Universal Journal of Educational Research 8(6): 2261-2269, 2020 http://www.hrpub.org
DOI: 10.13189/ujer.2020.080609

Comparison of Students' Perceived Learning in Two Similar Lab Courses with Different Teaching Staffs

Ingrid N. Haugen[1,*], Eirik Sundby[2]

[1]Department of Chemistry, Norwegian University of Science and Technology (NTNU), Norway
[2]Department of Materials Science and Engineering, Norwegian University of Science and Technology (NTNU), Norway

Received February 7, 2020; Revised March 31, 2020; Accepted May 13, 2020

Abstract At the Norwegian University of Science and Technology (NTN), two subjects with similar chemistry laboratory exercises have different practices with respect to the use of permanent and temporary staffs. In an ever-increasing focus on costs related to this type of teaching, we have investigated this difference and examined the students' perceived learning outcomes in two similar courses with different teaching practices. The results show that the students in both courses find the lab exercises relevant to the subjects and that they receive good guidance during the practical work. The most important findings reported by the students are related to the feedback students receive on their reports and most importantly how they choose to use this feedback. The students in the lab courses with permanent employees seem to use feedback more actively compared to the students in the courses with temporary employees. This might also be related to how much they engage in their own written reports. While one student group is given an allocated time to complete their report forms and hand them in during the lab hours; the other student group complete their reports in their own pace outside of the mandatory lab hours. This difference in how the written reports are completed might have an impact on the degree of reflection and learning outcome for the students. These findings further emphasize the importance of well-structured laboratory sessions with clearly communicated learning objectives as key to obtain the wanted learning outcomes for all STEM subjects with practical training. In conclusion, the use of permanent teaching assistants in laboratory teaching enhances the students' perceived learning in chemistry laboratory exercises and the present study further accentuates the need for motivated laboratory teaching assistants for the given feedback to be productive.

Keywords Learning Outcome, Practical Chemistry Laboratory, General Chemistry, Degree of Reflection

1. Introduction

Laboratory activities as an integral part of the teaching in technological and scientific subjects have played a key role in higher education for many decades [1], [2]. This type of teaching will by its nature be more resource intensive than one-to-many teaching, such as traditional lectures. It is natural that questions are raised concerning how useful this type of teaching is for the individual student's learning outcomes. In an education with ever-increasing demands for efficiency and resource utilization, the use of laboratory exercises in teaching science and technology is under pressure. Some have suggested that regular laboratory teaching can be replaced by software-based virtual laboratory exercises [3]. There still seems to be a consensus that some level of student-active laboratory teaching should be included when teaching technology and science subjects, focusing on developing higher order cognitive skills [4]. Laboratory activities have long played a distinctive and central role in the science curriculum and it is generally accepted that there are many benefits to engaging students in these types of activities. [1], [5]–[7]. More specifically research suggests that when properly developed, designed, and structured, laboratory-centred science curricula have the potential to enhance students' meaningful learning, conceptual understanding, and understanding of the nature of science. The laboratory as a platform for the development of learning skills is recognised around the world [7], [8].

Laboratory education provides a unique opportunity for students to practice their subject and apply theoretical concepts discussed in lectures. The chronological relationship between laboratory and lecture is critical to student knowledge synthesis [9]. In addition, having well thought out learning objectives that are clearly communicated, increases the likelihood of successfully completing them. [1]. Ideally educational practitioners should consider experiential learning theories [10], [11], and Bloom's Taxonomy [12] to clearly define the laboratory learning objectives of a laboratory. There is also some evidence that students themselves find practical work relatively useful and enjoyable when compared to other science teaching and learning activities. In a survey conducted among 1400 students in the United Kingdom [13], 71 % chose 'doing an experiment in class' as one of the three methods of teaching and learning science they found 'most enjoyable'.

Investigating learning outcomes from laboratory teaching is important, as this learning environment has a different context than traditional classroom teaching. Laboratory teaching is often more interactive with individual feedback and ideally allows the student to reflect and find answers themselves from the data obtained. This differs from traditional lectures, where the theory or answer is merely given. This means that an effective teacher in the laboratory must use different teaching techniques compared to a classroom lecturer, and research has shown that laboratory staff is important for students' learning outcomes in laboratory courses [5]. With this background, it should be evident that practical laboratory work is crucial in teaching science and that optimized laboratory learning sessions is of outmost importance.

Chemistry teaching in higher education is an example of a topic within Science, Technology, Engineering and Math (STEM) where the balance between obtained learning outcomes and added costs is particularly relevant. This is because practical laboratory teaching needs to be in small groups due to Health and Safety requirements, which leads to a higher demand for instructors per academic credit in these courses. In addition, chemistry laboratory courses often require the use of expensive instruments and consumables, which further add to the costs of this type of teaching. It is therefore of general interest to evaluate how these learning elements add to the students learning.

On the 1st of January 2016, the Norwegian teaching institutions NTNU and the university colleges in Sør-Trøndelag, Ålesund and Gjøvik were merged into one. As two academic environments with overlap in material technology and chemistry were merged into one institute, differences in student learning and resource management became obvious. The former Institute of Chemistry and Materials Technology (IKMT) from the Sør-Trøndelag University College (HiST) and the Department of Materials Technology (IMT) from NTNU were combined into the new Department of Materials Science and Engineering (IMA).

Traditionally, NTNU employs PhD-students as teaching assistants in the laboratories. Permanent staff engineers are primarily used in research support and as facilitators before teaching starts and have little student contact. This contrasts with the practice of the university college where all laboratory teaching has traditionally been carried out by permanent staff engineers.

As shown in Table 1, the laboratory training in chemistry courses at the three-year engineering degree programs in Norway is conducted with permanent staff engineers who are also partly involved in giving feedback on reports from the lab exercises.

Table 1. Overview of academic resources used in laboratory teaching in General Chemistry at different universities/colleges that offer three-year education in Chemical Engineering in Norway

University/College	Type of laboratory staff	Feedback on reports given by
OsloMet	Engineers	Lecturer
Østfold University College	Engineers/Lecturer	Lecturer
University of South-Eastern Norway (Campus Porsgrunn)	Engineers (most of them with a master's degree).	Engineers
Western Norway University of Applied Science	Engineers	Lecturer /Engineers
University of Stavanger	Engineers	Engineers (Lecturer in masters courses)

In the present paper we have looked at differences and similarities between laboratory courses in two similar introductory chemistry courses. We wanted to investigate how they are conducted and whether potential differences affect the students' perceived learning outcomes. In addition, we have examined how students make use of and assess the learning resources offered.

2. Methodology

The courses selected for comparison were TKJE1002 General Chemistry and TMT4115 General Chemistry. Both courses are taught in the first semester of their respective programs, and are of comparable size, both for lectures and lab course (Table 2 and 3). There is also a large degree of overlapping syllabus and similar tasks that are carried out in the lab, this is explained further below. Neither program has any formal requirements for chemistry from high school, so there will be a similar mix of students with and without experience of chemistry in both courses.

Table 2. Number of students who registered, attended and passed the exam, and number of students who passed the laboratory course in TMT4115 in 2013-2017

	2013	2014	2015	2016	2017
Registered for the exam	131	114	130	130	115
Attended the exam	118	105	121	127	112
Passed the exam	113	97	110	117	93
Passed the laboratory course	117	103	119	122	107

Table 3. Number of students who registered, attended and passed the exam, and number of students who passed the laboratory course in TKJE1002 in 2013-2017

	2013	2014	2015	2016	2017
Registered for the exam	152	161	172	142	149
Attended the exam	150	154	162	133	138
Passed the exam	139	134	149	114	122
Passed the laboratory course	145	150	153	128	130

The difference in the subjects is how the lab courses are taught. TKJE1002 uses the engineers to prepare everything before each task, teach in the laboratory and correct the reports afterwards. The engineers also help to improve the lab course over the years. TMT4115 uses engineers to prepare for the lab, while PhD-students teach in the lab and approve the written reports after the lab.

TMT4115 General chemistry is taught for students in the master's program in industrial chemistry and biotechnology (five-year). The course is completed in the first semester with nine lab exercises, each of which has been allocated four hours in the lab. Before the students arrive at the laboratory, they must answer questions on preparation forms and have three questions related to HSE and three questions related to current theory approved. The time in the lab is used for a short summary and then performing the exercise with PhD-students present to supervise. All the exercises conclude with students filling in individual report forms that are submitted for approval before leaving the lab.

TKJE1002 General chemistry is taught for students at a bachelor's program (three-year) in chemical engineering, materials technology and bioengineering. The course is completed in the first semester, with eight exercises, each of which has been allocated two hours in the lab. The time in the lab is used for a short summary and then performing the exercise with engineers present to supervise. In the fall of 2017, parts of the course were conducted with a hired fellow due to a sick leave. For seven of the exercises, preparation forms are made available to the students in advance, with the expectation that the students use this to prepare for the lab on their own. Reports are written in pairs in the students' own time after completion of the lab. The focus is on theoretical understanding and it is therefore chosen to use the report form for six of the exercises in the first semester for the students. Nevertheless, two complete reports are written in the laboratory course, where feedback is given on the formal report demands as well as the theoretical content.

A survey was conducted in the spring of 2018 among students who had completed one of the two General Chemistry courses, TKJE1002 and TMT4115.

The survey was conducted using SelectSurvey [14]. This was chosen as it was a tool available through NTNU and gave us the option to tailor the survey to our needs. As mentioned, the questions were divided into three sections with 5-8 questions in each section. The answers were on a scale from “Completely agree” to “Completely disagree” (five levels), with the additional option “Don’t know/not relevant”.

Because the students taking TKJE1002 follow a mainly set course plan, we used the subjects in the later semesters to reach students who have completed the General Chemistry subject from several years (completed the course in 2015-2017). The survey was sent to these students by enlisting the help of lecturers in the later subjects and sending the survey by e-mail through the learning management system (LMS) Blackboard. In total the survey was sent to 259 students, and 52 % replied to the entire survey.

For TMT4115 the course plan is not as set, so only the most recent group of students could be reached (completed in 2017). For these students the e-mail was sent using the General Chemistry subject’s “room” on the Learning Management System used (Blackboard). This is a total of 107 students, and 38 % replied to the entire survey.

A prize was promised for the student group with the highest percentage of answers compared to potential answers. This was divided by the subjects the students were

staff from the start of their education. This makes it easier to seek contact later in the semesters. The students in TKJE1002 also use the feedback they are given on written reports more actively, creating a good foundation for further written work during their education. The most important findings in the present study is that students seem to reflect deeper on practical laboratory work when the teaching assistants are involved in all aspects of the lab-work and when writing complete laboratory reports.

On a more general note, it could be added that when practical work is used to enhance learning outcomes in STEM subjects, it is important that the learning objectives are clearly communicated. The present study also indicates that to include the laboratory staff in planning of the lab curriculum and lab report evaluation enhances the students perceived learning outcome of the laboratory training.

To further develop the understanding of the different ways students enhances their learning outcome and how they use productive feedback when doing practical work in different STEM subjects, more research in different institutional contexts is recommended.

REFERENCES

[1] A. Hofstein and V. N. Lunetta, "The laboratory in science education: Foundations for the twenty-first century," *Sci. Educ.*, vol. 88, no. 1, pp. 28–54, Jan. 2004, doi: 10.1002/sce.10106.

[2] A. Hofstein and V. N. Lunetta, "The Role of the Laboratory in Science Teaching: Neglected Aspects of Research," *Rev. Educ. Res.*, vol. 52, no. 2, pp. 201–217, Jun. 1982, doi: 10.3102/00346543052002201.

[3] V. Potkonjak *et al.*, "Virtual Laboratories for Education in Science, Technology, and Engineering: a Review," *Comput. Educ.*, vol. 95, Feb. 2016, doi: 10.1016/j.compedu.2016.02.002.

[4] J. G. Quattrucci, "Problem-Based Approach to Teaching Advanced Chemistry Laboratories and Developing Students' Critical Thinking Skills," *J. Chem. Educ.*, vol. 95, no. 2, pp. 259–266, 2018, doi: 10.1021/acs.jchemed.7b00558.

[5] R. Lazarowitz and P. Tamir, "Research on using laboratory instruction in science.," in *Handbook of Research on Science Teaching and Learning Project*, D. L. Gabel, Ed. Macmillan Publishing Company, Division of Macmillan, Inc, 1993.

[6] V. N. Lunetta, "The school science laboratory: Historical perspectives and contexts for contemporary teaching," in *International Handbook of Science Education*, B. Fraser and K. Tobin, Eds. Springer Netherlands, 1998.

[7] V. N. Lunetta, A. Hofstein, and M. P. Clough, "Learning and teaching in the school science laboratory: An analysis of research, theory, and practice.," in *Handbook of Research on Science Education*, S. K. Abell and N. G. Lederman, Eds. Routledge, 2013.

[8] A. Hofstein and P. M. Kind, "Learning In and From Science Laboratories," in *Second International Handbook of Science Education*, B. J. Fraser, K. Tobin, and C. J. McRobbie, Eds. Dordrecht: Springer Netherlands, 2012, pp. 189–207.

[9] L. D. Feisel and A. J. Rosa, "The Role of the Laboratory in Undergraduate Engineering Education," *J. Eng. Educ.*, vol. 94, no. 1, pp. 121–130, 2005, doi: 10.1002/j.2168-9830.2005.tb00833.x.

[10] D. A. Kolb, "Experiential learning: Experience as the source of learning and development," *J. Organ. Behav.*, vol. 8, 1984, Accessed: Mar. 29, 2020. [Online]. Available: https://www.academia.edu/3432852/Experiential_learning_Experience_as_the_source_of_learning_and_development.

[11] D. Boud and D. Walker, "Experience and Learning: Reflection at Work. EAE600 Adults Learning in the Workplace: Part A." Adult and Wokplace Education, Faculty of Education, Deakin University, Geelong, Victoria, Australia., 1991, Accessed: Mar. 29, 2020. [Online]. Available: https://www.academia.edu/29435057/Experience_and_Learning_Reflection_at_Work._EAE600_Adults_Learning_in_the_Workplace_Part_A.

[12] B. S. Bloom, "Taxonomy of Educational Objectives, Vol. 1." McKay, 1956, Accessed: Mar. 29, 2020. [Online]. Available: https://www.uky.edu/~rsand1/china2018/texts/Bloom%20et%20al%20-Taxonomy%20of%20Educational%20Objectives.pdf.

[13] B. Cerini, I. Murray, and M. J. Reiss, "Student Review of the Science Curriculum: Major Findings," 2003.

[14] "SelectSurvey," Feb. 26, 2019. https://selectsurvey.net/ (accessed Feb. 26, 2019).