Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Informal physics teaching for a better society: a mooc-based and context-driven experience on learning radioactivity

To cite this article: N Pizzolato and D Persano Adorno 2020 *J. Phys.: Conf. Ser.* **1512** 012040

View the article online for updates and enhancements.

IOP ebooks™

Bringing together innovative digital publishing with leading authors from the global scientific community.

Start exploring the collection–download the first chapter of every title for free.

This content was downloaded from IP address 31.156.227.118 on 22/06/2020 at 13:46

Journal of Physics: Conference Series **1512** (2020) 012040 doi:10.1088/1742-6596/1512/1/012040

Informal physics teaching for a better society: a mooc-based and context-driven experience on learning radioactivity

N Pizzolato[1] and D Persano Adorno[2]

[1]Istituto Istruzione Superiore Statale "Pio la Torre", via N. Siciliana, 22, 90135, Palermo, Italy
[2]Università degli Studi di Palermo, Dipartimento di Fisica e Chimica, Viale delle Scienze, Ed. 18, 90128, Palermo, Italy

Abstract. The general objective of teaching physics is to provide the learners with useful knowledge, in terms of both interdisciplinary scientific concepts and practical problem-solving skills. In this work, we report the experimental evidence, collected during a first year physics class in an upper secondary technical school, for the urgent necessity to adopt an informal and inquiry-based strategy to teach physics effectively, in particular to all those students living in degraded socio-economic environments. Within the pedagogical framework of "Learning by Doing" and the paradigm "Learning by Teaching", we have explored the benefits of the students' participation to an informal ICT-based and inquiry-driven learning experience about radioactivity. Subsequently, the same students attended, as scientific communicators, a national science exhibition where the majority of the secondary schools in the region presents their scientific exhibits. About three months after the participation to the scientific exhibition, the students answered to a questionnaire about radioactivity. Their answers have been analysed in comparison with those provided by a control group of students who attended a traditional lecture-based instruction. A significant improvement in the memorization of the main aspects concerning a radioactive decay, such as the definition of isotope, particle and electromagnetic radiation, the understanding of the radioactivity process at microscopic level, as well as a stronger view of the useful aspect of radioactivity in the everyday life have been definitely achieved by the students involved in this study.

1. Introduction

Scientific literacy is a main target and recommendation of many National Standards of Education around the world [1-4], strongly convinced that a scientific culture can foster the development of better and safely lives. An effective physics instruction should support the students towards the development of specialist content knowledge, competences on using mathematical, scientific and technological tools to solve everyday problems, and the mind set for undertaking lifelong learning [5, 6]. The relevance for making people able to address the scientific problems they might face in the context of everyday life is higher in degraded socio-economic environments where most secondary schools face the problem of early leaving and the students usually do not consider the class as a place to learn useful concepts and practical abilities. This latter issue is probably due to a lack of intrinsic motivation, worsen by a lecture-based teaching approach or didactical settings not grounded on practical or laboratory activities. At this regard, it has to be noted that many high schools in rural areas do not have equipped laboratories, in particular for what concerns physics topics requiring expensive measuring devices, as in the context of radioactivity. Moreover, even a well-equipped science laboratory in a scientific lyceum cannot include and manage radioactive isotopes for safety concerns.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

For all these reasons, the topic of radioactivity is often poorly explored in physics classes, except for few studies [7-9], leaving the students with the old-fashioned idea of radioactivity as something bad emitted by dangerous materials, mostly used in military weapons. Of course, today radioactive isotopes are used in many positive contexts, such as in the field of nuclear medicine, for both diagnostics and therapy. So the impact for our students to clearly understand the concepts behind a radioactive decay and the properties of the different kinds of radiation is very important.

In order to surmount the teaching and learning difficulties related to a lack of laboratory equipment, the European Community financed the project "Open Discovery of STEM Laboratories" (ODL), within the Erasmus+ KA2 program - Cooperation for innovation and the exchange of good practices (http://opendiscoverylabs.eu). The project started on November 2015 and for 30 months the research teams from five different European countries cooperated to implement a teacher network of collaborations in creating and using microMOOCs (very short version of MOOCs-Massive Open Online Courses) for encouraging the use of STEM (Science, Technology, Engineering and Mathematics) remote or virtual laboratories into interdisciplinary lessons [10]. Within this project, we realized a specific microMOOC on radioactivity, which was experienced by a sample of selected secondary students as a practical ICT-based experience within a longer specific learning path. In the context of physics education, the ODL project promoted the pedagogical framework of an inquiry based method of instruction [11-14]. A teaching practice promoting an inquiry-based learning supports students' scientific questioning, and the subsequent process of designing investigations, collecting data, building explanation models, sharing results and eventually addressing new questions that might arise. The ODL project teams were engaged in developing this methodology for an effective use of the microMOOC approach in teaching and learning physics through practical experimentations of virtual or remote laboratories, freely available on the internet as open educational resources.

In this work, we investigate the learning benefits obtained by a group of students involved into a practical inquiry-driven exploration of a remote laboratory about radioactivity included within an ODL microMOOC, and a subsequent informal learning experience as scientific communicators in occasion of a big national science exhibition. The method adopted to support this study is provided in Section 2. All the main pedagogical aspects of the ODL project are presented in Section 3, together with the two main phases of the learning workshop, where educational resources involving physics contents in the field of radioactivity and their useful applications in everyday life are explored by the students within the microMOOC learning environment and subsequently presented to a wide audience. At the end of this learning experience, the students answered a questionnaire. In Section 4, the average scores of the students' answers to the questionnaire are reported, and in Section 5 the results of the overall formative process are finally discussed.

2. Method

This study addresses the efficacy of an informal inquiry-based learning workshop on the topic of radioactivity. In particular, the learning path is designed to first engage the students in a microMOOC exploration where an informal practice of scientific inquiry can be performed by means of a remote laboratory (http://www.ises.info/index.php/en/laboratory/experiment/radioactivity). The software of the remote laboratory has been developed inside the project "iSES Remote Lab SDK - internet School Experimental Studio for Remote Laboratory – Software Development Kit" at the Faculty of Mathematics and Physics of the Charles University in Prague, Czech Republic [15-19].

The microMOOC has been designed by following an inquiry-based teaching approach. As a matter of fact, depending on the amount of information and support provided by the educators, and by the microMOOC in this case, the learners can experience a structured, guided or open inquiry [20, 21]. Here, the microMOOC provides both the questions and procedures as in a typical structured inquiry, and students generate their own explanations, supported by the evidence they have collected. The microMOOC is developed by following the 5E model [22] of instruction, guiding the students through five phases of learning: Engage, Explore, Explain, Elaborate, and Evaluate. In the context of radioactivity, the different phases can be described as follows: (1) Engagement involves the setting of the learning environment in a way that stimulates motivation and curiosity by means of interesting videos and driving questions on everyday problems involving the physics concepts in a radioactive decay; (2) Exploration is the beginning of student engagement in inquiry, by approaching the virtual laboratory, exploring its features and measurements capability; (3) Explanation regards the process of data acquisition and processing, to be performed in small groups of students; (4) Elaboration is the phase in which acquired data are analysed, shared and discussed with other students and the teacher, with the aim of understanding how the acquired knowledge can be applied in everyday life; (5) Evaluation involves students' abilities to perform an assessment of their learning process, in comparison with the work performed by their classmates. The learning workshop has been designed to engage the students who experienced the microMOOC about radioactivity into a subsequent *teaching* experience as scientific communicators within the informal framework of a scientific exhibition, during which they were stimulated to explain the physics concepts just learned to a wide audience. The positive impact of science learning in informal environments, such as a natural history museum or a science centre, has been recently highlighted [23, 24].

This study involved a sample of 90 students attending the first year of a technical secondary school for economics and tourism in a middle/low-cultured part of the city. These students are not attending a scientific Lyceum or a secondary school specifically designed for preparing them to become scientists. They hold a general science background collected during the lower secondary school and attend a one-year long course of physics for two hours per week. At the time of their engagement in this learning workshop, they had attended about half of the expected physics lessons, mainly mechanics. Only 30 students participated to the full experimentation, while the remaining were selected as a control group for comparison. In particular, half of them attended only the first part of the workshop, i.e. only the microMOOC with the virtual laboratory experience, while the others simply participated to a one-hour long lecture about the physics concepts regarding the topic of radioactivity and their useful applications.

In summary, the sample of 30 students involved in the full experimentation attended first a two-week long (8 hours/week) MOOC-based laboratory focused on the topic of radioactivity, where they had the opportunity to discover the basic concepts of a radioactive decay and carry out real measurements into a remote laboratory, challenging themselves through an inquiry-based learning path suitably developed in the context of the ODL project. Before participating to the national science exhibition, the students built a 3D model of an atomic nucleus, alpha and beta particles, and practiced the use of a Geiger-Muller counter device (courtesy of the University of Palermo) for measuring natural radioactivity. After this practical session, they challenged themselves for a week by presenting an exhibit to the audience, firstly introducing the basic concepts of ionizing radiation and then the main medical applications, imaging/diagnosing, of radioactive isotopes.

3. The ODL Project and physics experimentation at school

The ODL project, funded by the European Community under the Erasmus+ KA2 program for 30 months, started in November 2015 and involved five countries: Spain, Italy, Greece, Estonia and Lithuania. It aimed to implement teacher collaboration in creating and using microMOOCs for promoting the inclusion of STEM remote or virtual laboratories into classroom practice. The challenge of the project was to impact on the teaching process and inspire pedagogical innovation and modernization by means of open education resources, teaching/learning tools and best practices provided by European educators. The ODL project consisted of different phases: the setting up of the pedagogical scenarios for the design and creation of the microMOOCs, their embedding in school environments and their subsequent dissemination [10]. The microMOOCs are the essential innovative component of the project. The microMOOC format allows to use the lessons modularity structuring various study subjects with similar content [14]. We successfully introduced and encouraged the usage of school MOOC approach supporting school modernization in learner-centred learning, teamwork and collaboration, active learning, participatory learning, and connected learning. The ODL microMOOCs with embedded remote, virtual labs and simulations, in a variety of European languages provide youth the equal access to the learning opportunity, experiences, study instruments, and knowledge. 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 the past three years, the project team organized a professional development course in the context of a teacher summer school for a sample of teachers selected from secondary schools in Italy, Lithuania, Greece and Estonia, with the aim of providing the teachers with the necessary background to define their own educational resources and create their microMOOCs. As a result of this course, the trained teachers carried out an experimentation of the inquiry-driven didactical micro-mooc about interdisciplinary physics contents in their classrooms.

3.1. The mooc-based and inquiry-driven laboratory: Radioactivity and useful applications

A sample of 60 randomly-selected secondary students, aged 14 to 16, were invited to join a 12-hour-long experimental activity, distributed in two weeks, within a MOOC-based and inquiry-driven learning environment at the upper Secondary School "Pio La Torre" in Palermo, Italy (Figure 1). The instruction path, focused on the topic of radioactivity and everyday applications, was carried out through the following phases:

- Engagement: The teacher presented the project to the students, providing a brief description of the context in which their work would have been developed and the motivation for an active participation.
- Exploration: The students were introduced to the ODL platform and stimulated to explore the micro-MOOC materials and the remote lab therein, in order to design their own experiences.
- Explanation: The students carried out their investigations, designed on the base of their hypotheses pointed out during the explorative phase.
- Elaboration: The students presented the most significant findings obtained as a result of their experimental work.
- Evaluation: Classroom discussion aimed at comparing and contrasting the results obtained by different groups of students.

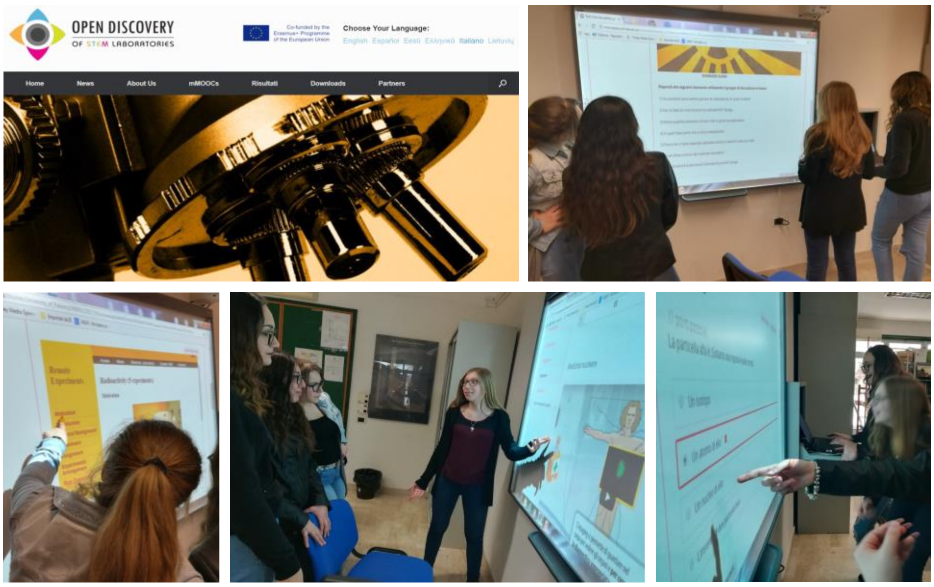

Figure 1. Students experiencing the ODL platform and the microMOOC about radioactivity.

3.2. Participation to the big social/scientific exhibition "ESPERIENZA INSEGNA 2018"

Two weeks after the conclusion of the MOOC-based inquiry-driven learning path on radioactivity, 30 randomly-selected students (over the original 60) were involved in a one-week-long science exhibition where they were stimulated to introduce the audience to the basic concepts of radioactivity, its origin at microscopic scale and the differences between alpha, beta and gamma radiation (with the help of an home-made 3D model of atomic nucleus, alpha/beta particles and electrons), and their useful applications in everyday life: medical imaging and diagnostics, anti-cancer therapies, fire prevention systems, security controls, safety systems, etc. They also performed some demonstrative measurements of the background radiation by mean of a Geiger-Muller counter (Figure 2).

Figure 2. Students actively participating in the national scientific exhibition "ESPERIENZA INSEGNA 2018", held from 21 February to 1 March 2018 at the University of Palermo, Italy.

4. Results

Three months after the conclusion of the whole learning workshop, all the students involved in this study were invited to answer an open-ended questionnaire devoted to the assessment of the student effective understanding of the basic concepts about radioactivity. The 20 questions of the test are reported in Appendix. The results of this study are based on the analysis of the answers provided by the students to the questionnaire, focused on five key concepts about radioactivity as listed in Table 1, in comparison to the answers provided by those students who experienced the microMOOC but not participated to the scientific exhibition or received solely a traditional lecture-based instruction. The answers to the questionnaire were analysed and evaluated by the teacher (who is also co-author of this work), with the support of the other author of this contribution, within a five points scale, depending on the accuracy and clarity of the provided explanations. In Table 1 we list the basic concepts in column 1 and report the average scores collected by the three different samples of students in columns 2, 3 and 4 for any of the explored physics concept.

As expected, the microMOOC experience had a positive impact on student learning outcomes with respect to those students attending merely a lecture-based instruction. However, the students involved also into the scientific exhibition have shown a significant improvement in the memorization and understanding of the main aspects concerning the topic of radioactivity, such as the understanding of the radioactive decay at microscopic level, the different characteristics of Alpha, Beta and Gamma radioactivity and their medical and safety applications. The active participation to the science exhibition stimulated the students to further practice the elaboration and evaluation phases experienced during the 5E-cycle of the inquiry-based learning path. As a matter of fact, the need for providing proper scientific explanations to an audience ranging from pupils to graduates has stimulated the activation of cognitive resources that made more effective the knowledge already acquired through the MOOC-based exploration.

Table 1. Average outcomes from students' answers to the questionnaire.

Explored Concepts about Radioactivity	Average scores on a 5-point scale (0-answer not pertinent to 5-fully understood)		
	Lecture-based Instruction	MOOC-based Lab	MOOC-based Lab with Exhibition
1) Characteristics of radioactivity and natural radioactivity	1.5	3.2	4.5
2) Microscopic origin of radioactivity	2.5	3.0	3.9
3) Alpha, Beta and Gamma radioactivity	1.8	2.8	4.8
4) Half-life of isotopes and penetration depth	2.6	3.2	4.5
5) Medical applications of radioactivity	1.4	3.0	4.4

5. Conclusions

Many research studies support the evidence for an effective physics education when an inquiry-based method of instruction is adopted. The process of scientific questioning, which is the base for any scientific investigation, is essential for developing a deeper comprehension of the concepts and also for improving reasoning skills. However, this method of teaching physics must be embedded within a learning cycle including an exploratory phase that sometimes can be performed in classroom, but sometimes needs to be carried out outside the classroom, in a science laboratory or any other suitably designed learning environment. Unfortunately, this latter is not often available in some schools, in particular those in rural areas or in degraded outskirt, while, on the contrary, an ICT laboratory is more probably present in these schools, making possible the use of open educational resources freely available on the internet, such as virtual or remote physics laboratory. Students' process of discovery, however, needs to be supported before, during and after a laboratory exploration. This is exactly what the ODL project has done when fostered and supported teachers' collaboration on designing and creating inquiry-driven microMOOCs.

In this study, we have shown that the use of the ODL microMOOC about radioactivity, a physics topic rarely addressed in secondary schools from a practical-experimental point of view, resulted effective to engage poorly motivated students, letting them to explore real laboratories (even if in remote mode) and perform real measurements and analysis in a school where no measurement facilities were available for that specific physics topic. In addition, we have also shown that these students further improved their understanding of the basic concepts about radioactivity after their participation to a national scientific exhibition. This finding confirms the relevance for engaging the students in informal learning activities, such as those performed as scientific communicators, in highly motivating environments, suggesting how the support/reinforce/motivation offered by the participation to a scientific exhibition might constitute an effective integration of inquiry-based teaching and learning strategies.

References

[1] National Research Council 1996 *National Science Education Standards* The National Academies Press (Washington, DC)

[2] Rocard M, Csermely P, Jorde D, Lenzen D, Walberg-Henriksson H and Hemmo V 2007 *Science Education Now: A renewed Pedagogy for the Future of Europe*, EU Research Report, ISSN 1018-5593

[3] National Research Council 2012 *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* The National Academies Press (Washington, DC)

[4] National Research Council 2013 *Next Generation Science Standards: For States, By States* The National Academies Press (Washington, DC)

[5] Riendeau D 2015 Lifelong learning *The Physics Teacher* **53** 58

[6] Gandhi P R and Livezey J A 2016 Attending to experimental physics practices and lifelong learning skills in an introductory laboratory course *American Journal of Physics* **84** 696-703

[7] Austen D and Brouwer W 1997 Radioactive balloons: experiments on radon concentration in schools or homes *Phys. Educ.* **32** 97

[8] Rego F and Peralta L 2006 Portuguese student's knowledge of radiation physics *Phys. Educ.* **41** 259

[9] Koželj M and Istenič R 2013 Radioactivity Experiments For Schools *Proceedings of the 22th International Conference Nuclear Energy for New Europe* (NENE) 1313-9

[10] Persano Adorno D, Pizzolato N, Fazio C, Battaglia O R, Dziabenko O, Tsourlidaki E, Volungevičienė A, Žvinienė V and Lõssenko J 2018 The first year of the "Open Discovery of STEM laboratories" (ODL) project *J. Phys.: Conf. Ser.* **1076** 012015

[11] Llewellyn D 2002 *Inquiry Within: Implementing Inquiry-based Science Standards* Corwin Press, Inc. (Thousand Oaks, California)

[12] Persano Adorno D, Pizzolato N and Fazio C 2015 Elucidating the electron transport in semiconductors via Monte Carlo simulations: an inquiry-driven learning path for engineering undergraduates *Eur. J. Physics* **36** 5

[13] Persano Adorno D, Pizzolato N and Fazio C 2018 Long term stability of learning outcomes in undergraduates after an open-inquiry instruction on thermal science *Phys. Rev. Phys. Educ. Res.* **14** 010108

[14] Dziabenko O and Persano Adorno D 2017 Application of remote experiments in a secondary school using MOOC approach, in *IEEE Proceedings of 2017 4th Experiment at International Conference: Online Experimentation*, exp.at 2017 **7984358** 191

[15] Dvořák J, Kuriščák P and Lustig F. iSES Remote Lab SDK – internet School Experimental Studio for Remote Laboratory Software Development Kit. http://www.ises.info/index.php/en/systemises/sdkisesstudio.

[16] Schauer F, Lustig F, Dvořák J and Ožvoldová M 2008 Easy to build remote laboratory with data transfer using ISES – Internet School Experimental System ISES *Eur. J. Phys*. **29** 753

[17] Schauer F, Ožvoldová M and Lustig F 2008 Real Remote Physics Experiments across Internet – Inherent Part of Integrated E-Learning, *International Journal of Online Engineering* (iJOE) **4** 54

[18] Schauer F, Lustig F and Ožvoldová M 2009 ISES - Internet SchoolExperimental System for Computer-Based Laboratories in Physics. INNOVATIONS 2009 (USA). World Innovations in Engineering Education and Research. iNEER Special Volume 2009. chapter 10, pp. 109

[19] Krbeček M, Schauer F and Lustig F 2013 Easy Remote ISES Development Environment for Remote Experiments. INNOVATIONS 2013 – World Innovations in Engineering Education and Research, MD, USA : Potomac, pp. 81 -100

[20] Herron M D 1971 The nature of scientific inquiry *School Rev.* **79** 171

[21] Banchi H, and Bell R 2008 The Many Levels of Inquiry *Sci. Child.* **46** 26

[22] Bybee R W 1993 *An instructional model for science education in Developing Biological Literacy* Biological Sciences Curriculum Study (Colorado Springs, CO)
[23] Hauan N P and Kolstø S D 2014 Exhibitions as learning environments: a review of empirical research on students' science learning at Natural History Museums, Science Museums and Science Centres *Nordic Studies in Science Education* **10** 90
[24] Chen G, Xin Y and Chen N-S 2017 Informal learning in science museum: Development and evaluation of a mobile exhibit label system with iBeacon technology *Education. Tech. Research Dev.* **65** 719

Acknowledgments

Authors wish to acknowledge the support offered by the European Union. Authors wish to thank Prof. Nicoletta M. A. Lipani, Headmistress of the Secondary School "Pio La Torre" in Palermo, Italy.

Co-funded by the Erasmus+ Programme of the European Union

"The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein."

Appendix

Questionnaire

Characteristics of radioactivity and natural radioactivity:
a. Who discovered the radioactivity? b. List some chemical elements that you think are radioactive. c. What is the meaning of natural radioactivity? d. Which of the following foods contains higher doses of natural radioactivity?
Microscopic origin of radioactivity:
a. Where are the electrons in an atom? b. Where are the protons located? c. How do protons stay close each other in the core? d. From what atomic number does the nucleus become unstable?
Alpha, Beta and Gamma radioactivity:
a. What is an ionizing radiation? b. What is an alpha radiation? c. What happens in beta decay? d. What is a gamma radiation?
Half-life of isotopes and penetration depth:
a. Which product of radioactivity is more penetrating? b. What is preferable to use to shield beta radiation? c. What is used to best shield the gamma radiation? d. With the same shielding material, what happens when the thickness increases?
Medical applications of radioactivity:
a. What do you know about radioactive materials? b. What is nuclear medicine? c. Which radiation is mainly used for sterilization? d. Is radioactivity dangerous? Please, explain.