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The Impact of a Professional Development MOOC on the Teaching Beliefs of University Science Laboratory Teachers

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Research Article

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The impact of a professional development MOOC on the teaching beliefs of University Science Laboratory Teachers

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Abstract: This study contributes to the understanding of online professional development of university STEM (Science, Technology, Engineering and Mathematics) lecturers. An active learning massive open online course (MOOC) to develop best practice in teaching in university science laboratories was developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model in three cycles. The teaching beliefs and intentions of the participants were determined before and after they completed the MOOC and their level of satisfaction with this professional development opportunity was examined using a survey. The results showed high completion rates and an appreciation of the online course design. Participants who completed the course evaluation were satisfied and they identified the usefulness of the active learning components that required them to discuss and reflect, develop plans and peer-assess. A large majority developed new ideas to help them to improve their teaching. The participation in the course increased participants' understanding of the multidimensional aspects of laboratory teaching and the challenges related to it. The majority of participants changed their teaching beliefs to become more student-centred.

Keywords: HE lecturers; laboratory education; MOOCs; professional development; STEM.

Introduction

Most science and engineering curricula in higher education include some laboratory courses. Designing and teaching of laboratory classes are two essential competencies needed by most STEM lecturers. Laboratory courses have an ambition to achieve a number of objectives and thus put heavy demands on students and instructors. In laboratory courses, students are expected to learn manipulative techniques, apply relevant knowledge to a scientific task and interpret data, but also interact with teaching staff and other students, and successfully navigate the lab itself. Many laboratory courses aim to include development of inquiry skills such as critical analysis, planning experiments, deduction and cooperation with peers and communication of results as outcomes. Seery (2020) recently considered how to describe the pedagogic goals of laboratory work in chemistry and concluded that "the place to learn how to do chemistry" best captured this complex learning environment.

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Learning in laboratories requires educators who are capable of guiding students through a challenging learning process (Mutambuki & Schwartz, 2018). Unfortunately, full achievement of the effectiveness of laboratory classes is often not accomplished. In their report "Tertiary Science Education in the 21st Century", Rice, Thomas and O'Toole (2009) discuss the key role that laboratory instructors have in science higher education. Dragisich et al. (2016) refer to the impact of laboratory instruction on career choices. O'Neal et al. (2007) and Dotger (2010) examined the effect of teaching assistants and retention in science and engineering classes. The importance of high quality instruction in laboratory classes was emphasised in both studies.

Continuous professional development is one of the important dimensions in lifelong learning. Informal learners often enrol in MOOCs as they are accessible to everyone who has a device connected to the internet and are usually free. The development of a MOOC can be very expensive (Hollands & Tirthali, 2014) and is often organized by a complex team of different experts (Wopereis et al. 2019) at big universities. A study by Herranen, Aksela, Kaul, and Lehto (2021) showed that MOOCs for professional development in STEM education were relevant for school teachers. There is not much known about the use of MOOCs in professional development in teaching and learning of university teaching staff. Kormos and Nijakowska (2017) have demonstrated that taking a MOOC increased the self-efficacy beliefs of teachers of second languages who participated. Basantes-Andrade et al. (2022) showed that short MOOCs (nanoMOOCs) could be used to improve digital teaching competences of university lecturers.

Teachers' beliefs and intentions toward learning facilitation and knowledge transmission

The way teachers and lecturers teach is associated with their conception about good teaching and their discipline (Lindblom-Ylänne et al., 2006; Rienties et al., 2014). Research has shown that traditional lecturing doesn't have a sufficient learning effect and often results in surface learning (Freeman et al., 2014; Lombardi & Shipley, 2021). Nevertheless, many teachers in higher education institutions (HEIs) still use traditional teaching methods. This is because their conceptions about what good teaching is are teacher-centred and connected to knowledge transmission. Teachers who have adopted a more student-centred approach to teaching are more likely to stimulate students to achieve deep learning (Gow & Kember, 1993; Postareff, Lindblom-Ylänne, & Nevgi, 2007; Prosser, Martin, Trigwell, Ramsden, & Lueckenhausen, 2005; Trigwell, Prosser, & Waterhouse, 1999; Uiboleht, Karm, & Postareff, 2018). Gow and Kember (1993) classified conceptions of teaching on a continuum from a totally teacher-centred, content-orientated conception to a totally student-centred and learning-orientated conception.

Changing teachers' attitudes to a student-centred approach takes time. A study by Postareff et al. (2007) implied that it takes at least a one year long training process until significant effects emerge. Vilppu et al. (2019) however showed that a short online training course can affect interpretation of teaching and learning situations, especially for less experienced lecturers. Rienties et al. (2013) studied online professional development of university teachers. They argued that lecturers could benefit from online training programmes irrespective of whether they are more inclined towards student-centred or teacher-centred approaches. According to their results from using the teachers' beliefs and intentions (TBI) instrument devised by Norton et al. (2005), Rienties et al. (2013) showed that lecturers often don't have a strong orientation and that they can be classified as having both student and teacher-centred beliefs.

Teaching beliefs of chemistry lecturers have not often been examined. A recent small scale study by Popova et al. (2020) focussed on early career chemistry lecturers. Participants were found to have a range of beliefs. Some were teacher-centred, some were student-centred and some had transitional beliefs at the midpoint between these two. Content knowledge determines the pedagogical approach as well as the adoption of particular technologies (Mishra & Koehler, 2006). In a review of 118 course designs for transitional remedial education, Rienties et al. (2012) found that lecturers from 22 countries consistently aligned their content with their pedagogical approach. Norton et al. (2005) note that several authors have concluded that a change to a

more student-centred approach can only be achieved through a professional development course if it involves addressing teachers' underlying conceptions of teaching and learning.

Online course for university laboratory teachers

Many universities recognize nowadays that there is a need for professional development of lecturers in higher education and they organize professional development activities for their teaching staff. In some countries, lecturers can achieve a University Teaching and Learning Certificate or a similar qualification. Nevertheless, these programmes are often generic and don't focus on subject specific STEM pedagogical aspects that have a consequence on how students learn (Walsh, 2017). Currently, the importance of professional development in STEM teaching is not recognized to the extent that it should be Winberg et al. (2019). There is also not enough attention given to teaching in university science laboratories.

The European Chemistry Thematic Network (ECTN, www.ectn.eu) has over 100 European HEI members and is committed to the improvement of university chemistry education in Europe. The focus of the ECTN Working Group on Lecturing Qualifications & Innovative Teaching Methods, which was established in 2015, is the improvement of teaching practice in chemistry laboratory classes in higher education and of teaching approaches of newly appointed higher education teaching staff. This Working Group has developed an open online course entitled "Teaching in University Science Laboratories (Developing Best Practice)". Its purpose is to support relatively inexperienced university lecturers and their teaching assistants to cope with the complex teaching demands in laboratory classes and to connect them in fruitful discussions about this across university and country borders. The design of the course was established in a position paper (Brouwer et al., 2016). The approach used was to launch a pilot small private online course (SPOC) initially and to make modifications based on what was learned in order to develop a massive open online course (MOOC) as the next iteration.

The learning outcomes of the online course are that participants will be able to:

- Identify the purposes of implementing laboratory classes in higher education.
- Provide strategies on how to increase student engagement.
- Develop effective questions to probe student understanding of laboratory practice.
- Create a rubric for assessing a student performing a lab activity and subsequent reports.

Research aim

To develop the MOOC, the ECTN Working group followed the ADDIE (Analysis, Design, Development, Implementation, Evaluation) course development approach (Peterson, 2003). The purpose of this research study is to explore the experiences of the participants of this open online course and what they have learned from it. The main research question for this study is:

To what extent have participants who completed the open online course Teaching in University Science Laboratories (Developing Best Practice) changed their conceptions about teaching in university science laboratory courses?

We also report what has been learned about developing an online open course by an international team with a restricted budget.

Research questions

A series of four research sub-questions were formulated to allow all aspects of the development and implementation of this open online course to be evaluated;

(1) To what extent was the chosen development process successful for developing a MOOC for continuing professional development of university laboratory teaching staff?

(2) What are the differences in course completion between the SPOC and the MOOC phases, if any?
(3) Did the open course change the beliefs of participants about good teaching and, if so, how?
(4) Were there aspects of the online course that the participants found useful for their teaching practice and, if so, what were they?

Methodology and methods

In this section we present the design and development stages and implementation including the collection of data. Data collection and analysis involves a mixture of quantitative and qualitative methods. The sources used are attendance and completion data (obtained from the MOOC platform Coursera), demographic data, results of TBI questionnaires (Norton et al., 2005), a participant evaluation survey on the online course conducted on completion, and analysis of comments from this survey.

All participants were asked to sign an informed consent. The first section of the TBI pre- and post-questionnaire had a series of additional demographic questions. Informed consent was also part of the evaluation survey. The data were collected anonymously. For the TBI pre- and post-test, instructions were provided so that participants could create an alphanumeric personal code that only they would recognize, but which they would not need to remember, as this instruction was also provided in the post-test. This allowed the researchers to match the pre- and the post tests. There was no personal code needed for the evaluation survey. The data were stored on a secure server and they were only used by the researchers, the authors of this paper who performed the analysis.

Design and development of the online course

In order to reach as many lecturers in higher education who are involved in university laboratory courses as possible, the ECTN Working Group on Lecturing Qualifications & Innovative Teaching Methods decided to develop an open online course. The working group had no specific budget. The time and effort of its designers was provided on a voluntary basis and the University of Amsterdam enabled the working group to host the course on the MOOC platform Coursera. In several phases of the development of the online course, the team used voluntary input and feedback from ECTN network members across European universities. The approach used to design and develop the online course followed an adapted ADDIE model (Peterson, 2003) Figure 1 and had three ADDIE cycles. The steps within each cycle are described in Appendix A. The first cycle resulted in pilot 1, a SPOC 1 in 2017. The second ADDIE cycle resulted in SPOC 2 in 2018. This online course took 6 weeks (one week per module) and remained open for the participants to complete for another two weeks. The third cycle resulted in a MOOC 1 in 2019. The MOOC 1 took 6 weeks with an additional seventh week for completion of all assignments if needed. Once the initial 6 week iteration of MOOC 1 was complete, it remained available on the Coursera platform from the beginning of 2020 as MOOC 2. The MOOC 2 is operating in fully automated mode and participants could choose to begin the course whenever they prefer. We have analysed the data of all iterations. MOOC 2 data from March 2nd 2020 to February 14th 2021 are of special interest for several reasons. In March 2020, numerous restrictions to face to face interactions were introduced globally because of the COVID-19 pandemic. Also, the online course was not being promoted to the same extent through ECTN from stage MOOC 2 anymore and it was anticipated this could have an impact on the number of participants and the participant profile.

Participants in the study

The participants in the study were enrolled on one of the four course iterations: SPOC 1, SPOC 2, MOOC 1 or MOOC 2. Table 1 presents the information collected on the number of participants and the responses obtained to questions focused on demographic information.

The female to male ratio favored women in all iterations of the online course in this study, but in MOOC iterations the ratio became more balanced (Table 1). The number of participants in the study who completed the evaluation survey in all four course iterations is 283: 23 in SPOC 1, 45 in SPOC 2, and 36 in MOOC 1 and 179 in MOOC 2. The number of participants who completed the TBI questionnaires in SPOC 1 was pre-test 33, post-test 14 and 11 completed both tests, for SPOC 2 pre-test 52, post-test 32 and both tests 21, and in MOOC 1: 84 pre-test, 42 post-test, and 27 completed both tests. 580 completed the TBI pre-test in MOOC 2, 85 post-test and 60 participants completed both TBI tests.

The participants in SPOC 1 and SPOC 2 came from 80 different countries. Further details are presented in the table in Appendix B. This information is sourced from the SPOC registration questionnaire and covers the period from Dec 2017 to Dec 2018.

The majority (54.6%) of participants in SPOC 1 and SPOC 2 came from European countries. The SPOCs also had participants from countries on other continents. In the table in Appendix C, the location of all participants up to July 2021 is presented based on Coursera data. It can be seen that the course reach after the SPOCs became even more global over time and that most participants (46.7%) now come from Asia.

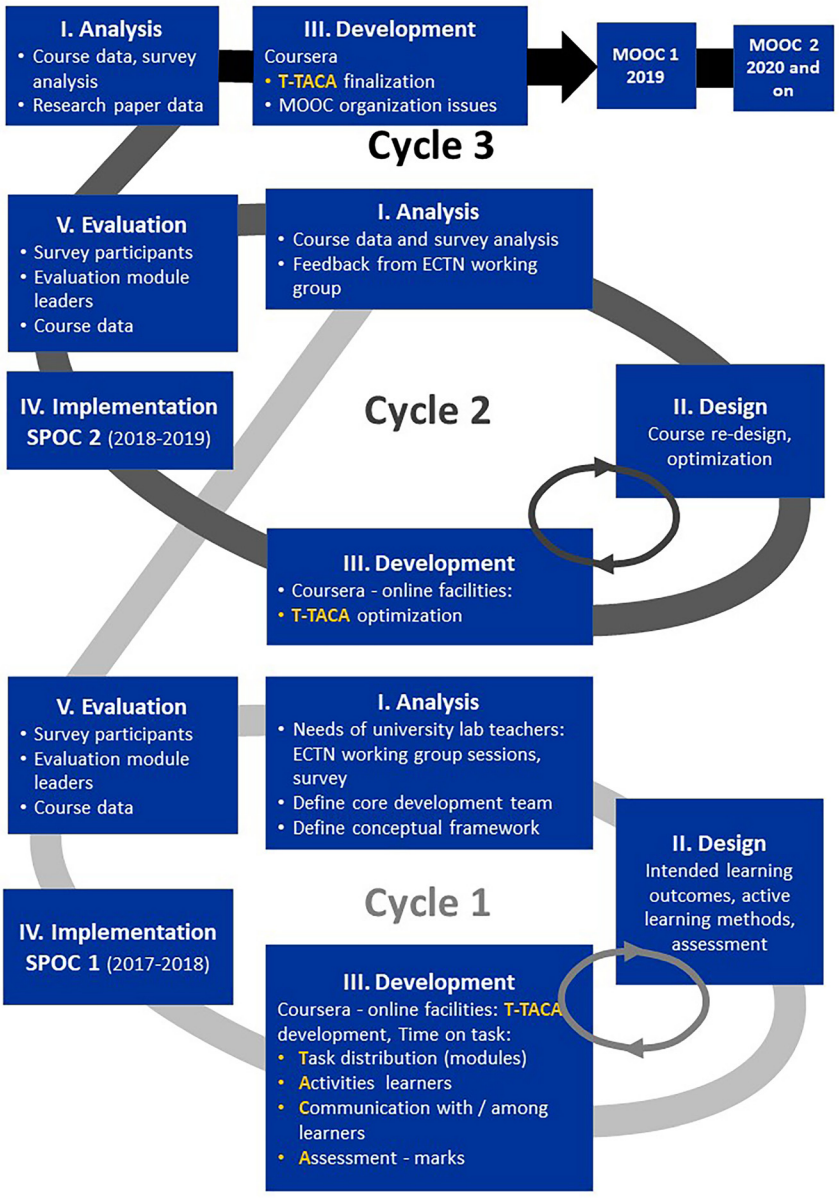

Figure 1: MOOC creation process, adapted ADDIE model (Peterson, 2003).

Classification of teachers' beliefs and intentions (TBI) profiles

Based on the scores in the TBI questionnaire instrument, the participants were classified in three different groups and the criteria used are shown below.

(1) Teacher centred

TBI score in Teaching Beliefs: Learning Facilitation < Knowledge transmission and TBI score in Teaching intentions: Learning Facilitation < Knowledge transmission.

(2) Student centred

A) Student centred 1

TBI score in Teaching Beliefs: (Learning Facilitation > Knowledge transmission) ≥ 0.3 and TBI score in Teaching intentions: (Learning Facilitation > Knowledge transmission) ≥ 0.3

Table 1: Participants on the online course iterations (up to February 14th 2021).

	SPOC 1 Dec 17–Jan 18	SPOC 2 Nov–Dec 18	MOOC 1 Oct–Dec 19	MOOC 2 continuation March 20–Feb 21
Enrolled[a]	133	128	287	3558
Started[a]	55	112	184	1792
Completed[a]	31	56	42	266
Female:Male[b]	70:30	72:28	58:42	57:43
University teaching[b] experience	<2 years 21% 2–5 years 33% >5 years 46%	<2 years 61% 2–5 years 16% >5 years 23%	<2 years 38% 2–5 years 25% >5 years 37%	<2 years 51% 2–5 years 18% >5 years 32%
Teaching areas[b]	Chemistry, biochemistry, biology	79% Chemistry 17% Biology 1% Physics, engineering, pharmacy	62% Chemistry 13% Biology 10% Biomedical sciences 5% Physics 2% Pharmacy 2% Engineering 6% Other	68% Chemistry 11% Biology 4% Physics 4% Engineering 4% Biomedical sciences 2% Pharmacy 2% Biotechnology 4% Other

[a]Based on Coursera analytics data. [b]Based on the data collected in the TBI pre-test questionnaire.

B) Student centred 2

TBI score in Teaching Beliefs: (Learning Facilitation > Knowledge transmission) ≥ 0.3 and TBI score in Teaching intentions: (Learning Facilitation < Knowledge transmission) > 0 and < 0.3

or

TBI score Teaching Beliefs: (Learning Facilitation > Knowledge transmission) > 0 and <0.3 and TBI score in Teaching Intentions: (Learning Facilitation > Knowledge transmission) ≥ 0.3

(3) Student- & Teacher centred

TBI score in Teaching Beliefs: (Learning Facilitation > Knowledge transmission) < 0.3 and TBI score in Teaching intentions: (Learning Facilitation > Knowledge transmission) < 0.3.

Results and discussion

In this section, completion rates and the results from the evaluation survey and TBI questionnaire instrument will be presented and discussed.

Completion rates and engagement in the course

Table 2 presents the completion numbers and rates for each iteration of the course. The final iteration, MOOC 2, had the lowest completion rate of 15%. However, as it was more flexible and participants could join at any stage over the timeframe analysed of almost 12 months, the completion number (266) was over 6 times greater than MOOC 1 (42). As explained in the footnote to Table 2, SPOC 1 and SPOC 2 included a cohort of blended learners and all of this group of participants completed the course (19 for SPOC 1 and 23 for SPOC 2). This method of embedding engagement with a SPOC into a larger CPD programme that includes face to face interaction is an approach that some other universities could consider (Jia et al., 2019). The large difference in completion rate could be explained by more intense involvement of the teaching staff (instructors) in the SPOC in comparison to the MOOC and thus a greater teaching presence. It is known that a balance of three presences: cognitive presence, teaching presence and social presence, is crucial for a successful online learning experience (Garrison, Anderson, & Archer, 2010; Nazir & Brouwer, 2019). Boltz et al. (2021) examined implementation of a

Table 2: Completion rates for each version of the course.

Course version	Completion number	Rate (started/completed) (%)
SPOC 1	31[a]	56 (33[c])
SPOC 2	56[b]	50 (37[c])
MOOC 1	42	23
MOOC 2	266	15
Total	395	18

[a]19 participants followed the course in a blended learning format as a part of their CPD programme at Jagiellonian University (Krakow, Poland). They all completed the course. [b]23 participants followed the course in a blended learning format as a part of their CPD programme at Jagiellonian University (Krakow, Poland). [c]Completion rate for participants who were taking the course only online (blended learners omitted).

MOOC to support school teachers and reflect that completion rates should be compared to those for other digital content such as podcasts instead of to formal online courses. They also report that a certificate of completion may not be the main motivation for some MOOC participants and their focus could be on learning something new or networking instead. For this reason, participants may not finish all elements of the course but may still have learned from it and achieved their goals.

Some participants expressed in the evaluation that they needed more time than was described in the instructions for the course. Based on these comments, the authors redesigned several parts of the course and added summaries of the reading material.

Evaluation of the participants' experience

In the last course module, the participants were asked to complete a survey (Appendix D) with nine Likert scale questions, five open questions in which the participants could discuss their experience of the course and several demographic related questions. There was a response rate for the post-course evaluation survey of 77% of those who completed SPOC 1, 77% for SPOC 2, 86% for MOOC 1 and 67% for MOOC 2. From October 25 2019 to February 17 2021, 215 (of 2015) participants from 45 different countries and five unidentified participants completed the evaluation. The country that had most participants was India.

We were interested in the experiences of the participants with professional development. The answers to the Question "Which way do you usually develop your teaching competences? (you can choose more than one option)" provided by participants in MOOCs 1 and 2 are presented in Table 3. More than 34% had never before thought about developing teaching competences.

Table 3: Answers to the question in the evaluation survey about the experience of participants in MOOCs 1 and 2 with professional development as lecturers.

Q26 – Which way do you usually develop your teaching competences? (you can choose more than one option)[a]			
#	**Answer**	**%**	**Count**
1	I have never thought about developing my teaching competences before I started this course.	34.6%	71
2	I have participated in some regular introductory activities e.g. lectures, workshops, seminars about teaching and learning at university level devoted to newly appointed teaching staff or doctoral students.	52.0%	106
3	I have obtained a University teaching qualification certificate.	22.4%	46
4	I haven't thought about CPD (continuous Professional Development) in the role of a university teacher.	8.8%	18
5	I have participated in some CPD activities (courses, workshops, conferences about teaching and learning) at university level before I have entered this course.	27.8%	57
6	I regularly participate in CPD activities.	17.6%	36

[a]Percentages are calculated based on the number of survey participants who have chosen an option and not on the total number of participants in the survey.

Table 4: Answers to the question in the evaluation survey about the experience of participants with online learning (205 participants answered this question).

Q27 – What were/are your previous experiences in learning using on-line courses?			
#	**Answer**	**%**	**Count**
1	I have never participated in an online course before.	33.2%	68
2	I have participated but I have never finished such a course.	11.2%	23
3	I have participated in a few online courses and successfully completed some of them.	38.1%	78
4	I learn quite often in online courses and I have obtained already many certificates.	17.6%	36
	Total	100%	205

Responses to another question revealed that 33.2% of the participants in MOOC 1 and MOOC 2 had never before followed an online course and 44.4% had never completed one. However, 17.6% regularly participated in and completed online courses (Table 4).

The Likert scale section of the post-course evaluation allowed participants to evaluate the course quality using a range of criteria. Table 5 shows the results and each course iteration is presented separately. The values in each follow-up course after SPOC 1 show that the improvements made based on the evaluation of the previous iteration were beneficial.

For the question "What do you consider to have been the most useful aspects of the course?" (Appendix D), the answers can be classified in different categories, as shown in Figure 2. Participants mentioned topics such as rubrics, Johnstone's triangle and cognitive overload. Several participants mentioned that the activities in the course were most useful, i.e. readings, discussion prompts and the assignments. Several mentioned that

Table 5: Responses to Likert scale section from participant surveys of the online course iterations.

Statement	**SPOC 1[a] average**	**SPOC 1 STDEV**	**SPOC 2[b] average**	**SPOC 2 STDEV**	**MOOC 1[c] average**	**MOOC 1 STDEV**	**MOOC 2[d] average**	**MOOC 2 STDEV**
1 The structure of the course was clear.	4.39	0.66	4.58	0.66	4.54	0.60	4.52	0.61
2 Information about the educational goals and learning outcomes of the course was clear.	4.52	0.67	4.56	0.67	4.73	0.50	4.60	0.57
3 Recommended reading material for the course was easily available.	4.61	0.58	4.60	0.69	4.70	0.37	4.54	0.63
4 The summaries of research articles in module 1 and 2 helped me to comprehend difficult pedagogical language.	3.83	0.93	4.47	0.74	4.59	0.59	4.51	0.64
5 I have developed some new ideas to help me to improve my teaching as a result of this course.	4.43	0.66	4.53	0.67	4.68	0.52	4.67	0.54
6 The course assignments were relevant to learning the subject.	4.30	0.70	4.53	0.70	4.62	0.48	4.56	0.64
7 Participation in the course increased my understanding of the multidimensional aspects of laboratory teaching and the challenges related to it.	4.48	0.59	4.58	0.66	4.54	0.53	4.61	0.61
8 I enjoyed participating in this online course.	4.13	0.87	4.26	0.88	4.46	0.60	4.54	0.64
9 I would recommend this course to others.	4.26	0.81	4.40	0.88	4.57	0.59	4.56	0.61

[a]SPOC 1: 24 participants. 21 completed all of the modules, 3 completed most of the modules. [b]SPOC 2: 43 participants. 41 completed all the modules, 2 completed most of the modules. [c]MOOC 1: 38 participants, 35 completed all the modules, 3 completed most of the modules. [d]MOOC 2: 179 participants, 140 completed all modules, 18 completed most of the modules.

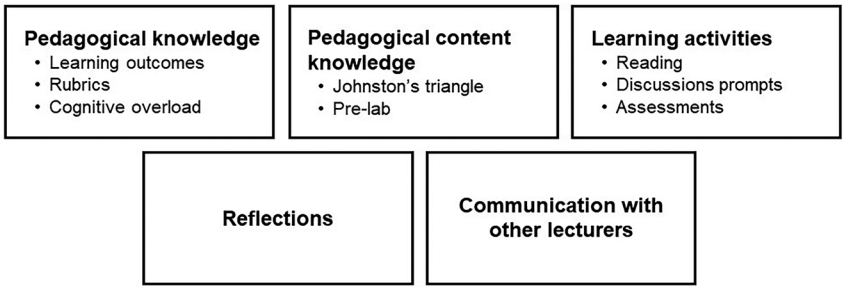

Figure 2: Categories of participant responses to the question: "What do you consider to have been the most useful aspects of the course?"

communication with other lecturers who were participating was most useful and others said the reflective activities were the most useful for them.

Several examples selected from responses by MOOC 1 and MOOC 2 participants show these different perspectives and are presented in Figure 3.

For the evaluation survey question, "What differences (if any) do you think participating in this course will make to your teaching practice?", the answers showed different plans to improve their courses. In particular, respondents intend to improve the interactivity of their courses, improve their questioning techniques and introduce rubrics as an assessment instrument. Some representative responses are shown in Figure 4.

The participants from Jagiellonian University who experienced a blended learning format instead of fully online provided feedback that they appreciated the blended format. Three face-to-face meetings made it possible to present the principles of the SPOC course, to deal with queries that arose during the implementation of the first three modules and to summarize and, at the last meeting, to correct any misconceptions. Taking part in the course allowed these participants to address stereotypes, such as the belief that the main goal of laboratory classes is to help learners understand the content presented during lectures. The new element for many of the participants was peer evaluation of their work with the help of rubrics. This raised doubts for them and clarification was needed (Brouwer et al., 2018). The observations from teaching this group in the blended format were very informative and were considered when making changes when SPOC 1 and 2 were being reviewed.

- *The new information on approaches to first make laboratory sessions more appealing to students has been very useful. Also it has been important to realise that it is important to know the background level of the subject of the students prior to starting the course.*
- *Reading and participating in the optional discussions*
- *That we could see the other participants' ideas*
- *Construction of goals and Rubrics*
- *Johnston's triangle and threshold concept*
- *I'm a beginner in teaching so all of it was quite new for me, and therefore very helpful. Maybe most importantly it provided me with a will and recognition that I CAN change things in the course I have started teaching.*
- *The discussion prompts allowed for reflection on each topic, viewing different points of view through engagement with other learners. Implementation of the concepts learnt in the readings to one's own laboratory experiments during assignments was also very useful; the first step in applying the concepts to specific lab sessions.*

Figure 3: Representative responses of participants in MOOC 1 and MOOC 2 to the question: "What do you consider to have been the most useful aspects of the course?"

- *I'll be even more concerned about the students' understanding in the lab.*
- *I intend to keep the student in mind during the design stage of lab practices.*
- *I feel I am better prepared at asking questions to students and also helping them formulate better questions.*
- *I will be using more structured rubric.*
- *It has helped me think like a student, even though I am now the teacher.*
- *I'm now more specific to the needs of students and their capacities.*
- *I will try to use different strategies to increase student engagement, ask students the right questions to direct their thinking, and keep in mind Johnstone's triangle, threshold concepts and the IPM[1], when preparing for and delivering pre-lab sessions.*
- *I will definitely make sure to plan better the lab session by fragmenting it into sections to make it easier for the students to comprehend. I will also include more visual demos of the work that needs to be done.*
- *I want to focus more on the discussion with students., Also, I found it handy to use questionnaires to get to know the knowledge of my students.*
- *I have prepared a new plan for one experiment during the course (with a rubric as an assessment method)*
- *Participating in this course has helped me realize that there are more styles of laboratory classes than just "follow a recipe" style and I definitely will try to apply some scenarios into my next year classes accompanied with the use of rubrics to help the students.*
- *I'm going to change my way of teaching. I would like to save more time during the class for students to discuss their needs and involve them more in problem solving through independent thinking rather than giving methods.*

Figure 4: Representative responses of participants in MOOC 1 and MOOC 2 to the question: "What differences (if any) do you think participating in this course will make to your teaching practice?"

Evidence that the chosen course design was effective includes the relatively high completion rate, in particular in both SPOCs, together with very positive evaluations from the participants in all iterations of the online course which demonstrated that participants who completed the course felt that they achieved the learning outcomes. As shown in Table 5, a large majority agreed that, as a result of this course, they developed new ideas to help them to improve their teaching and that participation in the course increased their understanding of the multidimensional aspects of laboratory teaching and the challenges related to it. Figure 4 provides some specific examples of new ideas and approaches generated from the course. In their comments on the open question on what they consider the most useful aspects of the course, the participants often mentioned design elements, such as discussion prompts.

Teachers' beliefs and intentions

By applying the profile classification system specified in the methods section to the responses to the TBI survey (Norton et al., 2005), it was possible to gain insights into what participants thought was most important in relation to teaching and learning. Figures 5–8 show a pre and post comparison by survey category for the teachers' beliefs of 11 of the participants who completed SPOC 1, 23 who completed SPOC 2, 27 who completed MOOC 1 and 60 who completed MOOC 2 respectively.

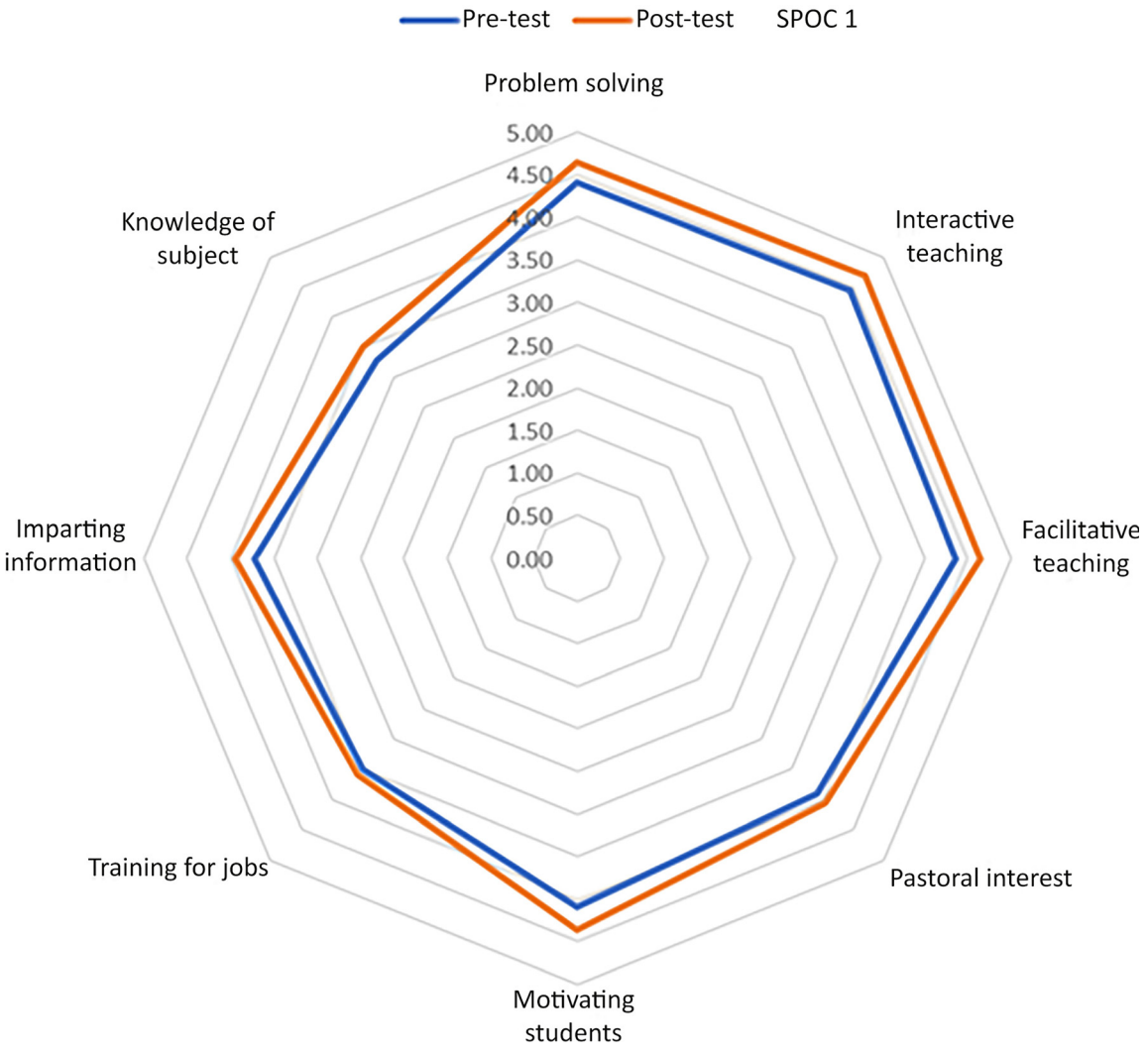

Figure 5: Teachers' beliefs of participants in SPOC 1 (Dec 2017–Jan 2018) who completed both the pre- and the post-course survey, *n* = 11.

For all iterations of the online course, an increase after the course was completed was observed in all of the teachers' beliefs categories associated with Learning Facilitation (problem solving, interactive teaching, facilitative teaching, pastoral interest and motivating students). In SPOC 1 and the two MOOCs, an increase was also observed after the course was completed in the three categories associated with Knowledge Transmission (training for jobs, imparting information and knowledge of subject). However, this increase was to a lesser extent than for the Learning Facilitation category. For SPOC 2 participants, a decrease was observed for all Knowledge Transmission categories of questions while the increase for the Learning Facilitation dimension was more modest than for the other course iterations. The main outcome from this analysis is that Learning Facilitation beliefs increase for all participants after course completion and that Knowledge Transmission beliefs either decrease or do not increase to the same extent as the Learning Facilitation beliefs. This demonstrates that, on average, participants had a more student-centred focus after course completion.

Table 6 shows a comparison of the TBI pre-course profile classification for each short course cohort alongside data from another online teaching course which one of our team was involved in previously that included lecturers teaching a wide range of disciplines (Romero & Barberà, 2011).

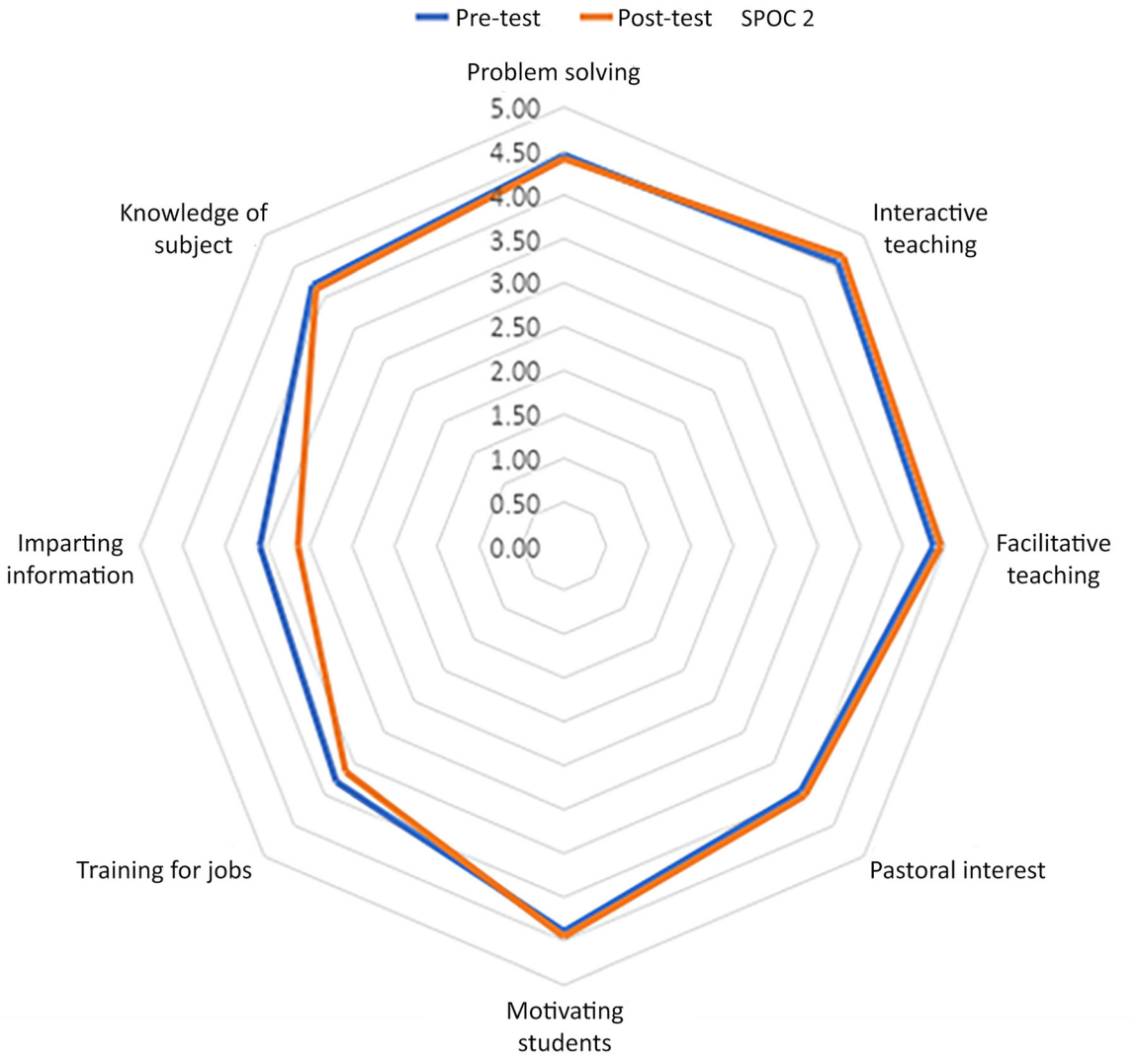

Figure 6: Teachers' beliefs of participants in SPOC 2 (Nov 2018–Jan 2019) who completed both the pre- and the post-course survey, $n = 23$.

Table 6 shows that the higher education lecturers who teach in the laboratory courses have less teacher-centred beliefs than found by Rienties et al. (2013) when they studied lecturers across a wide range of disciplines.

Table 7 shows the pre- and post-course TBI profile classifications for each course cohort and includes the participants' teaching experience.

The results in Table 7 show a reduction in the number of participants categorised as teaching-centred for SPOC 1, SPOC 2 and MOOC 1. There is also an increase in the percentage of participants with a student-centred profile (the sum of categories SC1 and SC2) in SPOC 2, MOOC 1 and MOOC 2. The result observed in SPOC 1 showing a slight decrease in the percentage of participants with a student-centred profile is difficult to interpret and may not warrant too much focus. This is because the sample size is small and the participants included several experienced academics who provided specifically feedback to the course designers. These participants were not the intended target audience.

For MOOC 2, it was observed that, although the percentage of participants with a student-centred profile increased, the percentage with a teacher-centred profile also increased slightly from 18.3% (11 participants) to

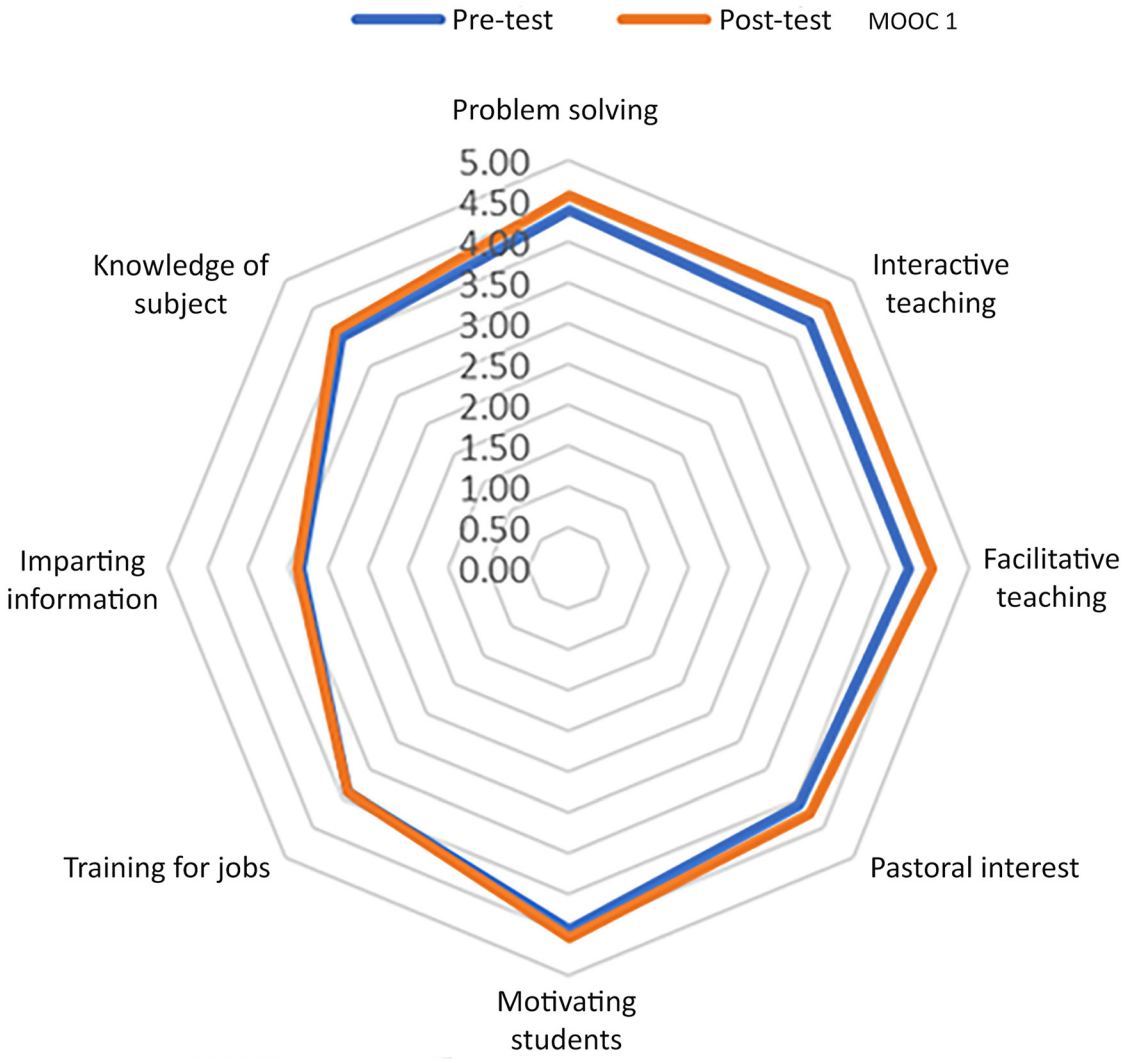

Figure 7: Teachers' beliefs of participants in MOOC 1 (October–December 2019) who completed both the pre- and the post-course survey, *n* = 27/26 (one post-test was not fully completed).

20.0% (12 participants). Further analysis of the teaching beliefs scores for the 12 participants with a post-course teacher-centred profile showed that 2 of them showed increases in one or more Learning Facilitation categories (in the rest of the categories, there was no change). Four of them showed increases in two or more Learning Facilitation categories but showed a decrease in one other category and no change in the others. Therefore, six of the participants with a teacher-centred profile showed some aspects of being more student-centred after taking the MOOC 2. MOOC 2 was in operation during the COVID-19 pandemic and perhaps this may have had an impact on teachers' beliefs of some participants. Also, because a MOOC doesn't involve interaction with facilitators in the discussion board activities, there may have been some peer interaction taking place that reinforced teaching-centred beliefs and intentions. One disadvantage of MOOCs is the limitations to assessment of learning and the lack of opportunity for feedback to be provided from a tutor (Cabrera & Fernández-Ferrer, 2017; Kang & He, 2018; Wei, Saab, & Admiraal, 2021). Huisman et al. (2018) investigated the impact of peer-reviewer ability on performance of learners for a MOOC essay assessment. They observed a positive relationship.

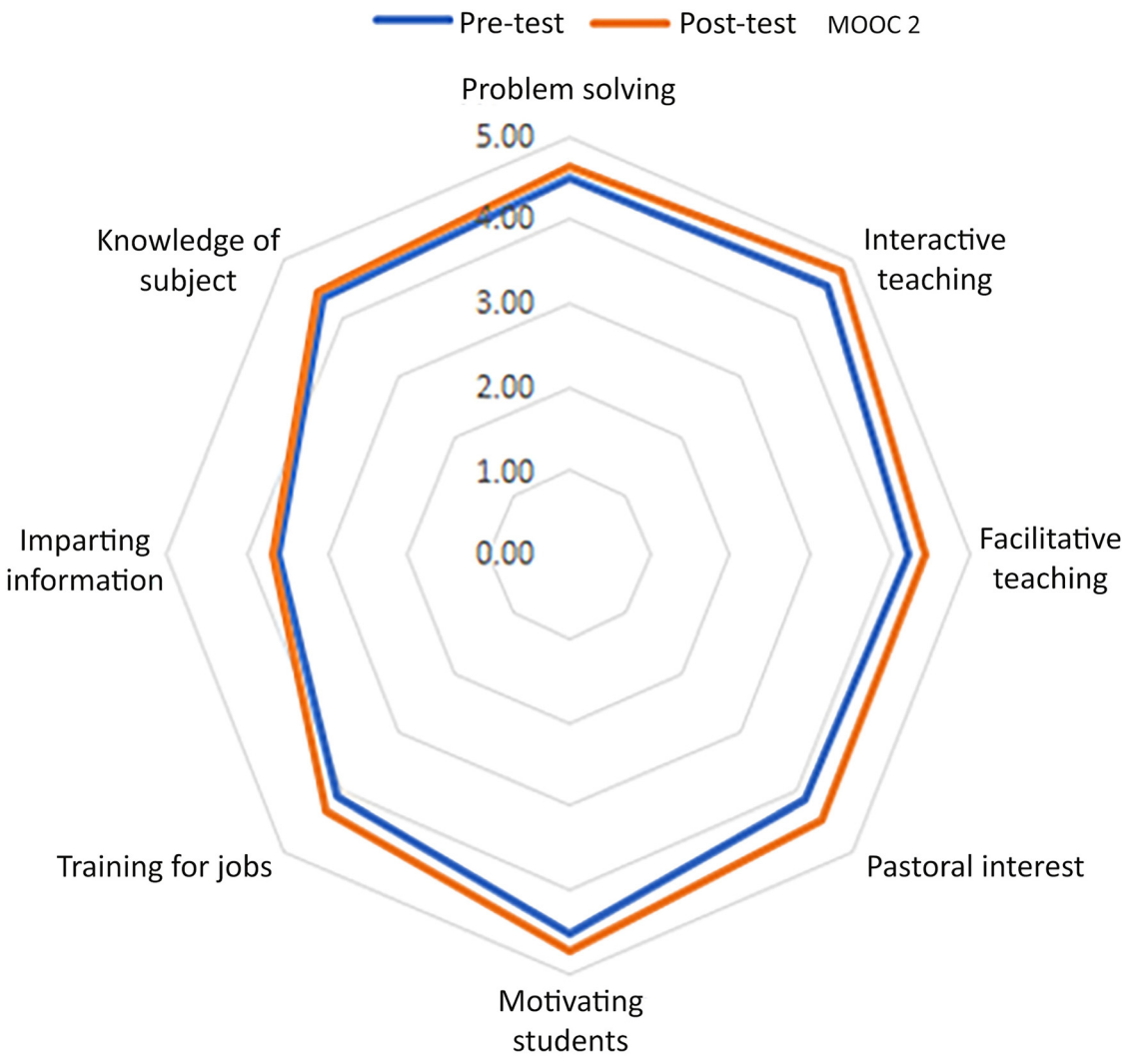

Figure 8: Teachers' beliefs of participants in MOOC 2 (March 2020–February 2021) who completed both the pre- and the post-course survey, *n* = 60.

Table 6: Classification of participants in three groups (teacher-centred, student-centred or student & teacher-centred) from the pre-course TBI survey in this study as well as a previous one (Romero & Barberà, 2011).

TBI profile	Cohort				
	Rienties et al. (2013) (*n* = 33)	SPOC 1 2017 (*n* = 30)[a]	SPOC 2 2018 (*n* = 52)[b]	MOOC 1 (*n* = 83)[c]	MOOC 2 (*n* = 580)[d]
Teacher-centred (T-C)	24%	20%	15.4%	18%	23%
Student-centred (S-C)	40%	67%	69.2%	63%	51%
			S-C1 34.6%	S-C1 41%	S-C1 19%
			S-C2 34.6%	S-C2 22%	S-C2 32%
Student-& Teacher-centred (S&T-C)	36%	13%	15.4%	18%	26%

[a]SPOC 1: 60.0% of those who began the course completed the pre-course survey. [b]SPOC 2: 46.4% of those who began the course completed the pre-course survey. [c]MOOC 1: 45.1% of those who began the course completed the pre-course survey. [d]MOOC 2: 32.4% of those who began the course completed the pre-course survey.

Table 7: Correlation of teaching experience and the TBI profile for participants who completed both the pre- and the post-course test.

Experience *n*: number participants	**TBI profile**							
	Pre-test S-C1	**Post-test S-C1**	**Pre-test S-C 2**	**Post-test S-C 2**	**Pre-test S&T-C**	**Post-test S&T-C**	**Pre-test T-C**	**Post-test T-C**
<2 years SPOC 1, *n* = 11	1	1	0	0	1	2	1	0
2–5 years, SPOC 1, *n* = 11	4	3	0	1	0	0	0	0
>5 years, SPOC 1, *n* = 11	2	1	2	2	0	1	0	0
Overall SPOC 1, *n* = 11	**7 (64%)**	**5 (45%)**	**2 (18%)**	**3 (27%)**	**1 (9%)**	**3 (27%)**	**1 (9%)**	**0**
<2 years SPOC 2, *n* = 23	4	10	8	5	1	0	3	1
2–5 years, SPOC 2, *n* = 23	0	3	3	1	1	0	0	0
>5 years, SPOC 2, *n* = 23	2	2	0	0	0	0	0	0
Overall SPOC 2, *n* = 23	**6 (26%)**	**15 (65%)**	**11 (48%)**	**6 (26%)**	**2 (9%)**	**0**	**3 (9%)**	**1 (4%)**
<2 years MOOC 1, *n* = 27	3	6	2	3	3	1	3	1
2–5 years, MOOC 1, *n* = 27	3	5	1	0	1	0	0	0
>5 years, MOOC 1, *n* = 27	6	4	4	6	0	1	1	0
Overall MOOC 1, *n* = 27	**12 (44%)**	**15 (56%)**	**7 (26%)**	**9 (33%)**	**4 (15%)**	**2 (7%)**	**4 (15%)**	**1 (4%)**
<2 years MOOC 2, *n* = 60	11	14	6	7	8	6	9	6
2–5 years, MOOC 2, *n* = 60	2	3	3	1	4	4	2	4
>5 years, MOOC 2, *n* = 60	1	6	5	2	9	5	0	2
Overall MOOC 2, *n* = 60	**14 (23%)**	**23 (38%)**	**14 (23%)**	**10 (17%)**	**21 (35%)**	**15 (25%)**	**11 (18%)**	**12 (20%)**

Conclusions

We will conclude our paper by discussing the results as aligned to each research question:

(1) To what extent was the chosen development process successful for developing a MOOC for continuing professional development of university laboratory teaching staff?

As presented in the Methodology and Methods section, we followed the ADDIE model which assured a strong course design of good quality. The online course was developed by a small core team of five people living in different parts of the world but having substantial support from the community of lecturers within the ECTN network in Europe. This allowed the core team to precisely define what lecturers teaching laboratory courses need. The core group collaborated only online and had no support in terms of a budget or technical staff. However, they succeeded in creating a high quality online course that, although it has some limitations from the graphical design perspective, is still at an acceptable level in this regard. Even though this lack of funding and support didn't diminish the pedagogical quality of the course, it did cause delays. We would recommend that other groups try to get some support to speed up the process. Participants who completed the course evaluation were satisfied and they identified the usefulness of the active learning components that required them to discuss and reflect, develop plans and peer-assess.

(2) What are the differences in course completion between the SPOC (small private online course) and the MOOC phases?

As presented in the Results and Discussion, we achieved relatively high completion rates (ranging from 15 to 56%) and participation numbers. The teaching presence (Garrison et al., 2010) in a SPOC is stronger than in a MOOC (Kang & He, 2018). This stronger presence of instructors, including monitoring the participants' discussion board interactions, could better prevent misconceptions from spreading between them. The use of the online course in a blended format integrated with the CPD programme at one institution in Poland was observed to have a substantial positive impact on completion rates. SPOC completion rates were in general substantially higher than in MOOCs but, the completion number for MOOC 2 was high relative to the SPOCs and MOOC 1 as participants had the flexibility to start whenever they chose to. Nevertheless, there was no significant difference between the evaluation results in different iterations of the course and

between the SPOCs and the MOOC iterations. The course reach afterwards became even more global over time and, in the MOOCs, the majority of participants came from Asia.

(3) Did the open course change the beliefs of participants about good teaching and, if so, how?
In all iterations of the online course except SPOC 1, there was a gain in the number of participants with a student-centred teaching approach. The pre-test showed that lecturers who teach in laboratory courses have less traditional teaching beliefs than lecturers who teach in more theoretically oriented programmes. We have demonstrated an increase in all Learning Facilitation categories of the teacher's beliefs survey from pre to post-test. Interactive and facilitative teaching show the largest increases. Among our participants, there was a significant proportion with student-centred profiles before we began. This may be a reflection of the type of teaching required in laboratories or of the type of educator who will choose to participate in an online course on teaching and learning.

(4) Were there aspects of the online course that the participants found useful for their teaching practice and, if so, what were they?
Based on the post-course evaluation, respondents indicated that they intend to improve the interactivity of the courses, improve their questioning techniques and introduce new teaching and learning tools or assessment tools (e.g. rubrics).

This study shows that the open online course (SPOC or MOOC) enabled effective professional development experiences of STEM lecturers who teach laboratory courses and that this stimulated them to develop more student-centred teaching beliefs. We recommend more research in relation to different activities and in other areas to generalize these findings to other disciplines and to continuous professional development in teaching and learning in general.

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Conflict of interest statement: The authors declare no conflicts of interest regarding this article.

Appendix A: Steps in the 3 ADDIE development cycles for the online course

A.1 ADDIE cycle 1

The first ADDIE cycle took two years and resulted in pilot 1, a small private online course (SPOC) on the Coursera MOOC platform.

- Step I Analysis (Figure 1). In this step, a needs analysis of university laboratory teachers was conducted in two different ways: (a) using a short survey that was distributed by e-mail within the ECTN network in 2015 and (b) by structured group discussions during two Working group sessions at the ECTN General assembly in April 2016. Next, the core development team was assigned and the conceptual framework with a list of aims for the course was set up and published as a position paper (Brouwer et al., 2016).
- Step II Design In this step the intended learning outcomes were defined, the type of learning activities to be used were chosen and the corresponding assessment methods were selected according to constructive alignment principles (Biggs & Tang, 2011). This was done in several cycles and in tandem with step III of the ADDIE model (Figure 1).

The final design of the Teaching in University Science Laboratories (Developing Best Practice) online course can be viewed on Coursera and a summary on the MOOC can be accessed on the ECTN website: http://ectn.eu/work-groups/lecturing-qualifications-and-innovative-teaching-methods/online-course-for-lecturers/

– Step III Development The Coursera MOOC platform was chosen as a platform for the online course. Development was conducted as a complex system of separate interrelated actions: **T**ask distribution, **A**ctivities for learning, **C**ommunication and **A**ssessment dependent on **T**ime on task, that we named a T-TACA structure (Figure A1).

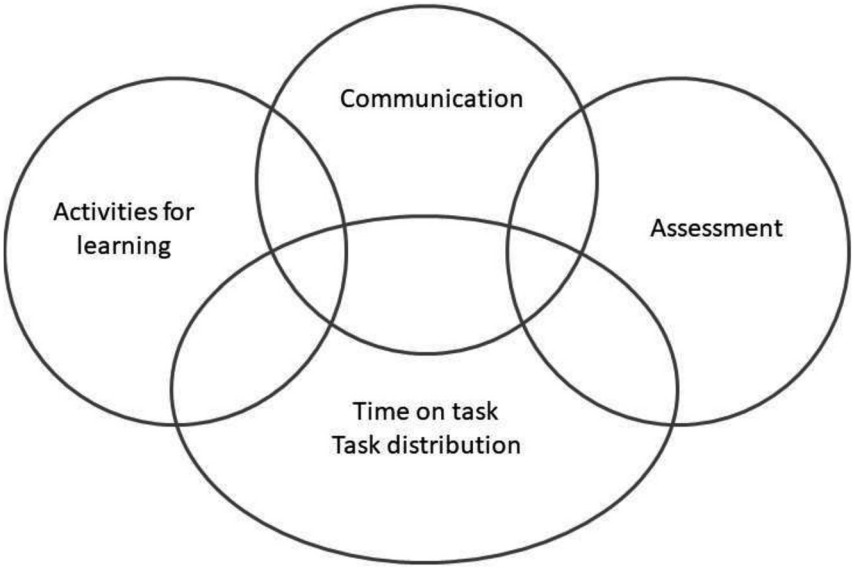

Figure A1: T-TACA. Task distribution using time on task principle for the activities for learning, communication and assessment.

In all four elements of the T-TACA structure, an average time needed for learners to complete was determined.

(i) **T**ask distribution: all tasks in the six modules were designed according to the time-on-task principle (Chickering & Gamson, 1987, Romero & Barberà, 2011);
(ii) **A**ctivities for learning: In each module there were different assignments that supported active learning behaviour.
(iii) **C**ommunication: in each module there were discussion prompts to stimulate thinking and support communication between the participants and there was a discussion board for asking the facilitators questions. For each week of the course, two support emails were developed to be sent to the participants by the facilitators.
(iv) **A**ssessment: in each module there was at least one peer-graded assignment.

– Step IV Implementation A small private online course (SPOC 1) was launched on Coursera and the online course started at the end of November 2017. The start of the course was announced at the ECTN General assembly in April 2017 and invitations to apply were communicated via the ECTN network channels and in July at the European Variety in University Chemistry Education conference in Belgrade. The course was open and free of charge. Applications were via a form published on the ECTN Working group website. Several members of the ECTN Working group participated in this course and provided feedback.
– Step V Evaluation Collection of data and evaluation were achieved in several ways. (i) All participants were requested to complete a survey about their personal experience and to give feedback about the quality of the online course and their suggestions for improvements. (ii) The participants were asked to

complete the TBI questionnaire (Norton et al., 2005) as a pre- and post-test as a part of the reflection assignments. (iii) The Coursera analytical data were exported by the development team. (iv) The development team monitored the activity of the participants during the course to establish where improvements could be made.

The T-TACA structure was cyclically tuned with the course design, the goals and the available time for the course in all three ADDIE cycles (Figure 1).

A.2 ADDIE cycle 2

The second ADDIE cycle also incorporated the T-TACA approach and lasted 11 months. It resulted in a small private online course (SPOC 2) on Coursera which was launched in the beginning of November 2018. The online course took 6 weeks and it remained open for the participants to complete for a further two weeks in January 2019.

- Step I Analysis (Figure 1). The data obtained from the evaluation of the SPOC 1 were thoroughly analyzed. The experiences of the participants from the ECTN were discussed at the working group session at the ECTN General assembly in April 2018. The participants were very positive about the course but they also suggested several improvements.
- Step II Design Based on the evaluation, the course design was slightly adapted. The order of Modules 2 and 3 were switched and several improvements were made to the learning assignments.
- Step III Development The online course on the Coursera MOOC platform was adapted according to the re-design made in Step II. Several new videos were recorded using a free recording tool. Several assignments were shortened to fit to the recommended time on task and summaries of research articles were added.
- Step IV Implementation The small private online course (SPOC 2) was launched on Coursera and started at the beginning of November 2018. As in the case of SPOC 1, the start of the online course was announced at the ECTN General assembly in April 2018 and invitations to apply were again communicated via the ECTN channels. The course was open to all and free of charge. Applications were made using a form published on the ECTN Working group website. The core development team enrolled the participants in the SPOC and sent them introductory information via the Coursera platform.
- Step V Evaluation The evaluation was done in the same way as in the first SPOC using a range of sources. These were; (i) Survey. (ii) the TBI questionnaire (Norton et al., 2005) as a pre- and post-test as a part of the reflection assignments. (iii) export of Coursera data. (iv) The development team monitored the activity of the participants during the course to establish where improvements still could be made.

A.3 ADDIE cycle 3

The third ADDIE cycle lasted 10 months and it resulted in a MOOC on Coursera which started on October 14th 2019. The MOOC took 6 weeks (one week per module) and had an additional seventh week for completion of all assignments if needed.

- Step I Analysis (Figure 1). The data obtained from the evaluation of SPOC 2 were thoroughly analyzed. The participants were very positive about the course. The development team identified several minor improvements. Module 6: Reflection was restructured by incorporating a quiz assignment which contained the reflection prompts.
- Step III Development The online course on the Coursera MOOC platform was copied to a new version in which the latest adaptations based on the evaluation were introduced. The new version was modified to become a massive open online course (MOOC 1). Two automatic emails per week/module were set up to be sent to all the participants during the course.

– Step IV Implementation The (massive) open online course (MOOC) was launched on Coursera and it started on October 14, 2019. As in the case of the first and the second SPOC, the start of MOOC 1 was announced at the ECTN General assembly in April 2019 and the invitations to apply were communicated via the ECTN channels. The MOOC launch was announced on Coursera also. The application and enrollment was arranged by Coursera and was automated.
– Step V Evaluation The evaluation was again carried out in several ways. (i) The participants were requested to complete a survey about their personal experience and to give feedback about the quality of the online course and their suggestions for improvements. (ii) The participants were asked to complete the TBI questionnaire (Norton et al., 2005) as a pre- and a post-test as a part of the reflection assignments in MOOC 1. The participants didn't earn any points towards the course certificate for completing the reflection assignments. (iii) The Coursera data were exported by the development team. (iv) The development team monitored the activity of the participants during the course.

Appendix B

Table B1

Table B1: Participant locations for SPOCs based on the private enrolment in SPOC 1 and SPOC 2. Total number of applicants *n* = 548.

Country	Number of participants in SPOCs
Poland	103[a] (18.8%)
Spain	64 (11.7%)
Australia	31 (5.7%)
Netherlands	25 (4.6%)
United States	25 (4.6%)
United Kingdom	20 (3.6%)
Italy	19 (3.5%)
Egypt	15 (2.7%)
Malta	15 (2.7%)
Belgium	13 (2.4%)
Slovenia	11 (2.0%)
India, Saudi Arabia	10 each (1.8% each)
Brazil, China, Ireland, Turkey,	9 each (1.6% each)
United Arab Emirates	8 (1.5%)
Mexico	7 (1.3%)
Canada, Greece, France, Pakistan, Somalia	6 each (1.1% each)
Germany, Ghana, Japan, Vietnam	5 each (0.9% each)
Russian Federation	4 (0.7%)
Hong Kong, Finland, Nigeria, Romania, Taiwan	3 each (0.5% each)
Argentina, Bolivia, Chile, Czech Republic, Guatemala, Iraq, Israel, Jordan, Kazakhstan, Korea, Lebanon, Malaysia, Norway, Peru, Philippines, Portugal, Republic of Morocco, Serbia, Sweden, Thailand, Ukraine	2 each (0.4% each)
Algeria, Azerbaijan, Bahrain, Bangladesh, Belarus, Colombia, Congo, Costa Rica, Côte d'Ivoire, The Democratic Republic of the Yemen, Ethiopia, Guyana, Hungary, Indonesia, Jamaica, Latvia, Macedonia, Montenegro, palestinian Territory, Qatar, Sudan, Singapore, Suriname, Switzerland, Uganda	1 each (0.2% each)

[a]41% of participants from Poland followed the course in a blended learning format as a part of their CPD programme at Jagiellonian University (Krakow, Poland).

Appendix C

Table C1

Table C1: Participant location for all four courses based on Coursera analytics data[a].

Country	Number of participants in all courses	Continent	% Participants in all courses
India	800 (29.0%)	Asia	46.7
Philippines	547 (19.8%)	Europe	20.7
United States	270 (9.9%)	Africa	13.5
Egypt	198 (7.2%)	North America	10.6
Pakistan	146 (5.3%)	South America	7.1
Turkey	142 (5.1%)	Oceania	1.4
Mexico	138 (5.0%)		
Spain	128 (4.6%)		
Poland	119 (4.3%)		
Nigeria	114 (4.1%)		

[a]Data obtained 22 July 2021; Enrolled participants: n = 5193, Participants who started the course n = 2758.

The Coursera analytics did not provide detail on countries when there was low percentage participation and instead identified only continents.

Appendix D

Questions/statements survey.

(1) The structure of the course was clear.
(2) Information about the educational goals and learning outcomes of the course was clear.
(3) Recommended reading material for the course was easy available.
(4) The summaries of research articles in module 1 and 2 helped me to comprehend difficult pedagogical language.
(5) I have developed some new ideas to help me to improve my teaching as a result of this course.
(6) The course assignments were relevant to learning the subject.
(7) Participation in the course increased my understanding of the multidimensional aspects of laboratory teaching and the challenges related to it.
(8) Which modules have you completed?
(9) If you have completed one or more modules, please tell us how much time you spent on each completed module. Our expectation was that each module would take participants about two to 3 h to complete. Was this in line with your own experience? Please explain.
(10) What do you consider to have been the most useful aspects of the course?
(11) Can you suggest any ways in which the course might be improved?
(12) Did you achieve the personal goals that you have set in the application for this course.
(13) I enjoyed participating in this online course.
(14) What differences (if any) do you think participating in this course will make to your teaching practice?
(15) I would recommend this course to others.
(16) Do you have any comments?
(17) My subject discipline is…
(18) I have been teaching in higher education for…
(19) I identify my gender as…
(20) My age is…

(21) Which way do you usually develop your teaching competences? (you can choose more than one option)
(22) What were/are your previous experiences in learning using on-line courses?
(23) What was your performance in this course?

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