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The first year of the “open discovery of stem laboratories” (ODL) project

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Abstract. The Open Discovery of STEM Laboratories (ODL) project, co-funded by the European Community Erasmus+ KA2 program for 30 months, starting from November 2015, involves five countries: Spain, Italy, Greece, Estonia and Lithuania. It aims to implement teacher collaboration in creating and using μMOOCs (very short version of MOOCs-Massive Open Online Courses) for encouraging the use of STEM (Science, Technology, Engineering and Mathematics) remote/virtual laboratories into lessons. The challenge of the project is to impact on teaching process and inspire pedagogical innovation and modernization by means of open education resources, teaching/learning tools and best practices provided by European educators via the ODL platform. The ODL project consists of different phases: the setting up of the pedagogical scenarios for the design and creation of the μMOOCs, their embedding in school environments and their dissemination to a wide EU audience. The strong points of the project rely on the opportunity for teachers of improving both digital skills and pedagogical competences, experiencing international collaborative work and having the availability of attractive open education resources in national languages, helpful to design creative lessons on STEM topics. In this contribution we present the ODL project and the results obtained in the first year of its activity. In particular, we discuss the difficulty to identify the pedagogical scenarios to be adopted to create suitable μMOOCs for physics education, able to increase student ability to solve real-life problems. The benefits of adopting inquiry-based approaches, differentiated by the amount of information and teacher guidance provided to students (confirmation, structured/guided and elicited/open inquiry), will be discussed and compared.

1. Introduction

ODL Project Motivation and Objectives

The “Open Discovery of STEM Laboratories” (ODL) project has been co-funded by the European Community Erasmus+ KA2 program (Cooperation for Innovation and the Exchange of Good Practices – Strategic Partnerships for school education) for 30 months, starting from November 2015 (Project Number: 2015-1-ES01-KA201-016090). In order to support educators to find and to organize digital resources, while designing and delivering personalized instruction in school learning environments, the Open Discovery of STEM Laboratories project aims to implement teacher collaboration in creating and using µMOOCs (very short version of MOOCs-Massive Open Online Courses) for the inclusion of STEM (Science, Technology, Engineering and Mathematics) remote/virtual laboratories in the everyday teaching practices (http://opendiscoverylabs.eu).

The report issued by the Organization for Economic Co-operation and Development (OECD) “Evolution of Student Interest in Science and Technology Studies” identifies the crucial role of positive contacts with science at an early stage in the subsequent formation of attitudes towards science (Global Science Forum 2008). Recent studies show that one of the factors that influence the increase of interest, of motivation and of positive attitude towards the study of sciences generally, and of Physics in particular, is represented by the didactic methods used within the teaching-learning process. More than that, the attention should be focused on the teaching method during secondary school, which is the most important level in determining whether students prefer Science studies, since it is at this stage that they can start choosing which subjects they wish to study (Dinescu *et al.* 2011).

School atmosphere changed a lot in last decades. School education started introducing new technology, such as tablets, 3D printers, interactive whiteboards, apps and scaffolds, and other various ICT education instruments. The new learning processes should be adapted to complexity, connectivity, and velocity of new knowledge society. New curricula should be flexible to the place and time of learners, incorporate and discover the potential of new technology, and empower students to take control of their learning, to grow and move onwards. Schools should provide the “new generation” students with such learning experience which would open the doors to the best academic achievement, would ensure economic growth and civic engagement.

Laboratory teaching is an indispensable part of science education. The processes of making observations, performing systematic and quantitative investigations, data collection, analysis and logical interpretation of results and drawing relevant conclusions, are fundamental skills to the training of all science subjects. Performing experiments also serve to reinforce students’ classroom learning experiences. Unfortunately, many of the scientific ideas are taught with only very limited support of the corresponding experiments, for a number of reasons. These could be cost, space and safety implications for implementing the experiments (Persano Adorno *et al.* 2015). At this respect, traditional face-to-face lectures and experimental laboratory sessions can be complemented with new online experimental frameworks (Gröber *et al.* 2007, 2008). In fact, while there already are lots of Internet resources (many of them accessible for free) to fulfil many theoretical aspects on education, engineering and scientific studies also need more specific Internet based tools to cover the practical part of their teaching. The challenge which should be met by educators as early as possible is that the inclusion of these laboratories in the curriculum is done within the frame of strategies that add value to teaching processes, giving real chances for the building of learning experiences (Concari & Marchisio 2013). Teachers should use innovative practices in their teaching through personalized learning approach and develop student critical thinking. Old traditional methods of instruction, almost exclusively based on lectures aimed at transmitting theoretical concepts to the students, are gradually replaced by methods taking into account the practice of experiments. In particular, by adopting a more constructivist view of science learning, teachers should be more oriented to stimulate the students to directly experience the natural phenomena under investigation.

In order to help schools to transform their curriculum emphasizing an academic excellence, and to support educators to employ new technological tools, creating innovative STEM school curricula, the ODL consortium offers to teachers the innovative approach based on school µMOOC development. The main innovation of this methodology is the inclusion of remote and/or virtual laboratories, but it is also ground on the developing and re-using of open education resources (OERs), the sharing of learning resources and experiences. For this purposes the project has the following objectives:

- develop a µMOOC methodology for school curriculum;
- establish the µMOOC platform adapted for STEM curriculum designing;
- train at least 300 school teachers to develop µMOOCs for STEM education by multiplier events and teacher schools;

- create a depository of μMOOCs for STEM education, complemented by remote and virtual laboratories, available for secondary school teachers and students.

After all collected materials will be available on the ODL platform the teachers would be able to: (i) compile the provided educational blocks (such as videos, exercises, tests, worksheets, material rationale, etc.) to create and share their own μMOOCs; (ii) merge different μMOOCs to design personalized teaching/learning paths; (iii) cooperate in European context by exchanging materials and feedbacks on μMOOC-based teaching experiences.

Fig. 1. The ODL logo

The ODL Partners

The ODL project involves five partners from different European countries: (1) DeustoTech Learning, Deusto Foundation, Bilbao-Spain; (2) Physics Education Research Group, Department of Physics and Chemistry, University of Palermo-Italy; (3) Ellinogermaniki Agogi, Pallini, Athens – Greece; (4) Hariduse Infotehnoloogia Sihtasutus – HITSA, Tallin – Estonia; Lithuanian Association of Distance and E-Learning, LieDM, Kaunas – Lithuania.

2. The first milestones of the ODL project

During the first few months of the project: (i) a close collaboration between partners has been established, (ii) local, national and transnational outputs have been discussed, (iii) decisions on quality assurance, evaluation, dissemination, exploitation, and communication plan, administrative issues-reporting, agreements, content and timetable template, property rights, financial rules and policy, working methods and participation in activities and outputs have been settled up. Moreover, the consortium partners deliberated that the first year of the project would be addressed on the finalizing of the μMOOC methodology for school curriculum and on the specification and design of the μMOOC project platform (including operational modules such as scenarios container, catalogue of STEM laboratories, teaching and learning zone, etc.).

The majority of MOOCs available today are university courses that have been put online, or courses which were created by corporations and target specific career skills. EdX platform very recently have proposed specially designed courses from top high schools, secondary schools and universities to help to prepare for Advanced Placement (AP) Exams and CLEP Exams. These courses covering subjects ranging from English language and composition to calculus, biology, statistics and computer science, give students around the world the opportunity to access quality courses and materials regardless of financial resources. Up now, to the best of our knowledge, there is no a widely accepted methodology for the realization of μMOOC to secondary school level, despite of several reports addressing the use and the efficacy of MOOC at university level (Crow 2013, Kellogg 2013, Bates 2014, Israel 2015). The greatest difficulties are related to the identification of the pedagogical scenarios to be adopted to create suitable μMOOCs for secondary school STEM curriculum, including characteristics, approaches, motivations and challenges of school teachers and to the choice of the possible frameworks and teaching strategies for the implementation in classroom, in particular in physics education.

The choice of the μMOOC Methodology for School Curriculum

To effectively determine a methodology for the design, the realization and the implementation of μMOOC at secondary school level all consortium partners decided to collect teachers' suggestions and feedback. After long debates and discussions, secondary school teachers involved in the project suggested the use of an Inquiry learning structured approach – flexible, but not too much – having different levels of complexity (Herron 1971, McDermott 1996, National Research Council 2000, Llewellyn 2002, Banchi & Bell 2008). This implies that the teaching strategies involved in μMOOC implementation should be grounded on the viewpoint that students are active thinkers, who construct their own understanding from interactions with phenomena, the environment, and other individuals. In fact, in inquiry-based learning, the students are engaged in identifying scientifically oriented questions, planning investigations, collecting data and evidences in laboratory and/or real life situations, building descriptions and explanation models, sharing their findings and eventually addressing new questions that arise.

All possible pedagogical frameworks (*scenarios*) for μMOOCs should be laboratory-based experiences and have a high degree of interactivity. Their duration will be approximately limited to 40-50 minutes, inclusive of the exploitation of remote/virtual labs. One of the keys role in making successful the proposed teaching strategy is played by the choice of the topic and learning environment. In fact, what piques student's curiosity will depend on the student's interests, experience and prior knowledge. A "good" μMOOC topic for the implementation in a classroom, should:

1. provide affective engagement to the students;
2. generate curiosity and leads to questions;
3. generate a cognitive conflict;
4. be scientifically investigated and explained within the competence of the students involved;
5. create scientific knowledge;
6. require the students to use inquiry skills to explain the involved phenomena;
7. be transversal and connected very closely to real life.

Another crucial aspect is that the laboratory has not to be considered the place where students only observe experiences carried out by others or attend fruitless demonstrations of the validity of laws previously introduced by the teacher theoretically. The students should be personally involved in experimental activities, facing problematic situations that requires reasoning efforts, in order to be solved effectively. Moreover, the laboratory activity cannot be limited to the conduction of experiments and observations, but it should include a preliminary phase characterized by posing scientifically relevant questions, designing procedures and a final critical evaluation of obtained results. Furthermore, the designing of effective μMOOC-based learning paths also include the sharing of ideas with peers, drawing explicatory models, supporting conclusions and making choices based on arguments and evidences.

The pedagogical approach to be used in the μMOOC design should take into account the 5E learning cycle (ENGAGE, EXPLORE, EXPLAIN, EXTEND, EVALUATE) to develop student critical thinking and to help students to explore and evaluate their learning (BSCS, 1993).

In particular:

(i) **Engage** state involves the setting of the learning environment in a way that piques student interest and generates curiosity in the topic under study. It get students personally involved in the lesson, while pre-assessing prior understanding. During the ENGAGE stage, students first encounter and identify the instructional task, make connections between past and present learning experiences, setting the organizational ground work for upcoming activities. The video format should arouse students' curiosity and encourage them to ask their own questions;

(ii) In the **Exploration** stage, by means of the remote/virtual labs, the students have the opportunity to get directly involved with phenomena and materials. The teacher acts as a facilitator, providing materials and guiding the students' focus. **Explore** is the beginning of student involvement in inquiry. They search for information, raise questions, develop hypotheses to test, collect data;

(iii) **Explanation** involves the process of data acquisition and evidence processing techniques for the individual groups or entire class (depending on the nature of investigation) from the information collected during the exploration. **Explain** is the stage at which students build models (descriptive or explicative), discuss their data with peers and the teacher and begin to communicate what they have learned;

(iv) **Extend** is the stage in which students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways, building possible generalizations;

(v) **Evaluate** is an on-going diagnostic process for both students and teachers. It involves students' capacity to make judgments, analyses, and evaluations of their work, also in comparison with the work of their colleagues. It also allows teachers to determine how much learning and understanding has taken place.

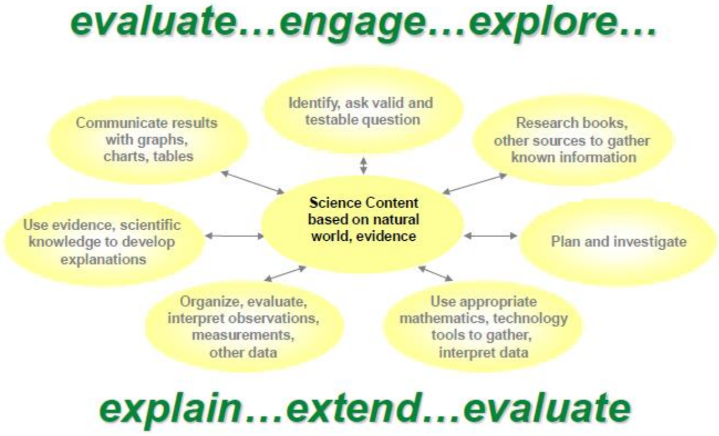

Fig. 2. The Scientific Inquiry/5E Learning Cycle

On the basis of teachers' suggestions, to ensure pedagogical coherence of all μMOOCs and, at the same time, to leave the teachers free to design personalized teaching paths, we have chosen to adopt inquiry-based approaches and differentiated the templates for μMOOC development for (i) the level of teacher guidance; (ii) the difficulty of the involved remote/virtual laboratories; (iii) the requested student's cognitive skills. In fact, there are various levels of inquiry in science education – the initial level where the teacher directs every aspect, to the highest level where the student holds the control and needs the intellectual and practical skills to become investigator, acting as a researcher. Through the series of different levels of inquiry, the student becomes more able to carry out his/her own independent inquiry, and the assistance of the teacher becomes different, less instructive, but more enabling and flexible (Pedaste *et al*. 2015).

3. Scenario development: the 3-levels inquiry-based approach

In order to develop scientific knowledge and stimulate the strengthening of reasoning skills, the students will be engaged into inquiry-based learning. The μMOOCs will be based on three key inquiry practices: 1) Coordinating hypothesis, observation and evidence; 2) Controlling variables; and 3) Studying cause and effect relationships (Kuhn 2005).

All phases of the 5E learning process will be included into the μMOOCs, but with different amount of support provided by the teacher (Zhang & Quintana 2012, Zacharia *et al*. 2015). Moreover, they should be well separated within the μMOOC in such a way that their administration could also be delayed in time.

In particular, we have chosen 3-levels Inquiry-based approach:

- *Basic* – Confirmation Inquiry

- *Intermediate* – Structured/Guided inquiry
- *Advanced* – Elicited/Open Inquiry

In order to facilitate the teachers in the transition from scenarios to educational resources we drew up the μMOOCs scenarios for the 3-levels Inquiry, by sharing key-aspects on the ODL European platform (see moocspace.odl.deusto.es).

Scenario 1: ***Basic approach*** (Confirmation Inquiry)
In the basic approach, the teacher provides students with the question, shows the use of the remote/virtual lab, illustrates the procedure and the method, but the results and their explanation are known in advance (Banchi & Bell 2008). Confirmation Inquiry is useful when the teacher purpose is to reinforce a previously introduced idea, introduce students to the experience of conducting investigations, or have students practice a specific inquiry skill, such as the collecting and recording of data.

Therefore, in this case the μMOOC topic will be previously introduced by the teacher and explained in depth; the novelty will be represented by its contextualization in real-life environments (Engage). The virtual or remote laboratories will be exploited by the teacher (Exploration). All other phases (Explanation, Extension, Evaluation) are faced and discussed by the teacher in the μMOOC. After the μMOOC vision, the students have the possibility to explore the remote/virtual experiments in class (in small groups working with tablets connected to the internet), or at home. They will be invited to write a scientific report on the experience done and on acquired concepts.

Main student outcomes: Practical applications of the theory.

Scenario 2: ***Intermediate approach*** (Structured/Guided Inquiry)
In the structured inquiry level, the question and the detailed procedure for the utilization of the remote/virtual lab are provided by the teacher. However, the students generate an explanation supported by the evidence they have collected by experiencing the remote/virtual lab by themselves. They are responsible for uncovering the answer. The teacher acts as a knowledge facilitator, providing support or materials in the μMOOC so that the students can experience a sense of success when working at this level (Banchi & Bell 2008).

Also in this case the μMOOC topic will be previously introduced by the teacher. Because this kind of inquiry is more involving than the first level, it is most successful when students have numerous opportunities to learn and practice different ways to plan experiments and record data. Therefore, after the μMOOC vision, the students should have the possibility to repeat the experiments (in class or at home) by changing the parameters. They will be invited to write a scientific report on the experience done and on acquired concepts.

Main student outcomes: Practical applications of the theory; reasoning efforts to generate explanations on the basis of their own investigation results.

Scenario 3: ***Advanced approach*** (Elicited/Open Inquiry)
In the Open inquiry the teacher takes the delicate role of defining the context for inquiry by presenting a multidisciplinary view of a theoretical problem or a real-life phenomenon. Subsequently, he/she stimulates the students to define their relevant questions, design and carry out their independent investigations, construct coherent explanations, communicate and share their results (Banchi & Bell 2008). An open inquiry-based instruction seems more efficient to reinforce learners' reasoning skills, also increasing the awareness of the process of scientific inquiry (Pizzolato *et al.* 2014). Despite this, students involved in open inquiry may develop feelings of frustration due to the lack of achieving the desired goals independently from teacher's hints (Quintana 2005).

In the Elicited/Open inquiry level, within the μMOOC the teacher will provide the students with only the research question, stimulating the learners to explore the potentialities of the remote/virtual lab by themselves. Here, the students design the procedure (method) to be followed in the use of the remote/virtual labs, record and interpret data, test their questions and share the findings. Although teachers are less instructive, they provide a framework (scaffolding) for the process when needed, prepare resource lists or support cards in order to help students to manage this level of inquiry. The students will be involved by mean of the μMOOC in a learning path with a specific process of activation – Elicited Inquiry – consisting of a learning environment in which the instructor actively will participate to the debate on the physics governing the observed experimental findings, never providing exhaustive explanations to the students, but giving comments and hints, sometimes expressly incorrect, always leaving the students in a state of uncertainty, stimulating their reasoning and activating their scientific inquiry (Persano Adorno & Pizzolato 2015).

Main student outcomes: Through self-designed or stimulated exploration students make hypotheses, test their own predictions, and draw their own conclusions; they should reach higher levels of autonomy and develop higher-order thinking skills.

4. Discussion and conclusion

The ODL project grounds on student’s active learning through inquiry-based science instruction and exploitation of remote/virtual STEM laboratories. ODL methodology incorporates four key innovations: first, the use of micro-MOOCs and ICT-based educational instruments to motivate teachers in the creation of flexible personalized teaching/learning paths and to increase students’ interest and involvement, due to the innovative methodology; second, the incorporation of remote/virtual laboratories, as didactical instrument for practice-based learning, with the aim to capture the students’ imagination and motivation, effectively engaging them; third, the 5E cycle to develop student critical thinking and to help students to explore and evaluate their learning; and finally, the inclusion of practical exercises, evaluation tests, etc, with which students will take control and awareness of their learning process.

In this paper we present the *Open Discovery of STEM Laboratories* European Project and share the results obtained in the first year of activity. In particular, we discuss the pedagogical scenarios to be adopted to create μMOOCs, able to increase high-school student abilities and skills and give some suggestions that can guide teachers in selecting topics and useful virtual/remote labs to develop suitable μMOOC-based teaching paths promoting inquiry learning. In fact, an inquiry-based teaching environment is today considered the natural framework where to develop opportunities for learning science in terms of an active construction of meaningful knowledge. Moreover, the dealing with remote/virtual labs allows new ways of experimentation and, in educational terms, it focuses on conceptual understanding. Student’s attention is focused mainly on the analysis of results that come from a real experimentation. These labs can extend the capability of a conventional laboratory and increase the number of times and places a student can perform the experiments.

The inclusion of these μMOOC-based teaching paths in the curriculum should be framed within proposals that add value to teaching, giving real learning opportunities. Our future research activity will be focused on the analysis of educational experiences carried out by our teachers in the classroom environment. Also we will investigate the evaluation criteria, from a didactic point of view, of these teaching/learning paths, in order to get information that will allow us to optimize its use for educational purposes.

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