with relevant content (created by the user, recent used content, etc.).

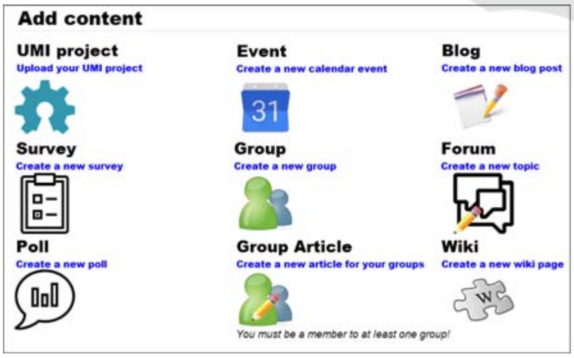

Figure 1: UMI-Sci-Ed portal UI.

The "UMI project" content type allows users to upload to the platform their UMI projects or download projects created by other groups. Each UMI project has a number of specification fields to assist searching and comprehension of the corresponding applications: title, tags, short description, difficulty level (easy, intermediate and advance are the possible values), learning outcomes, hardware required for the development of the project, photos, YouTube video (about the project), source code, rating (users can rate the project, 1 to 5 scale), other documents (any other files related to the project), and related content (users can create links to other content of the platform, related to that UMI project).

UMI-Sci-Ed software platform is developed using open source technologies such as HTML, PHP, JavaScript and MySQL. The core of the platform is based on Drupal 7, an open source CMS with a variety of contributed modules and themes from the community. Platform's user interface is based on the Bootstrap 3 theme for Drupal. Bootstrap 3 themes provide a clean, lightweight and responsive user interface, so the users can access platform's services also from mobile devices.

2.4 Services

Problem oriented project pedagogy (POPP) is a pedagogical framework that incorporates a series of integrated didactical principles as the basis for the design of the learning environment: problem formulation, enquiry of exemplary problems, participant control, joint projects, interdisciplinary approaches, and action learning (Dirckinck-Holmfeld, 2002). In this pedagogical approach, the learning is situated, meaning is created from the real activities of daily living and working, and knowledge is created in and through working together with a common purpose. POPP requires that the participants in the learning environment engage in a shared enterprise through the process of problem formulation and solution, and develop a shared repertoire of actions and discussions. This framework takes into consideration pedagogical, technological and sociability issues that are important in establishing functional CoPs (Barab et al., 2002). Participants' roles and responsibilities can vary between central and peripheral, participation based on their degree of knowledge, interests, and experience with a particular problem and project. As such, it is a vehicle for the development of CoPs and interdependencies among the participants

The UMI-Sci-Ed platform offers services that are aligned with the POPP framework and support the goals of many different user roles according to their requirements as well as the CoPs literature.

Content Management Services. Content and media sharing are central to the operation of CoPs.

[1] https://umi-sci-ed.cti.gr

Therefore UMI-Sci-Ed platform supports various forms of content management from typical file organization in folders to metadata annotated resource filtering. Given the large amount of data the UMI-Sci-Ed needs to handle it is required to provide the proper functionality to organize and navigate such kind of content. In UMI-Sci-Ed the following content management services are supported:

- Management of educational content
- Management of student project specification and results
- Management of UMI app store
- Management of career opportunities/advertising
- For all the above categories of content management metadata editing is a provided feature especially for large document repositories.

Besides content management other collaboration services are evolved around content. Several such services are included in UMI-Sci-Ed platform:

- Collaborative document authoring
- Collaborative UMI app authoring
- Manage discussion forum content
- Manage blogs/microblogs content
- Manage wikis content.
- Support social bookmarking
- Import on-line content libraries

Project Coordination Services. Here we have services that implement the project management module that support the creation of a project, allocation of tasks including documents (e.g. the informed consent of the participants) and organising activities with relevant information. Managing a calendar of events is mandatory so that all CoPs members can be informed of scheduled tasks and find information on previous tasks and meetings. Each user can add a new event to the platform and can visit the calendar section where all events are presented. Access rights can be also defined i.e., for a new event a user could set the group audience and visibility properties so that the calendar's view can be only seen by members that have access rights.

Evaluation of tasks and project milestones assessment are also provided. Since the participants in a project may create artefacts to solve problems of practice various decision making tools can be used to assist this process (e.g. rank ideas, establish consensus, systematically analyse information through series of steps).

Member Feedback and Research Services.
CoPs workings are facilitated by allowing their members to provide feedback in the form of rating a type of content, providing comments, and finding information according to the ratings and access frequency of their colleagues. For a large content repository, like the UMI-Sci-Ed repository, such feedback can be a powerful service to quickly discover the most appropriate content (e.g. a UMI project with specific characteristics and rating) and assist the comprehension on the details of development and usage of such a content.

Polls and surveys services are provided to facilitate participation to the workings of a community task from a broader group of users. Different types of questions are supported such as select options, likert-scale, and date and text fields. Analysis of the results is also provided (number of submissions per component value, calculations, and averages).

Social Media Sites Services. Although content management systems such Drupal Commons provide basic services to build social networking capabilities within the UMI-Sci-Ed platform mainstream social media such as Facebook and Linkedin could also be exploited by CoPs for their collaboration and interaction. As a design decision, a mix of both worlds can bring more benefits where the basic activities are supported by the platform and in addition some discussions and activities are extended into external social networking systems. Some of the mainstream platforms (e.g. Facebook) support programming linkages to their systems through Application Programming Interfaces (APIs) to allow custom integration.

Supporting Utility Services. A number of supporting utility services are provided in the UMI-Sci-Ed platform:

Login: Allowing user authentication either in the traditional way or login via Web-wide authentication services (e.g. authentication from social networking sites such as Facebook, Twitter, and Linkedin). Existing open standards are used such as OpenID or OAuth.

Access rights setting: Different roles may have different access rights on the stored content.

Characterize content visibility: A key feature of this service is a versatile set of access controls that facilitates imposing a variety of privacy policies. The dynamicity of the environment allows for setting access permissions on a fine-grain level allowing a post to be shared to a specific group of users and the next one to be shared with all the participants of a network.

Notification receive: Notifications are important for the operation of an active CoP. Various forms of notifications are supported such as e-mails, SMSs and social network notifications.

Web metric reports: Metrics reports provide information about the ways visitors (members and non-members) access, use, and benefit from CoPs content. At the initial stage of evaluating UMI-Sci-Ed platform, it is important metrics reports to provide statistics on the number of new members, total number of page views, average number of page views per visit, average number of messages posted per week, total number of messages posted, etc.).

Submit UMI app to execution: Instead of the user downloading a UMI project, this is an advanced feature that is supported by the platform's middleware where the user can submit remotely the application to the h/w platform.

2.5 User Interaction Design

User interaction design took into account five key dimensions which also constitute the evaluation criteria for the platform's usability tests during the pilots:

Navigation: Refers to the specification and assessment of all the necessary tools and facilities (e.g., navigation menu, search mechanisms, links, etc.) that assist the navigation of users through the UMI-Sci-Ed platform, enabling them to reach the needed information and services quickly and effectively.

Organization: Refers to the structure of platform's content which is divided into logical and unambiguous groups. Each group contains related information. The structure of the portal is made simple and operational. There are 3 main working areas: main navigation menu; user's menu containing links to login/registration, etc.; and content area where the actual content of the platform is presented. The structure of the content enables the application of simple rules such as the three click rule (no more than three clicks to access content) and one click rule (no more than one click to contribute content).

Ease of Use and Communication: Refers to the cognitive effort required to use the UMI-Sci-Ed portal and to the availability of useful information which facilitates communication with the administrator and the leaders of the various community groups. The approach of a user's dashboard is followed where user's information is clearly provided and is associated with relevant content (created by the user, recent used content, etc.). This approach allows easy interaction with the portal by different groups of users.

Design: This refers to the aesthetics of the portal design which includes the suitable design of portal's areas and pages, and the proper use of photos, images, fonts and colours. Finally, page layout and style is consistent throughout the portal.

Content: Refers to the assessment whether the portal provides the information required by the users. For example, educational information and scenarios need to be up-to-date and often updated with relevant information. The information should be sufficient and relevant to CoPs needs, e.g. content is clear and concise, terms are unambiguous.

3 UMI-SCI-ED EDUCATIONAL SCENARIOS

3.1 Scenario Structure

The use of educational scenarios is quite broad, targeted at all levels of typical and vocational training education and training. There are limited examples of extending STEM curriculum by employing scenario based e-learning opportunities using state of the art technologies. Educational theories support learning approaches that make learning engaging and meaningful, however the experientalism approach is linked to improving student performance. *Experientalism* is grounded in the idea that experience is the source of knowledge; providing students the opportunity to engage with each other and with science content by experiencing an authentic scenario. Scenario based learning provides an important framework for active learning (Elmore et al., 2003). For successful integration of STEM education, there are several characteristics that have to be implemented. The four major features of STEM education include STEM being collaborative, hands–on, problem solving and project-based (Carnegie Science Center, 2014). To launch orchestrating the learning process the UMI-Sci-Ed Educational Scenario Template has been developed; the template as the core instructional tool, has been designed to encapsulate all important components of the learning process. In UMI education we need to design "user experiences". Figure 2 presents the UMI-Sci-Ed Educational Scenario Template components (Fragou et al., 2017).

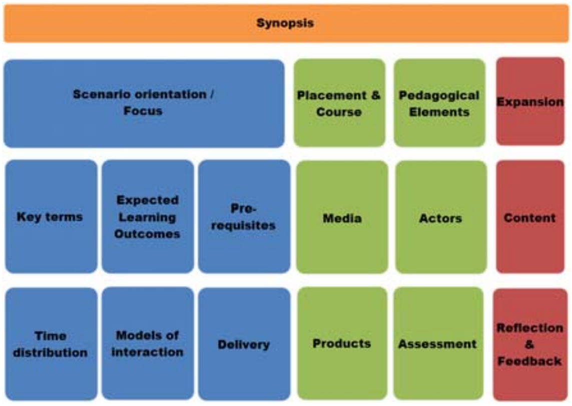

Figure 2: Schematic view of the Educational Scenario Template for UMI-Sci-Ed.

3.2 Educational Scenario "My Classroom's Social Panel"

The educational scenario "My Classroom's Social Panel" deals with Ubiquitous Computing in the context of UMI technologies. It is based on active exploration and adheres to the principles of reflective learning and peer learning, while further developing students' skills and knowledge acquisition, as well as attitude development. Its major learning objectives are: (a) the introduction of 14-16 year old students to web development technologies, (b) the realization of the value of UMI technologies and ICT applications, and (c) the adoption of a positive point of view as future professionals and citizens. Further learning outcomes are: (a) the orchestration of the exploitation of digital and printed media to support and disseminate a cause or project, (b) the comprehension of the benefits of collaboration and group work, (c) the utilization of effective work habits, (d) the appraisal of the potential of web applications, (e) a hands-on survey of the benefits of free/libre open source software, in order to cultivate a positive opinion towards its use.

The educational scenario guides students to the development and utilization of an artifact that handles a microcontroller equipped Single Board Computer (SBC) and a LED matrix module, as presented in Figure 3. The SBC operates a LAMP server (running on GNU/Linux, using an Apache web server, a MySQL database server, and a PHP scripts pre-processor) which supports polling by students. SBC's microcontroller drives a LED matrix hardware module to display voting statistics.

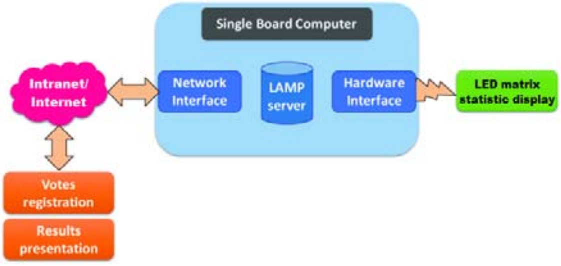

Figure 3: Block diagram of scenario's artifact.

The educational scenario is completed in six two-hour sessions, the activities of which are described in the following lines. In the first session the teacher presents a brief introduction to UMI technologies. Students install an image of system software on a micro SD card; operate the SBC, and install the intranet (LAMP) server software. They confirm the good operation of the implementation via a trivial web application.

During the second session students install a prototype web application that serves as a voting system. They alter application's source code accordingly, so that it works properly on the given SBC and network setup. They operate and test their voting application. The application allows any user to vote and see the poll results, by exploiting the application's web interface. Students investigate the applications of peer teams, present aspects of their implementation and reflect on their experience.

The third session concerns the design of a circuit that drives a LED matrix module. At first students use special software to draw the circuit. Later they construct the LED matrix circuit with actual hardware. They transfer, parameterize and execute the source code of a microcontroller application that drives the LED matrix. They observe other teams' circuits, present their artifact and discuss about the procedure in the classroom.

In the fourth session students bridge the web and the microcontroller applications. They modify the voting web application's source code to cooperate with the microcontroller driven LED matrix, which now displays positive votes using the matrix's LEDs. They test the good operation of the implementation, observe peer teams' work, present their solution and discuss their problems and ideas in the classroom.

During the fifth session students change their SBC's intranet address to an internet address using a dynamic DNS solution. They decide on a poll subject and disseminate a prompt to their peers in the school community, asking them to express their opinion by voting. Students reflect by discussion of this procedure.

The sixth and final session concerns the collection and analysis of poll data, and the definition of poll results. Students write a press release to communicate the poll findings. They disseminate it through school's website, social media, and possibly local media. They close the sessions by reflecting on all activities.

In the context of this scenario the broad CoPs schema shaped by researchers, users, teachers and domain experts intends to provide youngsters with: (a) project planning skills and problem-solving skills (apart from the programming skills as presented in the scenario), (b) acquaintance with the processes and products involved in the life cycle of a UMI application as faced in the context of a software company, (c) implementation of technological, communicational and working skills involved so as to perform effectively the role of a designer and developer in UMI applications, (d) acquaintance with important problems that UMI developers face on distributing in a large market scale applications.

3.3 Educational Scenario "Thermal Radiation Absorption"

The aim of this specific scenario is to explore the Physics laws and the related theory behind the absorption of thermal radiation on surfaces of different colour and material. The students by first configuring and then using the appropriate hardware and software components are able to measure, observe and explain the details of the different behavior of materials regarding thermal radiation absorption.

Its major learning objectives are: (a) to bring about problem solving skills that are connected with UMI technologies and STEM practice, (b) to elaborate on synthesis, analysis, critical thinking and decision making, (c) to provide an insight on how UMI technologies could be used as a means for updating educational practice, and (d) to support students in developing UMI projects through experts' feedback on specific problems.

The educational scenario and the UMI application developed can be examined from 4 different views:

One view is the *educational* which is related to the planning and implementation of the school activity with the selection of the topic, the presentation of the science theory behind the topic, and the organization of the course structure. Another view is the *technical* view which has to do with the UMI application development process in terms of hardware and software artifacts and involving an engineering approach which includes phases such as problem statement, requirement analysis, design, implementation, and testing of the solution. A third view is the design of the *experiments* on the science topic, involving the procedures, instructions, execution steps, observations and discussions. The final view is the *research* view which involves the hypothesis statement, design of questionnaires, their completion by the students, the data analysis and the conclusions drawn.

One of the experiments designed included the use of a desktop incandescent lamp as a heat source and paperboards placed underneath the lamp (Figure 4).

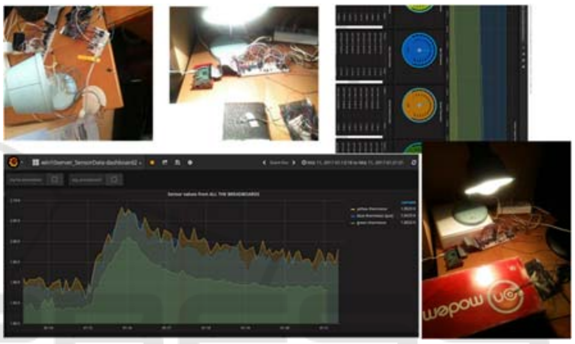

Figure 4: Educational Scenario "Thermal Radiation Absorption" software and hardware components.

The distance, position and angle of the material have to be specific according to the instructions and experiment scenario. Under the material a thermistor is placed to monitor its temperature. From the platform UI students can configure the experiment variables and parameters and give the command to start the measurements. When the lamp is turned on a timer is set typically to 1 min or more depending on the scenario. During the experiment the students are able to observe the temperature graphs displayed depending on the behavior of the material they test each time. So they have the opportunity to make observations, to compare, to reflect or to ask questions and discuss with their teacher.

The open source s/w platforms used to develop the application include:

- Node-red which is an IoT s/w platform that is used to integrate devices, APIs and on-line services with applications. We used this platform to build the user interaction environment of the application, to control devices like the lamp, and to gather values from the sensors in order to store them in the DB.

- The influxDB which implements our database to store the sensor measurements.
- The Grafana, which is the s/w tool used to create diagrams and graphs in order to visualize the sensor measurements.

Figure 5 shows the system deployment diagram with the main nodes and their connections as well as the deployment of the software components. The diagram shows that the microprocessors are connected to breadboards through the General-purpose input/output connections, the laptop can access the microprocessors through the VNC protocol, WiFi access is available, while all nodes can reach the Internet via a tablet and a 4G connection. There is also a machine-to-machine communication between the two microprocessors and between them and the tablet by using the MQTT Protocol and a mosquitto broker.

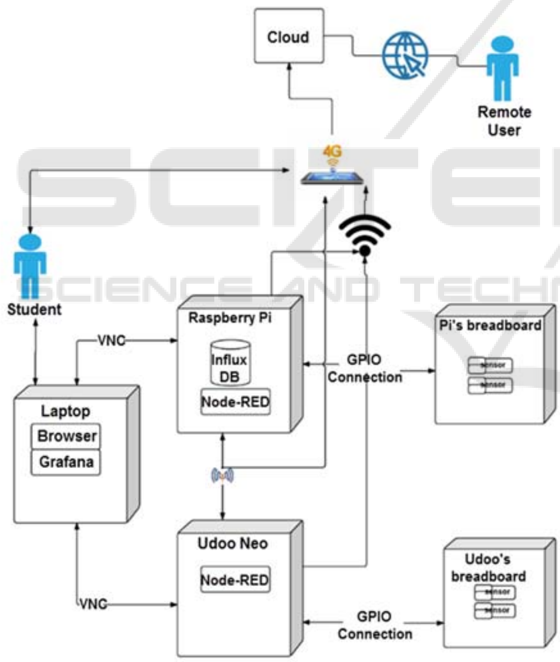

Figure 5: UMI application deployment diagram.

4 PRELIMINARY EVALUATION

A preliminary evaluation of the approach presented took place in a 2-day workshop in a secondary school in Athens with the participation of 14 students (Figure 6).

Topic: Evaluation of a UMI application in the context of an educational scenario designed according to UMI-Sci-Ed methodology in the subject of Physics.
Research type: Mixed (Quantitative-Qualitative)
Type of quantitative questions: closed type Scoring method: Cumulative Scoring Scale (Likert scale 1-5)
Researcher: Nikolaos Chanos
School: Metamorfosi-Herakleio High School
Class: A, B, C
Responsible teacher: George Fakiolakis, Informatics teacher (Physics)
Survey dates: 16 and 17 May of 2017
Duration: 2-day workshop of 4 hours total duration
Sample: 14 students (9 female, 5 male) from all the 3 lower secondary grades
Output: 14 questionnaire replies PRE and 13 POST, presentation file

Figure 6: Evaluation process data.

The first day was introductory and included activities such as setting up the equipment, presenting the subject of the course, exploring the features of the IoT and middleware platform and configuring the UMI application to be used in the experiments.

The students were asked to answer a pre workshop questionnaire. The purpose was to assess students' previous knowledge about the course topic, their experience, and relation to technology, as well as attitudes and receptiveness concerning the use of UMI technologies in formal education. The students replies showed that: a) all of them had adequate familiarity with technology; b) but they did not know much about the microprocessor boards and had little knowledge about IoT; and c) they had a positive attitude and expectation regarding the UMI enhanced educational activity.

In the second day the designed experiments were conducted and the UMI application was used to measure, display and record temperature changes under different conditions and various materials in order to have a hands-on experience regarding thermal radiation absorption mechanisms and make associations with the relevant physics laws.

On the educational part active exploration techniques was possible to apply in line with the principles of reflective and peer learning. For example, the students were asked through worksheets to explore the factors that affect thermal absorption i.e., distance of material from the heat source, material colour/thickness, position angle, heating duration and amplitude, heat type (radiation, current, conduction, combination), ambient temperature, surface/material temperature etc. They repeated the experiment by changing one factor each time, measured the temperature and compared the results to identify causality or correlations. A playful and participatory approach to increase engagement through gamification was also possible. Given certain task characteristics each team picked the materials that they believed can satisfy the requested properties and behaviour, and validated their hypothesis by using the UMI application. The teams that reached closer to the specifications won.

At the end of the second day the students were asked to complete a post workshop questionnaire. The purpose was to evaluate on the one hand the robustness of the application in terms of technical or usage problems that may have been encountered and on the other hand to assess the students' impressions after using the UMI application regarding the learning process.

The graph at the lower left in Figure 7 depicts the questionnaire results using a cumulative scoring scale method (Likert scale 1-5). Almost all students conveyed a clear benefit in understanding the theory and its connection to practical use through UMI applications. They also expressed a preference for using the IoT toolkit in combination with configurable software programs compared to traditional analogue instruments and manual recordings. We also surveyed whether the students realized that the approach presented was not representing a monolithic system serving a single purpose but a platform that can be adapted, configured and used in many other Physics experiments. The majority of the students embraced that view which justifies the point that such systems can be accepted as learning tools in school communities.

In general the students were satisfied with the UMI application and expressed their interest to interact with more applications like this. In addition they found the educational scenario to be helpful, the tasks performed useful and rated positively the overall learning experience.

This preliminary evaluation showed that the UMI approach is promising and can be developed to a valuable educational tool empowering students learning experiences. Even with this form of limited evaluation it was possible to test several aspects of the UMI-Sci-Ed platform including the versatility of the IoT toolkit towards supporting the circuit design and implementation of educational scenarios as well as the supporting services of the software platform including delivering of educational material on UMI technologies, sharing of UMI applications, gathering and storing experimental data, supporting polls and surveys and disseminating results and experiences via social media.

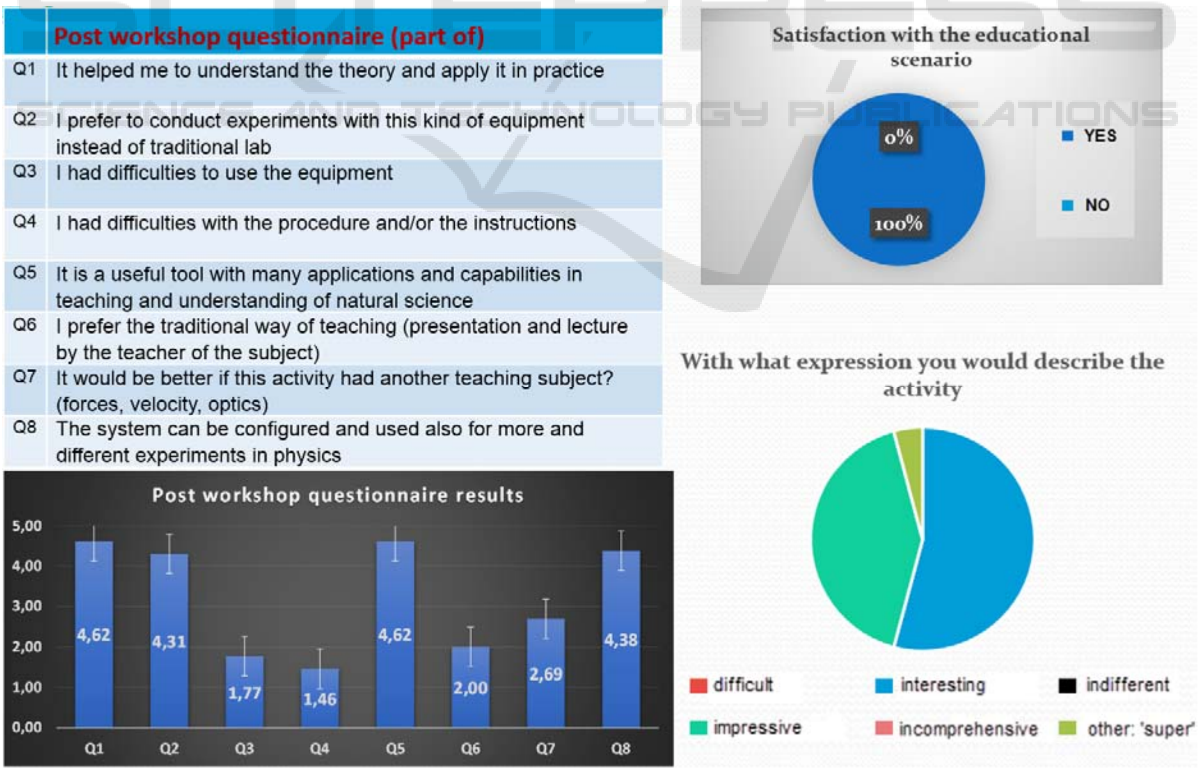

Figure 7: UMI application evaluation results.

5 RELATED WORK

The multifaceted nature of UMI-Sci-Ed platform to promote science education creates an intersection with different tool areas such as online CoPs management, computer-supported collaborative learning (CSCL), learning management systems (LMS) and IoT platforms. Although there is no complete match of each of the above tool areas with the target of our platform there are certain aspects of them that are merged in the UMI-Sci-Ed platform.

Although it is quite frequent that social networking tools are used to build online CoPs, on the other hand, it is not common to identify general purpose platforms that suit the needs of any CoP (Gunawardena et al., 2009). In this context the tendency is that CoPs platforms are built on demand for specific domains, or CoPs members use one or more different tools according to the task at hand (e.g. DISCUSS, twitter, YouTube, Moodle, wikis, and forums).

In response to the popularity of Web 2.0 technologies, LMSs evolved to include features such as blogs and wikis (Dalsgaard, 2006); it has been recognized, that the majority of LMSs introduced friction for instructors, trying to reuse and share course materials. To adhere to these market needs, tools for establishing collaboration between software community members so as to process code or software development material, have been recently introduced and developed, such as GitHub (Wu et al., 2014). Environments as such provide social and collaborative features in conjunction with distributed version control. GitHub is a popular Web based social code sharing service that utilizes the Git distributed version and control system. The rationale of circulating educational material and collaborating on this basis for further developing software applications is quite important in an effort to develop a culture of collaboration, transparent and active, for teachers, practitioners, educational policy makers involved in this creative and dynamic process.

Lamer et al. (2017) suggest the use of robotics as an enabling ICT platform for promoting STEM education. The multidisciplinary nature of the robotics field offers the opportunity for young children to enhance their creativity and problem-solving abilities. An open framework is proposed (ER4STEM) to bring together the main stakeholders of educational robotics i.e. teachers, educational researchers and providers of educational robotics in terms of a common ground based on an activity centered repository. The framework offers different perspectives and approaches such as learning through making to trigger the curiosity and interest of students about science and technology.

Lehman et al. (2015) discuss the use of HUBzero, an open software platform operated by Purdue University in US to support scientific collaboration, for the development of STEMEdhub which is a tool for collaboration, research and education in STEM domain. STEMEdhub users can find resources such as lessons plans, simulations and publications in the content repository. Moreover, using search engines they can find the most appropriate content in terms of topic, field domain, grade level or rating scores. The hub supports the concept of groups as the main organization unit to elaborate on the capabilities of the platform. A group can define a custom template design for unique view of the interface and associate key terms with STEM resources. The use of collaboration tools such as wikis, blogs, discussion forums, calendars, and project management allow groups to build various communities among their members.

The STEM4youth project builds a repository of educational content and teaching scenarios with a goal to make science education and scientific career more attractive for youngsters (Brzozowy et al., 2017). Various methodologies and tools such as learning by experiment, demonstrations, social media and games are employed to present the scientific challenges in several disciplines and their impact in everyday life. The STEM4youth approach emphasizes the social dimension and the career prospects associated with the science education by indicating the specific skills that are developed.

IoT platforms like Arduino and Raspberry PI provide tools through their web portals for creating and maintaining their communities. Such tools include forums with topics spanning from hardware and software to education and tutorials, wikis, blogs, newsletter, etc. Project repositories created and documented by the users are also maintained. Furthermore, Arduino Creative Technologies in the Classroom, or CTC, is a program focusing on STEM teaching for students of secondary education in collaboration with their teachers. The program provides IoT resources, learning materials and educational services to enable participants to create a more hands-on learning experience in the topics of programming, mechanics and electronics.

Although the UMI-Sci-Ed platform shares common characteristics and goals with the above approaches and other online portals that collect and present STEM educational material and provide collaboration support to active groups (e.g., Scientix, eTwinning, Micro:bit and Make World) it is diversified by integrating under a common technological environment CoPs management and the UMI/IoT technical tools to assist students both acquiring relevant competences and being motivated in pursuing a career in related domains. On the operational level, the integration of the UDOO Neo IoT platform allows to perform remote management of the device, visualize the data, and trigger actions as a result of rules on the received data.

Another differentiation of UMI-Sci-Ed platform is its orientation in instructional design: the educational scenario as a flexible structure has been the basis for designing the platform mechanism for leveraging UMI-Sci-Ed communities. CoPs' members create groups on the basis of designed educational scenarios and further negotiate and experiment on their implementation and splitting in smaller projects in a variety of educational contexts.

6 CONCLUSIONS AND FUTURE WORK

The UMI-Sci-Ed platform aims to bring together practitioners, students, school teachers, instructional designers, academics and IT specialists, who actually are going to act as members of the UMI-Sci-Ed CoPs, brought together on the basis of participating in on line activities, problem solving and exchanging reflection and experiences in the context of educational scenarios that incorporate UMI technologies, in order to cultivate relevant competences on high school students.

The hypothesis examined and partially explored in this work is that the students studying science topics can be empowered by using UMI applications developed in the context of model educational scenarios as students are provided with meaningful opportunities to participate in the learning process such as in terms of building applications that are relevant to the subject they like and having vivid interactions within student groups in a way that practical experiences can provide them a rich context to grasp scientific knowledge.

The work presented here is part of a set of initial activities that are required to lay the ground for UMI-Sci-Ed pilot studies. In this first cycle the expectation is to test parts of the approach in local schools. Field research will follow in educational conditions in 5 different countries (Norway, Finland, Italy, Ireland and Greece) in order to justify the proposed methodology. The research sample includes five schools from each country and about 25 students per class.

The participation of the students, the teachers and the school community members is expected to produce several outputs. Variables to be analysed include usability, motivation interest, knowledge and engagement. Media include surveys, interviews, observations and cognitive tests.

The collected quantitative and qualitative feedback elements are going to be analyzed to construct knowledge about the whole process. An evaluation framework that will assess the impact of such activities in terms of learning gains is also expected.

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