# Teacher professional development in the context of the "Open Discovery of STEM laboratories" project: Is the MOOC methodology suitable for teaching physics?

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**Abstract.** The "Open Discovery of STEM Laboratories" (ODL) project, funded by the European Erasmus+ KA2 program, was aimed at introducing the use of MOOCs in school curricula. In particular, it fostered teacher collaboration in creating and using micro-MOOCs for the inclusion of STEM (Science, Technology, Engineering and Mathematics) online remote or virtual laboratories in the everyday teaching practice. The project focused on teachers, educators and curriculum designers with the aim to strengthen their profile by supporting them to deliver high quality teaching practices and to adopt new methods and tools. Thanks to the project, in service and pre-service teachers had the opportunity to extend their knowledge about the inquiry-based science teaching approach, improve both digital skills and pedagogical competences, experience international collaborative work, explore attractive open education resources helpful to design creative lessons on STEM topics. In this contribution, we focus our attention on the results from the ODL teacher training in Italy, showing the valuable feedback collected by teachers on the impact of the ODL pedagogical approach on Physics education at secondary school, highlighting strengths and possible weaknesses of the proposed methodology. The feedback to the ODL experience provided by both teachers and students during the multiplier events, in the summer school and after the first pilot-studies in the classroom, was very positive. Experiencing micro-MOOCs' approach has been reported by the teachers as a very effective strategy for increasing students' motivation to learn physics more meaningfully. Thanks to the ODL methodology, student understanding of physics concepts has been achieved within a multidisciplinary learning context which also supports the development of transversal abilities, communication and reasoning skills. The ODL learning activities provided the students with the opportunity to develop a large range of complementary competencies, such as working in groups, interpreting and evaluating experimental data, designing models, facing and solving everyday problems, which are all very relevant in physics education.

## 1. Introduction

Recent studies have highlighted an alarming decline in young people's interest towards the study of scientific subjects, often considered fascinating but not easily understood and appreciated by students. 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 first contacts with science at an early stage in the subsequent formation of positive attitudes towards science [1]. Several reports show that one of the main factors that influences the increase of interest, motivation and positive attitude towards the study of Physics, is represented by the didactic method used within the teaching-learning process. Thus, the difficulty of learning Physics is often increased by an ineffective teaching methodology implemented by teachers, who prefer standard class lectures and focus on mathematical/theoretical calculations. Particularly, the attention should be focused on the teaching method adopted in secondary school, which is the most important level in determining whether students will prefer science studies in the future [2]. Current trends in education emphasize the need for a progressive switch toward learner-centered approaches in which the students should actively participate in the learning process. Active learning represents a radical change with respect to traditional approaches. In fact, this methodology is based on the idea that an effective knowledge is acquired through an active student engagement rather than directly transmitted by the educator. In addition, school education changed a lot in the last years because of the introduction of new technology, such as tablets, 3D printers, interactive whiteboards, apps and scaffolds, and other various ICT education instruments [3-5]. All 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 [6].

Inter alia, physics curricula should include integrative laboratory experiences that promote inquiry, relevance, and hands-on experience. The abilities of making observations, performing systematic and quantitative investigations, data collection, analysis and logical interpretation of results and drawing relevant conclusions, are fundamental goals in science education. Physics teachers should gradually replace the old lecture-based method of instruction by adopting innovative teaching strategies taking into account the practice of scientific inquiry. Indeed, performing experiments could help theoretical learning provided that there is a high level of integration between lectures and practice and also reinforce students' classroom learning experiences. Unfortunately, many of the physics topics are taught with only very limited support from experiments for quite a lot of reasons, such as cost, space or safety implications for implementing the experiments [7]. At this respect, online experimental laboratories could fulfill the lack of real equipment and should be included within innovative teaching/learning paths [8]. The inclusion of these laboratories in the curricula could add value to teaching processes, giving real chances for the building of learning experiences [9]. Moreover, the use of computer-based interactive learning materials has a strong potential in producing and assessing a constructivist learning methodology and it is appropriate to expand learning and training processes with considerable benefits. In fact, it promotes self-directed learning activities, improves motivation, learner engagement and limits costs. Furthermore, the students have the opportunity to use the software out of class times for reinforcement, revision or self-testing [10].

The Massive Open Online Courses (MOOCs) are high quality online courses delivered from the world's best universities aimed at unlimited participation and open access via the web. In addition to traditional course materials such as filmed lectures, readings, and problem sets, many MOOCs provide interactive user forums to support community interactions among students, professors, and teaching assistants. Although it has been extensively investigated if MOOCs are helpful in University and adult education [11-13], until now their impact and effectiveness in school education has not been explored.

The "Open Discovery of STEM Laboratories" (ODL) has been an Erasmus+ KA2 project aimed to implement teacher collaboration in creating and using micro-MOOCs (very short version of Massive Open Online Courses, MOOCs) for the insertion of STEM remote/virtual laboratories in the everyday teaching practices (http://opendiscoverylabs.eu) [14]. In order to support educators on creating innovative STEM school curricula by employing new technological teaching/learning tools, the ODL consortium offered to the teachers the opportunity of acquiring both technological and pedagogical skills for assembling separate educational materials within coherent learning paths. The consortium defined a methodology for the micro-MOOC design by adopting the well-known 5E model of instruction within an inquiry-based approach of science education [15,16]. The most innovative aspects of the project included the use of online remote and/or virtual laboratories, the development and re-use of open education resources (OERs), the sharing of teaching/learning good practices. From

November 2015 to April 2018, the project educators created more than 100 multidisciplinary micro-MOOCs and, during the multiplier events, they trained about 500 European teachers to design their own micro-MOOCs and implement them in their classrooms.

In this work, we focus our attention on the results from the ODL teacher training in Italy and from the first implementation in the classroom, showing the valuable feedback collected by teachers on the impact of the ODL pedagogical approach on physics education at secondary school. Physics, in fact, is one of the STEM subjects where the ODL methodology might support both the development of an effective knowledge of the contents and the achievement of reasoning skills and problem solving abilities. In particular, all the main pedagogical aspects of the project will be described (Section 2), together with the ODL activities within the contest of teacher professional development (Section 3). In Section 4 the outcomes from the first pilot studies in classroom are presented and discussed. In Section 5, some conclusions about the efficacy of the formative process in teaching physics will be drawn.

## 2. The ODL methodology for physics education

The study of physics in secondary school is too often characterized by a lack of interest and method, providing the learners with a knowledge based on the memorization of facts and laws which cannot be considered an effective understanding of the physics concepts. On the contrary, the teaching strategies involved in micro-MOOC implementation is grounded on the viewpoint that students are active thinkers, who construct their own understanding from interactions with phenomena, environment, and other individuals. In fact, in inquiry driven learning, the students are stimulated to identify scientifically valued questions, plan investigations, collect evidences in laboratory, build descriptions and explanation models, share their findings and eventually address new questions. 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 physics laws previously introduced by the teacher. Thus, all possible pedagogical scenarios for micro-MOOCs are laboratory-based experiences and have a high degree of interactivity. Their duration is approximately limited to 40-50 minutes, inclusive of the exploitation of remote or virtual laboratories. The students are personally involved in experimental activities, facing problematic situations that requires reasoning efforts, in order to be effectively solved. Moreover, the laboratory activity is not limited to the conduction of experiments and observations, but it includes a preliminary phase characterized by posing scientifically relevant questions, designing procedures and a final critical evaluation of obtained results. Furthermore, the designing of effective micro-MOOC-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 micro-MOOC design takes into account the 5E learning cycle, that leads students through five phases of learning: Engage, Explore, Explain, Elaborate, and Evaluate; it develops student critical thinking and helps students to explore and evaluate their learning [16]. All phases of the 5E learning process are included into the micro-MOOCs, but with different amount of support provided by the teacher [15, 17-19]. Moreover, these are usually well separated within the micro-MOOC in such a way that their administration can be delayed in time. Depending on the amount of support provided by the educators, the learners may be involved in a confirmatory, structured/guided or open/elicited inquiry [20-22]. In order to facilitate the teachers in the transition from scenarios to educational resources the ODL consortium drew up the micro-MOOCs scenarios for the different levels of inquiry, by sharing key-aspects on the ODL European platform (see http://opendiscoverylabs.eu/results/).

## 3. The ODL project activities

The "Open Discovery of STEM Laboratories" (ODL) project involved five partners from different European countries: (1) 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. It fostered teacher collaboration in creating and using micro-MOOCs for the inclusion of STEM online remote/virtual laboratories in the everyday teaching practice. It focused on teachers, educators and curriculum designers with the aim to strengthen their competencies by supporting them to deliver high quality teaching practices and to adopt new methods and tools. Thanks to the project, in service and pre-service teachers had the opportunity to extend their knowledge about the inquiry-based science teaching approach, improve both digital and pedagogical skills, experience international collaborative work, explore attractive open education resources helpful to design creative lessons on STEM topics. During the project, the ODL team educators created more than 100 multidisciplinary micro-MOOCs and organized several multiplier events, national meetings and an international teacher summer school, where they trained about 500 European teachers to design their own micro-MOOCs and implement them in their classes. In particular, the ODL partners organized two rounds of Multiplier Events in each country: "MOOC in the school sector" and "Micro-MOOC in your class", whose activities were aimed at making teachers familiar with the micro-MOOC scenarios and the edX-based ODL platform [14].

3.1 *The multiplier events in Italy*

In Italy, we organized several national multiplier events: Palermo (November 25, 2016), Catania (January 16, 2017), Milano (February 6, 2017), Udine (April 7, 2017), Caltanissetta (September 1, 2017), Palermo (January 17, 2018), Catania (February 16, 2018). During the workshops, the micro-MOOCs were presented as good examples of resources to be used in teaching practice. Starting from the guiding idea of sharing expertise, the educators from the ODL project team introduced the participants attending the workshop to the main pedagogical aspects of the ODL project and engaged them into a practical BYOD-based working session. The most part of the workshops was devoted to a fruitful interaction with the audience, supporting participants -working in small groups- aimed at to make them familiar with the edX-based ODL platform, designing and implementing their own inquiry-based micro-MOOC. Teachers had the opportunity to learn how to convert their scenarios into educational resources and received useful suggestions on how to incorporate their micro-MOOCs into school curricula.

**Figure 2.** Pictures from the ODL italian multiplier events.

At the end of the workshops, all groups presented their micro-MOOCs and an overall discussion supported the sharing of participant experiences. In particular, the ODL training stimulated physics teachers to: (1) explore, collect and organize new open educational resources on physics remote and virtual laboratories; (2) manage inquiry-based lesson plans, designing highly engaging student-centred learning activities, as laboratory and practical work; (3) build micro-MOOCs on interdisciplinary STEM topics.

The relationship between our training intervention and the teacher affective development and motivation to adopt new methods and tools has been quantified by means of a questionnaire suitably designed by the consortium partners in order to assess the experience acquired by the participants in relation to a specific activity. The questionnaire was administered to the teachers at the end of the training activity and the collected answers provided us a general overview of the teacher satisfaction on a ten-point Likert scale. The outcomes of the questionnaire are reported in Table 1 where the teacher satisfaction grade is listed for each topic of the two round of the workshops. According to their answers, the overall mean satisfaction grade provided by teachers in the multiplier events was very high.

**Table 1.** Multiplier event structure and outcomes from the questionnaire on the teacher satisfaction grade at the end of the two multiplier events

| **First multiplier event structure "MOOC in the school sector"** | **Mean teacher outcomes on a ten-point scale (n=110)** | **Second multiplier event structure "Micro-MOOC in your class"** | **Mean teacher outcomes on a ten-point scale (n=70)** |
|---|---|---|---|
| The "Open Discovery of STEM laboratories" (ODL) project (~30 min) | 9,2±0,1 | ODL project milestones for the second year (~30 min) | 9,2±0,1 |
| The Inquiry methodology in the teaching of Sciences and the ODL pedagogical framework (~60 min) | 9,1±0,2 | The ODL platform (~90 min) | 9,5±0,3 |
| The use of STEM virtual / in-remote laboratories: scenarios and "recipes" for the creation of micro-MOOCs (~60 min) | 9,4±0,3 | Examples of multidisciplinary microMOOCs (~60 min) | 9,5±0,2 |
| *Group Work* | | *Group Work* | |
| A possible scenario for a multidisciplinary micro-MOOC (~90 min) | 8,8±0,7 | Participants work on the platform in the activity "micro-MOOC & Inquiry: plan together our micro-MOOC" (~5 h) | 9,7±0,1 |
| Examples of micro-MOOCs on STEM topics (~60 min) | 9,1±0,7 | | |

3.2 *The ODL Teacher Summer School*

A 5-day long Teacher Summer School has been organized in Acicastello (CT), Italy, from 17 to 21 July, 2017 (https://odl-tss.jimdo.com/), as an essential part of the project assuring the achievement of its objectives in terms of teacher professional development. The Teacher School was an idea-generating training that introduced secondary school teachers to a new way of making STEM teaching more exciting and accessible to students. During this activity, thirty teachers from the five countries of the consortium were trained in the topics of interdisciplinary learning, open education resources: how to create, share and use them, MOOC concept and use MOOC in a STEM classroom, inquiry in the class, edX goodies, and transformation of a micro-MOOC into an inquiry-based micro-MOOC. During the week, the teachers collaboratively worked on creating innovative micro-MOOCs, discovering remote and virtual laboratories and their application in science education. In addition to the training on the specific ODL methodology, the participants exchanged their national culture and teaching practices. In particular, they exchanged and shared ideas, experiences, and educational resources with their colleagues from other European countries. The collection of STEM laboratories, best practices, and the educational tools complemented by hands-on activities facilitated the participants in learning, discovering and designing how to integrate an innovative approach in their everyday teaching practice and how to share own education resources and findings with European colleagues.

The teacher summer school was very appreciated by the participants: 76,8% of the participants rated their overall experience as very positive; 71,4 % claimed that they were able to apply new knowledge in practice without help; 85,7% promised to apply new skills in the next semester. The teachers found the course very interesting and not very demanding since they learned all things in a pleasant way. Moreover they found the ODL micro-MOOC methodology a very good tool in order to make available knowledge, information, scientific processes, to broader audience further their own class.

## 4. The ODL pilot-studies about physics in the classroom

More than half of the currently available micro-MOOCs on the ODL depository are on physics subjects. In 2018, several pilot studies of micro-MOOC experimentation in classroom started in different countries. In Italy, the first school implementation on physics topics has been carried out by educators belonging to our national teacher network trained on the ODL methods and on the micro-MOOC development during the multiplier events and the ODL Teacher Summer School. These teachers created their own micro-MOOCS in order to meet the needs of their classes, in accordance with the Italian physics school curriculum. This phase has been very important as it contributed to validate and evaluate the outputs and the methodologies previously created. It therefore constitutes the key factor for project evaluation and sustainability.

In the last year, three pilot events about physics have taken place in Italy. The following three micro-MOOCs have been explored in secondary school classrooms: 1) "*A small journey into matter*"; 2) "*Shedding light on the Light: a micro-MOOC on the vision mechanism*"; 3) "*What do we know about radioactivity?*". In total, 108 students have participated. With the aim to investigate the effectiveness of ODL methodology in the school environment, we administrated after each experimentation, to both teachers and students, a satisfaction questionnaire, consisting of 11 questions covering all the project aspects. To quantify the student/teacher appreciation, the following five-point Likert scale was used: 5: Totally agree; 4: Agree; 3: Neither agree nor disagree; 2: Disagree; 1: Totally disagree. The English version of the student questionnaire is reported in Appendix 1 and the one used for teachers in Appendix 2, respectively. In this work we present and discuss two of these pilot-studies; the latter will be discussed in a forthcoming paper.

### 4.1 *Pilot-study 1: "A small journey into matter"*

The main objective of the micro-MOOC "*A small journey into matter*" [23] is to propose to teachers and students an inquiry-based physics course on the different states of matter, with the aim to develop students' critical thinking and to help them to explore and evaluate their learning. The micro-MOOC starts with an introductory phase in which it proposes the students to watch short videos that lead them to discover the various states of matter and their density. Students are successively invited to discuss and answer to a list of driving questions in order to stimulate their curiosity. The embedding of remote or virtual laboratories, as educational tools for practice-based learning, aims to capture students' imagination and motivation by effectively engaging them. This micro-MOOC can be also used within a multidisciplinary learning context. In fact, the process of data collection, making plots, analysis and drawing conclusions can support the improvement of student reasoning, mathematical and ICT skills.

This micro-MOOC has been tested by 54 students (29 males, 25 females), 13-14 years old belonging to the first year of the Scientific Lyceum "Benedetto Croce" in Palermo. Three lessons were spent in the classroom in which the first sections of the micro-MOOC, namely Introduction, Engage and Explore, were discussed together. The students' impressions were positive. Students participated very actively to the class discussion and correctly answered to the driving questions. In Figure 2 we show the number of students as distributed within the five levels of possible answers (listed on top of the figure) for any of the questions labelled from QE to QK (see Appendix 1).

In general, the majority of the 54 students graded their experience with very good scores (purple and cyan are predominant in Fig.2). Almost all students have been satisfied by the ODL experience. They also stated that the lessons were well organized. Finally they graded with an average score of 4.6 the fact that they could generally work by themselves on this platform and that no special technology skills were needed. As it is shown in Figure 2, they graded with scores around 4.6 that they enjoyed this lesson, that they would like to have similar lessons in future and that they liked to use online (remote/virtual) laboratory in the science lessons. They also agreed that they were learning easily the new topic presented in this virtual environment (score 4.2). Some students in disagreement are evident only in the answers to questions QE (score 3.9) and QH (score 3.9).

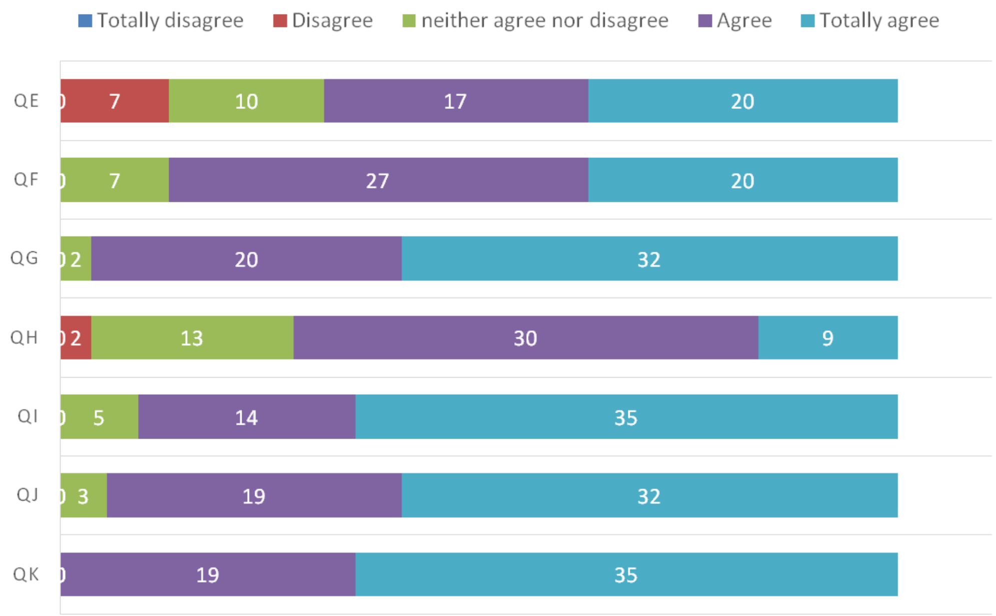


**Figure 2.** Number of students as distributed within the five levels of possible answers (top) for any of the questions labelled from QE to QK, according to the evaluation forms collected after the micro-MOOC implementation in the classroom.

4.2 *Pilot-study 2: "Shedding light on the Light: a micro-MOOC on the vision mechanism"*

The micro-MOOC "*Shedding light on the Light: a micro-MOOC on the vision mechanism*" offers to the students a learning path on a very interesting physics topic, such as the light, its propagation, and its characteristics [24]. It also stimulates the students to design and build their own glasses. This micro-MOOC has been tested by a sample of 21 students (15 males, 6 females), 14-16 years old, attending the second and third year of the Vocational Institute for Optician "E.Fermi-F.Eredia", Catania, Italy.

Firstly, the ODL platform has been illustrated by the teacher. Starting from a real problem, such as the creation of ophthalmic devices, the micro-MOOC stimulated student curiosity by inviting them to watch introductory videos on light's nature, on how it propagates, on the essential functions of the eye leading to the object vision. Then the students experienced the ODL micro-MOOC with interest and enthusiasm. In particular, the students explored various virtual and remote laboratories, investigating the laws of reflection and refraction, the dispersion of light through a prism, the equation of conjugated points. During the designing of the ophthalmic lenses, the students discovered the importance of the refractive index in determining the possible thickness of the lens to be used to make glasses, as well as the Abbe number for the quantification of the chromatic dispersion. The benefits of this didactical experience were mostly related to the opportunity of an hands-on exploration of the optics laws. Figure 3 shows the number of students as distributed within the five levels of possible answers (listed on top of the figure) for any of the questions labelled from Qf to Qk of the satisfaction questionnaire (see Appendix 1) administered after the implementation in the classroom.

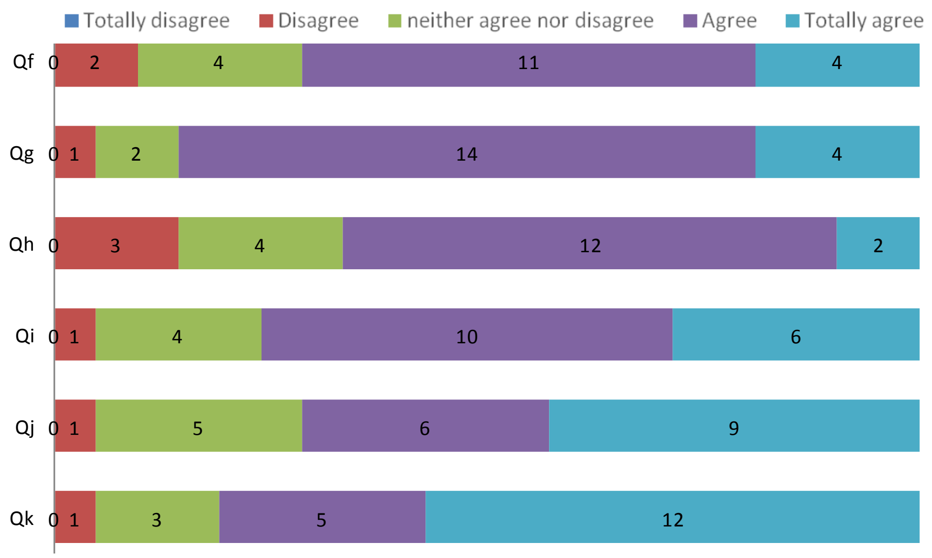


**Figure 3.** Number of students as distributed within the five levels of possible answers (top) for any of the questions labelled from Qf to Qk, according to the evaluation forms collected after the micro-MOOC implementation in the classroom.

In general, the 21 students graded their experience with high scores. Even in this case, a large number of students has been satisfied by the ODL experience, and agreed that they had very clear instructions by their teachers on what they were supposed to do (score 3.6). They also stated that the lessons were well organized. Finally, they graded with score 4.0 the fact that they could generally work by themselves on this platform, that no special technology skills were needed and that they enjoyed this lesson. Moreover, they graded with scores greater than 4.1 that they would like to have similar lessons in future and that they liked to use online (remote/virtual) laboratories in science lessons. They also agreed that they were learning easily the new topic presented in this virtual environment (score 3.8). The weakest points were related to the problems experienced in using the ODL platform, considering some technical problems in the internet connection in the classroom during the experimental works. Moreover, some students requested further lessons to better understand the platform. For some students this experimentation was similar to a recovery course. Students continued their work at home on the platform and this contributed to improve their understanding.

4.3 *The teachers' point of view*

After the implementation of the micro-MOOC in their classrooms, the teachers compiled the ODL satisfaction questionnaire (Appendix 2). Figure 4 shows the average satisfaction rate for any of the questions. According to their answers, the overall mean satisfaction grade provided by the teachers was 4.8.

In particular, the physics teachers highlighted that the use of micro-MOOCs enriched the lessons and raised students' interest in the subject, encouraging and motivating them to learn. They remarked that practical activities where students apply technologies make lessons more attractive. Also, they agreed that micro-MOOCs helped them to experience didactical innovations, to satisfy learners' interests and to meet new challenges. The micro-MOOCs increased students' interest in learning physics even among those who do not succeed in this subject well enough by attending a traditional lecture-based instruction. Teachers highlighted, however, that students aged 13-15 need to be guided through the micro-MOOC experience, in particular during the use of virtual/remote labs (reasoned exploration). Finally, the teachers reported that the ODL teaching/learning method is also effective on promoting a deeper understanding of the concepts, increasing practical abilities and communication skills.

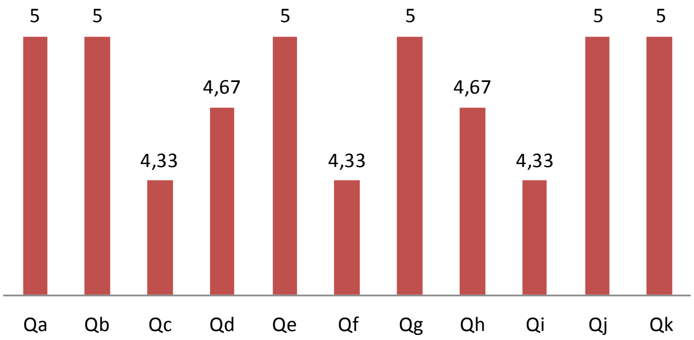


**Figure 4.** Teacher rating according to evaluation forms after implementation.

## 5. Conclusion

The "Open Discovery of STEM Laboratories" project supported educators to find and organize open educational resources within an inquiry-based framework of science instruction, while designing and delivering student-centred lessons in secondary school learning environments. In particular, the use of micro-MOOCs and ICT-based educational instruments motivated teachers in the creation of flexible teaching/learning paths and increased students' interest and involvement, due to the innovative methodology. Moreover, the incorporation of remote/virtual laboratories, as didactical instrument for practice-based learning, aimed to capture the students' imagination and motivation. Finally, the inclusion of practical exercises and evaluation tests, allowed the students to take control and awareness of their learning process.

The feedback to the ODL experience provided by both teachers and students during the multiplier events, in the summer school and after the first pilot-studies in the classroom, was very positive. Teachers highlighted that the use of micro-MOOCs as a tool for increasing students' motivation to learn physics more meaningfully might be an effective strategy. Thanks to the ODL methodology, student understanding of physics concepts could be driven within a multidisciplinary learning context which also could improve communication and reasoning skills, developing transversal competences. The described learning activities provided the students with opportunities to develop a large range of complementary skills, such as working in groups, interpreting and evaluating experimental data, designing models, facing and solving everyday problems, which are all very relevant in physics education.

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**Appendix 1**: ***Satisfaction questionnaire administered to students after the pilot studies***

Your School ____________________________________________

Your age ____________________________________________

*Please rate from 1 to 5, where 1 is totally disagree, 2 is disagree, 3 is neither agree nor disagree, 4 is agree and **5** is totally agreed.*

*Circle your preference*

a) It was clear to me what I was supposed to do in this lesson.

1 2 3 4 5

b) The lesson was well organized and ran smoothly.

1 2 3 4 5

c) I could myself work in the lesson covered today.

1 2 3 4 5

d) I could generally work comfortably by myself in this platform.

1 2 3 4 5

e) It was easy to communicate/work with the parts of the lesson, no technical problems.

1 2 3 4 5

f) I was learning easily new topic in this virtual environment.

1 2 3 4 5

g) I enjoyed this lesson.

1 2 3 4 5

h) It was clear to me what was expected from me for this lesson.

1 2 3 4 5

i) It was easy to work with platform: no special technology/computing skills are needed.

1 2 3 4 5

j) I would like to have similar lessons in future.

1 2 3 4 5

k) I like to use online (remote and virtual) laboratory in my science lessons

1 2 3 4 5

**Appendix 2**: ***Satisfaction questionnaire administered to teachers after the pilot studies***

Your School ________________________________________________

Years of professional experience ___________________________________

Subject __________________________________________________

*Please rate from 1 to 5, where 1 is <u>totally disagree,</u> 2 is <u>disagree</u>, 3 is <u>neither agree nor disagree,</u> 4 is <u>agree</u> and **5** is <u>totally agreed</u>.*

*Circle your preference*

a) MicroMOOOs encourage and motivate students to learn.

1 2 3 4 5

b) MicroMOOOs are interesting to students as they enrich and enhance lessons.

1 2 3 4 5

c) MicroMOOOs develop students' and teachers' digital competences.

1 2 3 4 5

d) MicroMOOOs help me to raise students' interest in subject learning.

1 2 3 4 5

e) Remote and virtual laboratories are a perfect tool to improve subject visualization.

1 2 3 4 5

f) MicroMOOOs encourage students to solve real life problems.

1 2 3 4 5

g) Students like activities where they apply technologies, it makes lessons more attractive to them.

1 2 3 4 5

h) MicroMOOOs make students think and act creatively .

1 2 3 4 5

i) MicroMOOOs create modeling and simulations as learning methods.

1 2 3 4 5

j) MicroMOOOs help to apply and experiment innovations, to satisfy learners interests and to meet new challenges.

1 2 3 4 5

k) MicroMOOOs increase interest in subject learning even among those students who do not succeed in this subject well enough.

1 2 3 4 5