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Online course to improve university laboratory teaching practice

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Introduction

Laboratory classes are an essential component of most science and engineering courses with the potential to achieve a number of practical and theoretical objectives. Subsequently, the demands on students (and instructors) are great. The students must not only learn manipulative techniques, but also link theory to practice, solve different kind of problems, interpret data, interact with staff and other students, and successfully navigate the lab itself. Learning in this situation can be greatly assisted by an educator who is able to guide students through this complex process. However, the effectiveness of laboratory classes is often not achieved to their full potential. Rice, Thomas and O'Toole (2009) showed in their report "Tertiary Science Education in the 21st Century" the key role of laboratory instructors for higher science education. They argue a huge impact a laboratory teacher has on the students' growth as chemistry professionals. O'Neal et al. (2007) and Dotger (2010), in their studies into the impact of teaching assistants and retention in science and engineering classes, both stressed the importance of providing high quality instruction in laboratory classes.

To improve this situation, the ECTN working group Lecturing Qualifications and Innovative Teaching Methods is developing an online course on teaching in laboratory classes entitled "Developing best practice in university laboratory education". The course is targeted at relatively inexperienced university teachers. First, a Small Private Online Course (SPOC) will be launched and, after a trial period, it will be made open and more massive (MOOC).

In this article, the argumentation for the chosen content of the course is given based on the inquiry among university teachers and students, the structure of the course and its component modules are described and the course design is briefly discussed.

Why choosing this Content of the online course

The content of the online course "Developing best practice in university laboratory education" is chosen to support relatively inexperienced university teachers in order to improve their teaching skills for active learning university chemistry laboratory courses. To define the learning outcomes of the online course that will be developed, first an inquiry among a

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sample group of teachers and among students was done about the learning problems that university laboratory courses nowadays encounter.

In order to adjust the course “Developing best practice in university laboratory education” to the needs of university teachers, members of ECTN working group “Lecturing Qualifications and Innovative Teaching Methods” answered personally and asked their colleagues, lab teachers at their institutions, one question “What are the most important learning problems of students who follow the lab classes at your faculty?”. We collected answers from more than 40 lecturers from 16 institutions from 8 countries.

Below the difficulties noticed by those teachers have been listed.

Almost everybody mentioned missing theoretical background, a solid preparation for the lab and lack of integration of theory and lab work. Students have problems using theoretical knowledge to carry out practical tasks in the laboratory (e.g. a student is able to do a computational task concerning the dilution of solutions, but the problem often arises when in the classroom the student is required to dilute the solution and perform the calculation beforehand).

Common difficulties include lack of motivation due to not knowing what the experiments are for, not grasping the key objectives and formulating the purpose of an experiment in their own words. In a recent study, Galloway and Bretz (2016) have shown the importance of interest, motivation and perseverance as first and second year students discussed a range of positive and negative emotions (affective domain) they had experienced in laboratory sessions. They also found that the motivating factor was often to obtain a ‘correct’ answer instead of to gain an understanding of the concepts that the experiment demonstrated.

Teachers highlighted a lack of inquiry skills: interpreting measurements and results of their experiment, formulating conclusions after executing an experiment (that does not necessarily result in a number). Students often make measurements without evaluating the obtained values. Issues were also reported with providing arguments (in relation to the necessity of using specific data, including a formula before calculations and data used for calculations) - the thought process of students is often that they would expect a reader to refer to the course textbook or laboratory handbook. According to some teachers, learners follow the recipe without their minds being focused (hands-on but not always minds-on). Galloway and Bretz (2016) found that when they interviewed undergraduates about their learning in the lab, most of the participants emphasized practical skills (psychomotor domain) instead of the underpinning concepts (cognitive domain). In the first term, the biggest problem is the extremely diverse pre-knowledge with respect to practical skills. Lack of these manual skills generates stress and it is caused by a significant gap in lab work often observed between secondary school and university. Non-compliance with health and safety rules is another issue – inexperienced students are not aware of hazards, or it can be the opposite – they are afraid of everything. Taking concise notes while working in the laboratory (in a laboratory

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notebook, laboratory journal), with a written, open form of expression is also difficult for them.

“Overloading” can be a keyword. Teachers think that learners have problems with simultaneous theoretical preparation for classes and reading the instructions, i.e. even if they prepare very well for the laboratory class as far as the required theoretical issues are concerned, they do not know exactly what they will be doing and why they do a given task. This problem of cognitive overload and the importance of ensuring that students are aware of the learning objectives of a laboratory session are common themes in the literature (Reid and Shah, 2007; Mewis, 2011).

Later on (the following semesters, with more experienced students), most problems arise from unsatisfactory working habits and practices but, on the other hand, it should be mentioned that sometimes the same skills (e.g. pipetting, weighing) are taught at different courses organized by teachers from various departments. Thus, students have difficulties with assimilating their knowledge of the various laboratory courses and consequently to transfer them from one course to another. They have problems transferring the knowledge they have gained when doing a given task to subsequent activities. Each task, on completion, is treated as a closed book.

Poor preparation by students for practical classes is sometimes observed. A common attitude among students is that “If something is not in the manual, or it cannot be found using the Google search engine, it is not important”. This issue has also been reported by Bruck, Towns and Bretz (2010). 1st year (Master level) learners present some problems similar to those already referred to for the 1st year 1st level (Bachelor) e.g. varied practical skills and habits due to students originating from different universities and departments where they have obtained their bachelor’s degree.

Respondents (teachers) told us that they would like learn more about:

- How to design active learning for the lab sessions (minds-on not only hands-on)?
- What do I do with a new laboratory course that I am required to teach?
- How to design an assignment and how to grade it?
- How to conduct classes showing routine procedures so as to make them interesting?
- What is a role of the demonstrators/GTAs in helping and mentoring students?

The problems that were identified by teachers from different European countries were very similar. To find out if the experiences of students with university laboratory courses align with the experiences that were listed by the university teachers, we have implemented a survey among the students at one European university. Students of the Jagiellonian University’s Faculty of Chemistry were asked about the main difficulties faced during laboratory classes. This was a paper-based survey and semi-open questions were used.

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Multiple-choice answers were based on the previously described problems reported in this work by European academic teachers and on inquiry competencies (IBSE). 150 responses were received, concerning various laboratory courses, from first year students to MSc courses.

The youngest respondents included Medical Chemistry students (44 people, 1st year of undergraduate studies, BSc studies) working individually or in pairs during “Basic Chemistry” course classes. The dominant problem for them is time management (66%), as well as data and measurement error analysis, including the related calculations (52%). One third of the students indicated a lack of prior (school) experience in carrying out even simple operations and that found it difficult to formulate conclusions.

Seventy five Chemistry students and eight students of Environmental Protection (1st year of MSc graduate studies) presented their feedback on the “Instrumental Analysis” course. Those students worked in groups of 5-8 people. Time management was not as problematic as in the case of the previous group (only 1/6 of the group mentioned it). However, the difficulties in data analysis (indicated by almost half of the chemists – 47%) and drawing conclusions (32%) remained. Mewis (2011) has shown that, for the sample she surveyed, staff rate the development of deduction and interpretation skills as a more important outcome of lab practicals than students do. Two new problems were emerging with a similar frequency: setting up the apparatus necessary to perform experiments or performing more complex operations (32%), and teamwork, including the distribution of tasks within the group and unequal contributions by group members (37%). These results are related to the organization of work and increase in the degree of difficulty of analysis in relation to the previously mentioned level of studies. Large majority of students of Environmental Protection (86%) who, when doing undergraduate studies, had a much smaller number of laboratory classes, are afraid to perform potentially dangerous operations associated with the use of concentrated acids, flame or glass. In the responses to open questions, the following elements were apparent: time-consuming report preparation, the necessity to select information and prepare for laboratory classes by reading extensive literature not directly associated with the measurements performed, lack of understanding of the required calculations, lack of experience in the analysis of deviations from the expected results.

At the final year of studies, when doing research necessary for master theses, the issue of time management returns, as well as the problem of setting up more complicated apparatus, working with hazardous reagents and data analysis.

Some challenges are mentioned by both teachers and by students:

- Lack of preparation to make independent decisions and plan actions; problem with time management when performing experiments
- Problem with task distribution when doing activities in groups
- Fear/anxiety about the performance of some laboratory work is quite common (e.g. avoiding working with a burner, concentrated acids, etc.)

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Structure of the online course

To tackle the issues defined by the data collected which are discussed above, we have divided the course into six modules as shown in figure 1. Each of the six modules requires approximately two hours work by the enrolled participants. In each module, explicit learning outcomes are communicated. Learning materials and learning activities are provided specifically per module and theme and are aligned with the learning outcomes. In this online course, assessments are available that will enable the participants to apply for a certificate.

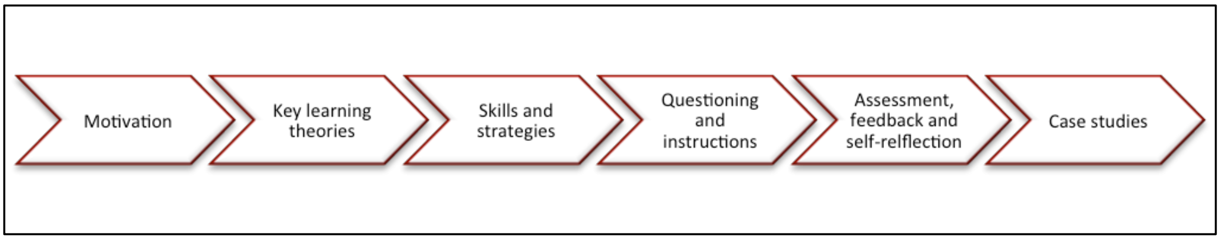

Figure 1: Modules of the course

The description of the content for each of the six modules follows.

Module 1 gives the **motivation** for the online course and a short overview. It presents the learning outcomes of the course as a whole and it sets expectations about the effort expected from the participants. In this introductory module, general aspects of practical classes and demonstrators are discussed. The module explains why we should have laboratory classes in the first place and what the difference is between practicum classes and demonstrations. The focus of this module is on the key learning that is best achieved in a laboratory environment. With reference to both practicum classes and demonstration classes a participant will be teaching, it provides strategies on how a teacher could increase student engagement.

Module 2 presents the **key learning theories** that a laboratory teacher needs to be aware of. Throughout the entire online course, learning and sharing experiences in a community of practitioners is of great importance. In this module, a space is provided for peer learning activities, where participants read and comment on relevant literature about laboratory classes and also reflect on their own teaching experience. It is important to be aware of the differences in characteristics of students and to know how to address them in lab classes. An essential element is knowledge of the different learning theories used in lab work and how they could be applied when designing lab activities for students.

Module 3 focuses on the **skills and strategies** to become a good laboratory teacher. Here the key competencies required for teaching in laboratory classes are introduced (Herrington and Nakhleh, 2003). This module explains how teaching in laboratory classes is different to regular classroom instruction. How to manage classes of students with diverse backgrounds, abilities and interests is also discussed. Participants develop a laboratory teaching plan for selected individual experiments from their own teaching program, including time management strategies. The second part of Module 3 focuses on strategies to assist students in

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learning in the laboratory class. These include, helping students identify the key aims of the experiment, better prepare before the class and ideas to motivate students.

Module 4 is about **questioning** skills and about giving **instructions**. The main aim of questioning is to develop students' learning and thinking abilities. Here, we introduce the value of good questioning skills and strategies to develop this skill. This will allow the instructor (and student) to probe student understanding of a variety of aspects of laboratory ranging from safety, experimental design and assessment. The key focus on giving instructions is to be clear and concise, without information overload. Using their own classes, participants develop effective strategies for giving instructions on a number of topics, including using a laboratory notebook, safety and pre-laboratory guidance.

Module 5 has two parts. In the first part the focus is on **assessment and feedback** in the laboratory. Assessment and feedback are connected to each other. The assessment indicates the student's current level of expertise while feedback provides information on how to improve that level. During this module, a summary of different assessment methods for laboratory skills are given. Afterwards there will be a discussion about how feedback can motivate students to go forward and learn from their mistakes. In a final exercise, the participants of the online course are invited to write down an assessment and feedback plan for a lab activity that they will apply in their own teaching practice.
The second part of Module 5 concerns evaluation of the actions taken by the laboratory teacher for student centered learning activity. The participants of the online course will be invited to act as **reflective teachers** and check which actions had positive effect on the behavior of the students so that the students became more involved into the lab activities and which teaching and learning activities still need attention and be improved.

During Module 6, the last module of this online course presents several **case studies** of lab situations. The participants of the online course will be invited to identify the problem in those situations and outline an action plan to resolve the situation. They will take the topics learned in this online course into account to use them in their action plan. The action plans will be discussed on a discussion forum.

Design and development of the online course

The online course "Developing best practice in university laboratory education" takes six weeks and has a SPOC (small private online course) format which means that the participants need to apply for the course and be admitted. The course design is online active learning. Each module has online reading and/or video material related to the theme of the module and along with it the corresponding assignments which take about two hours per module. The assignments help the participants to construct understanding and apply it to their own teaching practice and they stimulate communication and peer-feedback between the participants. The

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learning activities (assignments) are diverse. They include participation in online discussions about relevant literature or case studies, development of a reflective practice journal related to their own teaching practice (lab classes) or peer review of teaching strategies and educational scenarios. Motivation is a core issue for online learners and it is essential to build in peer interaction as well as online tutor inputs (e-moderators). Regular interaction with e-moderators is particularly important to include in the first module. Therefore, the course requires some supporting materials but key to the design are online activities that are designed to be interactive and engaging as well as regularly scheduled inputs from online tutors (e.g. formative feedback on learning journals, moderation of online discussions) and is quite different to an online repository of learning materials.

The core group of module coordinators comprises: Natasa Brouwer - WG Leader (senior consultant specializing in ICT in teaching and learning, Faculty of Science, University of Amsterdam, The Netherlands), Iwona Maciejowska (Jagiellonian University in Krakow, Poland), Pita Vandevelde (AP University College, Antwerp, Belgium), Erwin Rosenberg (TU Vienna, Austria), Mauro Mocerino (Curtin University, Perth, Australia), Gunther Fleerackers (UC Leuven-Limburg, Belgium) and Nineta Hrastelj Majcen (EuCheMS, EU). The core group members all have extensive experience in university chemistry laboratory teaching and knowledge about innovative teaching methods.

Conclusion

The development of the online course "Developing best practice in university laboratory education" is started in 2016 and the first results will be presented at the ECTN general assembly in April 2017 on Malta. To produce a quality online course that is relevant to the target group of university laboratory teachers, feedback on the development of the course will be obtained from lecturers at ECTN member universities.

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