An Interactive Teaching Module for Combined Simulation and Laboratory Work

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ABSTRACT: Laboratory work is a key element in engineering education; however, the preparation for laboratory sessions, frequently, is not very thorough. In this article we present an interactive approach on improving students' learning outcomes through student-active simulation work and reflective workshops prior to laboratory exercises. A course in chemical engineering with 22 students was the case study. Previous experiences revealed that the students understanding of theoretical topics was not adequate enough to carry out laboratory experiments successfully. This was the motivation for developing a more interactive teaching module with special focus on the laboratory work. The module is based on a didactic model that combines classroom sessions and simulator training prior to the laboratory exercise. The practical part of the teaching module consists of briefing, simulation session, simulation debriefing, laboratory session and final debriefing. For the simulation session, a model of the laboratory process and equipment was designed using a dynamic simulator. The results of the interactive module were evaluated using theoretical pre- and post-test, qualitative surveys, a focus group interview and four individual interviews. The qualitative results showed that 100% of the students agreed that their participation in the course increased their understanding of the laboratory topic. The theoretical pre- and post-test showed 48% and 71% of correct answers, respectively. The correspondence between the qualitative and quantitative results indicates that the practical teaching module fulfilled its purpose. In this study, we propose a general methodology on how to combine simulation, reflective workshops and laboratory work for optimal learning outcome.

Keywords: teaching module, laboratory work, simulator training.

1 INTRODUCTION

Many topics in academia are learned through the execution of laboratory exercises. Normally, the students count on theoretical lessons and laboratory materials, which they can read to prepare themselves before attending the laboratory exercises. Finally, the students have to write and deliver a report related to the activities developed during the laboratory work. This traditional scheme can be challenging when the lab experiment is the first and only source for practical learning about a new topic. Therefore, the main goal of this study was to develop a practical part of the teaching module that could be implemented to improve the learning outcomes from laboratory work, this by offering the students a more structured method that help them to be more prepared for the lab practice and also reflect on what they have done. At HiOA bachelor program for Biotechnology and Applied Chemistry, the topic of distillation has been taught during the last years through theoretical lecture, numerical exercises and a laboratory exercise. The students take the distillation lab at the beginning of the second year of their studies; this is a topic included in the course Introduction to Chemical Engineering. There is not previous formal preparation to the lab. Consequently, a teaching module was developed and implemented for the distillation lab of this course, in order to observe and evaluate the effectivity of this strategy.

The implementation of simulator training and reflective workshops are the main new features of the practical teaching module i.e. the laboratory work. Simulator training is a very common learning strategy applied with successful results both in the industry and in academia [1-3]; it helps the users to get a useful overview of the actual processes and equipment. The purpose of the simulator training implemented in the teaching module was to offer the students a more didactic and hands on preparation before attending the actual lab, so they could start getting familiar with the topic within the safe environment given by simulators.

1.1 Experience with simulator modules at HiOA

Our work on implementation of dynamic process simulation modules for courses in chemical engineering (laboratory distillation system) and dynamic systems (an industrial large-scale oil production facility), are presented in [1], [4], [5].The results show that simulation modules enables students to gain additional skills: industrially relevant process knowledge, and teamwork skills. Simulation module prior to laboratory exercise increased the theoretical understanding of the topic, as indicated by better average mark of simulation tasks than other tasks in the final exam. However, simulation module without a laboratory exercise did not improve the final exam result. Our conclusion from this work is a need for (a) qualitative research on how the students learn with simulators (b) a system that indicate how well the students have reached their learning goals, and (c) a system that gives feedback to the students during simulation. [6]

1.2 Problem statement

Student’s preparation for laboratory work must be improved, in order to ensure student's understanding and learning outcomes from the laboratory activities. Therefore, the following research work aims to study the possibility of improving student’s laboratory experiences by implementing a simulation session as preparation before the lab work.

1.3 Theoretical framework

We apply the following learning theories and learning methods for the development of the five stages of our practical learning module: student-active learning, peer-learning, experiential learning, transfer of learning and reflection. The student-active learning method in scientific subjects minimizes the time when students passively listen to the teacher, and give better learning outcomes than traditional teaching methods [7], [8], [9]. We apply: quizzes, dynamic feedback and workshops as student-activating teaching methods.

Peer-learning is one of the most effective methods of learning [10]. During the simulation and laboratory work students work in groups, and during debriefing sessions the students are encouraged to analyze what was done, to ask questions and make conclusions together with the instructor and their peers.

Simulation and laboratory work can be analyzed through the theory of “experiential learning”, it allows learners to set up goals for their own learning, and let them see what they do as important and useful. It provides a learning that is “filled” with emotions and feelings, and is considered as important as “facts”. The learner moves from the known to the unknown, which can be anxiety provoking, and therefore requires trusting learning environment with possibilities for experimentation and risk taking [11].

The link between the simulator learning and learning in the laboratory can be analyzed through pedagogical concept “Transfer”; transfer of learning experiences from a limited training situation to a specified application context [12-14]. A literature review on various forms of transfer is given in [15].

During the debriefing sessions, the students reflect on their learning. Dewey’s four specific criteria for reflection are [16]: 1. Reflection is a meaning-making process that moves a learner from one experience into the next with deeper understanding of its relationship with and connections to other experiences and ideas. It is the thread that makes continuity of learning possible, and ensures the progress of the individual and, ultimately, society. 2. Reflection is a systematic, disciplined way of thinking, with its roots in scientific inquiry. 3. Reflection needs to happen in community, in interaction with others. 4. Reflection requires attitudes that value the personal and intellectual growth of oneself and others.

2 METHODS AND MATERIALS

2.1 Educational model

The teaching module for the laboratory work is built up using the six common categories of the didactic relation model: learning goals, content, learning process, learning conditions, settings, and assessment [17]. The didactic model for the course is presented in detail in [4]. The teaching and learning methods of the practical teaching module was organized in five stages:

1) Briefing: the briefing consists in an introductory session during which the students are informed about how the module is going to be carried out. Additionally, a short test about the subject matter is imparted, so the instructor can get an overview of the knowledge the students have before starting the module. Finally, some basic concepts and equations related to the main topic are explained.

2) Simulation session: the simulation session is a hands on session where the students can interact with a model that simulates the actual equipment they are going to use in the laboratory. They have to follow an instruction manual that guides them through different activities. There is an instructor during the simulation session, who guides the students if needed.
3) Simulation debriefing: the simulation debriefing is a reflective session during which, the students, guided by the instructor discuss about all the tasks done during the simulation session, and together analyze and reflect on what was done and the results.
4) Laboratory work: during the laboratory work, the students execute the actual exercise in the lab.
5) Final Debriefing: the final debriefing is a session to reflect on the entire practical teaching module experience. The students and the instructor discuss about the activities done, the results obtained and conclude together about what was learned.

2.2 Research methods

This research intends to identify two elements in the learning process 1) how the students experienced the training initiative and 2) the learning outcomes. Quantitative (theoretical tests results) and qualitative (questionnaires, focus group and interviews) approach was employed in order to assess the student's progress and gather feedback.

2.2.1 Sample selection

There were 22 active participants; all of them were second year bachelor students of the course Introduction to Chemical Engineering at HiOA.

2.2.2 Data collection

Different strategies were implemented to collect data, with the aim to determine the benefits of the teaching module for the laboratory work. Two 5-point scale questionnaires were delivered to the students, one during the simulation debriefing, in order to get feedback from the students about the simulation session; and the other one at the end of the course, to collect the student’s general opinion about the practical teaching module.

In order to evaluate the student’s theoretical improvement after the teaching module, there was developed a theoretical test (quiz) with overview questions about the corresponding engineering topic. The same theoretical test was imparted at the beginning and at the end of the teaching module. Additionally, a final theoretical test with relevant questions about the main topic, related to the learning goals of the teaching module, was also imparted at the end of the module.

Finally, qualitative data of the learning process was gathered. A focus group interview with eight students, and individual interviews of four students were carried out, which allowed us to collect personal insights from the participants of the teaching module for laboratory work [18]. The samples were taken from the entire group (22 students) that participated in the teaching module.

A focus group activity offers good advantages since the participants feel more comfortable talking and giving their opinions freely within a smaller group. However, it can be difficult to follow everyone’s ideas; it can be helpful that there is more than one person organizing the focus group, one that just takes care of leading the conversation in the right path, while another one handles the technical issues as recording and taking notes [19].

2.3 Laboratory Equipment and Simulation Software

The laboratory equipment used in this study was a distillation column UOP3CC produced by Armfield Ltd. The simulation software used for the teaching module is K-Spice®, from Kongsberg Oil and Gas Technologies. K-Spice® is a dynamic process simulation tool, which offers a variety of solutions such as conceptual process studies, engineering verification, control system checkout, operator training and real-time production monitoring systems [20]. The model developed in K-Spice is based on the laboratory equipment. Both, the actual distillation column and the simulation model consist of an isolated column with eight sieve trays, a reboiler tank, a condenser, an automatic reflux valve, different manual valves and thermocouples, feed and product tanks, a feed pump and a feed heater.

3 RESULTS

3.1 Qualitative Research: Questionnaires on Students Opinion

Two questionnaires were handed to the students, one after the simulation session and one at the end of the teaching module. The results from the most relevant questions are shown in *Fig. 1* and *Fig. 2*. From *Fig. 1* it can be seen that 91% (68% agree and 23% strongly agree) of the students agreed that the simulation exercises were useful for learning. Further, 95% (55% agree and 40% strongly agree) of the students agreed that the simulation session increased their understanding of the process they were going to practice in the laboratory, in this case, distillation. *Fig. 2* shows some of the results of the questionnaire related to the whole experience with the practical teaching module, 100% (73% agree and 27% strongly agree) of the students agreed that the practical teaching module increased their understanding of the principle that was studied. *Fig. 2* also shows the students' overall evaluation of the practical teaching module, 73% of the students gave a score of 4 over 5, and 27% a score of 5.

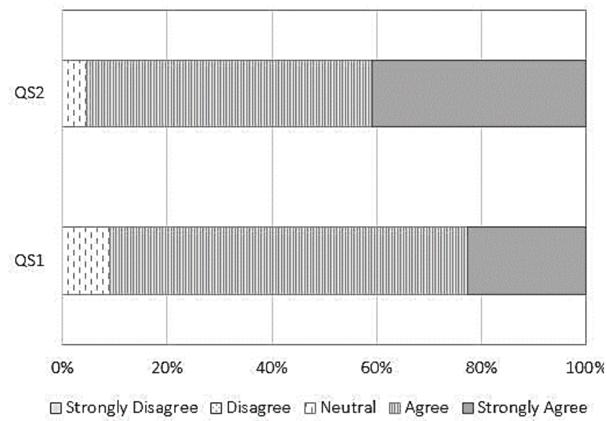

Fig. 1. Simulation Session Questionnaire. QS1: The simulation exercises were useful for learning. QS2: The simulation exercises increase my understanding of the distillation process.

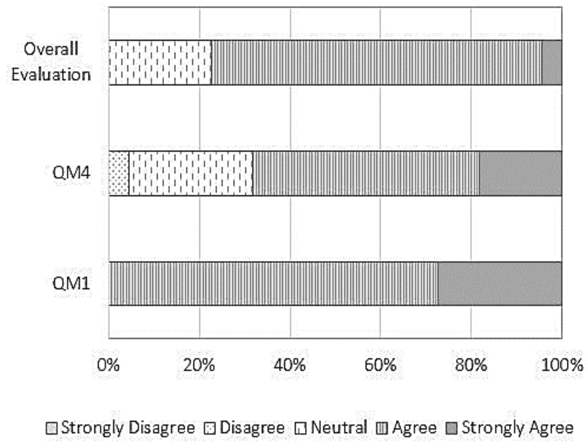

Fig. 2. Practical Teaching Module Evaluation. QM1: The Distillation Module increase my understanding about the principles of distillation. QM4: The Simulation Session is an essential part of the Distillation Module.

3.2 Focus Group Interview and Individual Interviews

The following statements were gathered from the study of the transcription of the recordings made during the focus group interview and individual interviews, as a general overview of the students' appreciation of the practical teaching module:

1. The students were satisfied with the teaching module structure (five stages: briefing, simulation session, simulation debriefing, laboratory work and final debriefing). Below is shown a comment of one of the students referring to the debriefing sessions:

"I liked that we have these summaries afterward, you kind of get a deeper understanding." (Anon. Stud. 6)

2. The students showed enthusiasm for the simulation session, they liked having a "schematic overview" of the process before going to the lab, and the possibility of making changes in the simulation and analyzing the effect on the system. However, they indicated as well, that the simulation model should be improved in order to get even better results. Some of the comments about the simulation session are presented below:

"I like the simulation lab, because there we were introduced to the real lab, so I think it is good." (Anon. Stud. 2)

"…it was a bit confusing. But I see the potential as well; it was nice to get a schematic overview." (Anon. Stud. 7)

"That was very good, then you can actually see it, and you can actually picture it for yourself, and you can actually test out what would happen if you make the heater warmer." (Anon. Stud. 4)

3. In general, the students considered they reached the learning goals of the teaching module.

4. It is important for the students to be aware of the learning goals from the beginning of the teaching module, so they can analyze if they are fulfilling them.

3.3 Theoretical pre- and post-tests (Quiz)

A theoretical multiple-choice test (quiz) with basic concepts of distillation was imparted at the beginning and at the end of the practical teaching module, this was done with the aim to observe the students' improvement by the end of the module. The test was implemented in "Kahoot!" The results from the quiz are shown in *Fig. 3*. The quiz consisted of nine questions, the figure shows the percentage of students that selected the correct answer for each question, and the overall percentage of correct answers is shown at the right end of the figure. It can be seen a noticeable improvement in six of the questions (Q2, Q3, Q4, Q6, Q7 and Q9). The first question had 100% of correct answers both times. Question five shows a significant decline of correct answers, it indicates there was a confusion among the students, so the question statement should be refined. Question eight also had a decline of corrects answers but just by 11%.

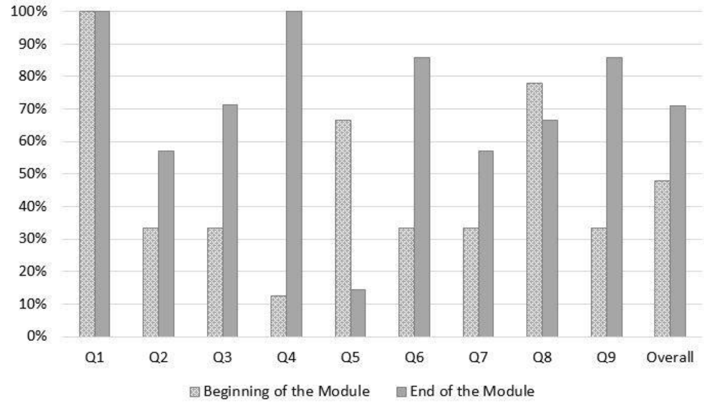

Fig. 3. Comparison of the quiz results at the beginning and at the end of the teaching module

4 DISCUSSION

The practical teaching module was developed in order to give the students a more solid and interactive preparation for the laboratory work. The results obtained indicate that positive outcomes were achieved. The qualitative results are very promising and show that the teaching strategy for laboratory preparation had a good level of acceptance among a significant majority of the 22 active students, and it was also considered helpful. This was further confirmed during the focus group interview and the individual interviews, where some of the students expressed openly their opinions about the practical teaching module. Some of the general statements gathered from the focus group interview and the individual interviews show how students felt about using simulation as experiential learning [11], they were satisfied with having the safe option of trial and error exercises. On the other hand, during the focus group interview, the students also agreed that the debriefing sessions were useful to get "a deeper understanding" of the activities realized, which indicates that the debriefing sessions' purpose of giving the students the chance to reflect on what was done, was fulfilled, and these reflections should influence positively their learning process [16].
Finally, besides the qualitative results and direct opinions obtained from the students, it was necessary to developed quantitative assessments that would allow us to confirm the students' knowledge in a more tangible way. Therefore, a theoretical pre-and post-test with basic concepts of the subject matter was prepared. The theoretical test was imparted at the beginning and at the end of the practical teaching module, this way the results could be compared, and improvements would be noticed, which was the case. The overall results indicate that there was an increase of 23% of correct answers the second time the quiz was taken at the end of the practical teaching module, which is in agreement with the qualitative results and can be considered as a concrete prove of the students' improvement after participating in the practical teaching module.

5 CONCLUSIONS

In this work we have developed an interactive practical teaching module combining simulation, laboratory work and reflection. Both qualitative and quantitative research was performed to get better insights into the students' learning processes and learning outcomes. The quantitative results show that students' knowledge on the engineering subject increased by 23%, which indicates that the practical module has very positive effect on learning. Qualitative research interviews enables the students to tell about their experiences and give anonymous feedback on the teaching module. The main findings of the qualitative research show that the students appreciate the possibility for trial- and error in safe simulation environment, and they like the structure of the module. Students' suggestions for further work include: tour at the laboratory to introduce the "real situation" before the practical teaching module, some technical improvements on the simulation model, and more build-in information/help in the simulation model.

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