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Course development for laboratory exercises in Organic Chemistry and Spectroscopy to stimulate deep learning

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Introduction

The Organic Chemistry and Spectroscopy course at the (former) Faculty of Life Sciences, University of Copenhagen, for second- and third-year students provides general organic chemistry training for a variety of different educational programmes. The primary recipients are students from the biotechnology field. The teaching of the course is divided into (i) lectures, (ii) theoretical exercises, and (iii) laboratory exercises. Twenty-eight students attended the laboratory course. The laboratory exercises were conducted as group work in pairs, and two supervisors were allocated to the course. Thus, seven teams or 14 students were supervised by each supervisor. The practical part of the laboratory exercises was conducted over a period of five weeks with one course day of 4.5 hours each week. Subsequently, one week was allocated to reporting of results.

In general, students enrolled in the course have attended several chemistry courses prior to the Organic Chemistry and Spectroscopy course, and they have also completed laboratory exercise courses in an introductory chemistry course and in biochemistry courses. The students therefore have already acquired some basic technical laboratory skills and are accustomed to laboratory teaching.

A key focus of the course, as a whole, is to motivate students to learn the basic concepts underlying chemical reactivity.

Identification of problem and focus area

The course has been taught for several years with remarkably good evaluation of the theoretical aspects from students in mandatory course evaluations. The laboratory exercises, however, have suffered from very poor evaluations in the preceding years, and course development within this part of the course is clearly required.

A general problem of this type of laboratory course that is taught concurrently with lectures is that the exercise content is often ahead of the lecture content. A widespread consequence of this fact is that the treatment of the theoretical background of the exercises is postponed until the final part of the course and the student report writing phase, and students are left with little or no supervision of the learning process. Additionally, supervisors obtain a low level of feedback on the student learning progress.

The focus of this project has been to elevate the treatment of theoretical and conceptual aspects of the exercises into the earlier parts of the laboratory course, and to allow students to have feedback on their learning progress along the course. Three pedagogical measures to stimulate deep learning (Biggs & Tang 2007) were evaluated in the current project: (i) The application of an open and flexible course structure (evaluation of current course structure), (ii) individual team discussion sessions, and (iii) a formative course reflection or evaluation process.

Several other important problems could be identified, however, these are not elaborated in the current project.

Methods: Description of pedagogical measures

Motivating students: Open and flexible course structure

An important aspect of student motivation is the opportunity for students to take ownership in the teaching and learning activities (Biggs & Tang 2007). The laboratory exercises constitute a great opportunity for students to participate actively in decision making regarding the subject, planning and conduct of experiments, and reporting of results. The course previously had a relatively open and flexible structure; students in teams would be (i) allowed to pick four exercises of their own choice from the laboratory manual, (ii) schedule the five course days individually to complete their four exercises, and (iii) decide how to report their results. This part of the

course was considered to be aligned well with the intention of motivating the students.

On the first day of the laboratory course a plenary introduction was given with the aim of matching expectations between students and supervisor in terms of (i) the active participation required of the students, and (ii) that the primary focus of the course was not on the final, summative assessment of student reports.

Team discussion sessions

The decision to maintain an open and flexible structure of the laboratory course obviously had some consequences for the potential of conducting plenary introductions and instructions to individual exercises. On the other hand, the high degree of supervising time available for each student in this part of the course allowed for dedicated, individual team supervision. A scheme for conducting these discussion sessions was developed through the course period: Individual teams would prepare for topics of their own choice and sit down with the supervisor to discuss the difficulties most often related to the theoretical and conceptual background of the exercises. Typically, one discussion session was conducted with each team for each course day.

Formative course reflection and evaluation process

A formative evaluation process, consisting of written questionnaires and plenary discussions of student responses for each course day, was conducted. A summary of the questions is listed in Appendix A. Topics such as Intended Learning Outcomes (ILOs) of the course, student peer supervision, student preparation and course improvements were discussed. The purpose of this process was to make students reflect on various aspects of the teaching and learning process through the course in order to stimulate the students to abandon a surface approach and adopt a deep approach towards learning.

Evaluation of teaching methods from the student perspective – Focus group interview

A focus group interview was conducted at the end of the course in order to evaluate the teaching methods from the student perspective. Five students

from three different teams participated in a joint interview over a period of 1.5 hours. The interview guide is listed in Appendix B. The following section contains a summary of the interview responses with a focus on factors related to motivation and teaching methods.

The students reported that they were positively surprised by the open structure of the laboratory course. From previous introductory laboratory courses they were expecting a rigid structure with fixed exercises for individual course days and plenary introductions to exercises. One student explained how the fixed structure in one course had led students to perceive the conduct of the exercises as a racing game with the goal of finishing their exercises before the other students. The open structure relieved this type of inter-team competition, and also led to a more thorough conduct of the exercises due to the inability of students to compare exercise results with neighbouring teams. None of the interviewed students found that the freedom to select exercises or the consequences thereof had led to frustration or confusion and in their opinion that was not the general feeling among other students either. On the other hand, students pointed to a lack of clear framing of the course as a main element of confusion; (i) the laboratory course was not adequately introduced during the lectures, (ii) there was some confusion as to the number of practical course days, (iii) the deadline for handing in reports was given too late, (iv) the duration of individual exercises was unclear, (v) technical support from lab technicians was inadequate, etc. Relatively simple adjustments within these areas would mean that a lot of confusion could be avoided.

A second main element of confusion was the style of the laboratory manual. All the students interviewed found the manual confusing and difficult to apply for the planning of the experiments, which was an important part of motivating the students (vide supra). An overview of workload for all exercises and a clearer designation of workload for different course days within each exercise again would avoid a lot of confusion with relatively simple means. A discussion of the technical language of the manual as a motivating factor resulted in conflicting views from the students; some students thought that technical terms should be complemented with thorough textual explanations in the manual whereas other students reflected on the potential loss of motivation or ownership from a highly detailed manual. However, none of the interviewed students were interested in a downgrading the technical language leading to a cookbook-style manual.

The students were highly satisfied with the team discussion sessions, and they stated that this part of the laboratory course had a strong influence

on their performance in the final course exam within the areas of writing reaction mechanisms and spectroscopic interpretation, which are two central ILOs of the course. Importantly, the consultative style of the sessions was stimulating for the students. The students reported that they were not accustomed to engaging in the theoretical background of the exercises before or during the conduct of the exercises from previous laboratory courses. In previous courses with written questionnaires before exercises (so-called pre-lab), students said there was a high degree of copying of responses between students and a low personal benefit; however, with the open course structure and individual selection of exercises this could less problematic. Students were hesitant to agree that an understanding of the theoretical and conceptual background prior to or during the conduct of an exercise was necessary to motivate them, however, they agreed that background knowledge enhanced their motivation. Some students said they only realized the true value of the team discussion sessions at a later stage.

The students reported that they were unfamiliar with the course reflection or evaluation process and that they found great difficulties in answering the questionnaires. Some students said they found the process irritating or annoying.

Evaluation of teaching methods – Personal reflections

Student motivation

Students were generally highly motivated towards performing the laboratory exercises according to the laboratory manual instructions and towards finalizing exercises. They were to a high extent self-driven and able to work independently with the exercises. On the first course day we discussed during a reflection and evaluation session, the potential for student peer supervision to promote student reflection and deep learning (Biggs & Tang 2007, Hofstein & Lunetta 2003); the individual scheduling of the exercises allowed in some cases for one team, who had completed a given exercise, to supervise a second team on the conduct of this exercise. It was my impression that the students benefitted from peer supervision. The students in the focus group interview also responded positively to peer supervision and said they had benefitted personally.

Even though we had spent some time explaining that the focus of the course was not on finalizing exercises this was clearly an important concern

of the students during the course. The individual scheduling of the course days meant that many teams would initiate several exercises concurrently which resulted in a poor level of day-to-day understanding of individual exercises and a further drive towards finalizing exercises. These activities may be explained as a negative backwash effect (Biggs & Tang 2007), i.e. students focus on the assessment task, in this case the delivery of the required reports to the supervisor at the end of the course and on gaining answers to questions posed in these reports (Krystyniak & Heikkinen 2007).

It was my impression that student reactions towards the open and flexible course structure fell into two groupings; some students responded positively and were motivated by the possibilities for independent course participation, however, other students found the lack of structure confusing. As such, the course structure might demotivate some students. This could perhaps in part be explained by differences in student attitudes towards learning as described by Perry (Winberg & Berg 2007).

Team discussion session

The laboratory course is taught concurrently with lectures. Previously, an early treatment of the theoretical background of the individual exercises in the laboratory course has generally not been encouraged, and theoretical aspects have been deferred to the student reporting process at the end of the course. This approach may be more or less informally communicated. Students are to a great extent accustomed to this way of teaching from previous introductory laboratory courses. In the extreme cases, the practical part of the course becomes completely detached from the theoretical part, and students follow the laboratory manual blindly with little idea about what they are actually doing in the laboratory and why. I would argue that this teaching approach encourages students to adopt a surface approach to learning (Biggs & Tang 2007). This view is also supported by students in the focus group interview. Additionally, there is empirical evidence indicating that most students will not learn the theoretical concepts that underlie the exercises in passing from conducting hands-on activities, rather, explicit instructional efforts should be devoted to conceptual learning (Tamir 1989).

At the outset of the course, discussion sessions with individual teams were conducted on an ad hoc basis. Students would fill out a questionnaire at the beginning of each course day to point out which topics or problems they would like to discuss, and we would sit down for 10-20 minutes when time permitted. Initially it was difficult for students to allocate the time

for these discussion sessions, and I had to persuade some teams to devote the time. Additionally, some students were poorly prepared for the discussion. This problem was discussed with my pedagogical supervisor Lotte E. Sjøstedt; as an outcome, a fixed timetable (scheme) was instigated for the discussions. The timetable had several positive consequences: (i) I did not have to spend time gathering students, (ii) students were better prepared since they knew when the session would begin, (iii) time was spent more efficiently during the discussions, which could be shortened to 10 minutes per team. Students also responded positively towards the fixed timetable in the focus group interview.

When students participated in the discussion sessions it was my clear impression that they found the sessions highly stimulating and rewarding. The consultative style of the sessions motivated students to bring up problems of all kinds that they had encountered. The working atmosphere was positive and students were not afraid to take part and make mistakes. Perhaps most importantly, the discussions allowed me to assess the students individually and stimulate the learning process by questioning students at their individual level. This format thus allows teaching that builds upon and enhances students' knowledge, attitude and perceptions described as a special opportunity for laboratory courses by Hofstein & Lunetta (2003). Both declarative and functioning knowledge (Biggs & Tang 2007) could be assessed and stimulated in these sessions.

A few topics that were general to all exercises, mainly regarding spectroscopy and reporting of results, were introduced in plenary discussion sessions. Students were reluctant to participate in open dialogue to discuss their own difficulties in interpreting results. This behavior was in sharp contrast to the open attitude during the individual discussion sessions. In plenary sessions, only one or two students participated actively whereas all students participated actively in discussion sessions.

Formative course reflection and evaluation process

The main purpose of this process was to make students abandon a surface approach by raising their awareness of teaching and learning aspects particular to the laboratory exercise format. Additionally, the process was intended to explicate the general and specific purposes of laboratory activities, and explicate course objectives to reduce a negative backwash effect (vide supra), as the explicit format is an important guide for the teaching and learning process (Hofstein & Lunetta 2003).

The written format of the questionnaires prompted students to take part in the reflection and evaluation process, although the level of detail in responses was low. An effort was made to phrase questions in colloquial language in order not to startle students. A discussion of the course ILOs was conducted on the first course day with good student response, however, student response in plenary discussions was again generally low.

The extent of the reflection and evaluation process was lowered on the third course day after some criticism that the discussions were taking up too much time. At this point, however, the intended main objectives of this process were achieved.

Conclusions

Three pedagogical measures to stimulate deep learning were evaluated in the current project:

Firstly, the open and flexible course structure adopted was found to motivate students, as intended. Students responded positively and said it led them to take ownership in the teaching and learning activities. There was some discrepancy between my own observations and student responses in the focus group interview at this point; it seemed to me that the freedom to select exercises was a source of confusion to some students, however, students reported that confusion resulted from the poor framing of the laboratory course and from the laboratory manual. These findings should be utilized in the further development of the laboratory course.

Secondly, the team discussion sessions allowed the treatment of theoretical aspects of the exercises in the earlier parts of the laboratory course. Students found these sessions highly stimulating and rewarding. The discussions allowed me to assess the students individually and stimulate the learning process by questioning students at their individual level. Importantly, students reported that these sessions had a strong influence on their learning outcome and performance at the final exam.

Thirdly, the formative course reflection and evaluation process fulfilled the purpose of explicating learning outcomes and raising students awareness towards teaching and learning aspects. However, students were reluctant to participate and criticized the process.

In summary, these results indicate that a deep learning approach could be stimulated, and that this should be an integral part of future course development.

A Summary of questions from formative course reflection and evaluation questionnaires (translated)

Course day	Question
1	Try to describe what you think are the objectives of this laboratory course?
1	How do you think the dialogue with the supervisor has been today?
1	What did you think worked well about today's exercise?
1-5	What could be improved for the next course day? Where should the focus be? (recurring)
2	How much time did you spend preparing for today's exercise? (a) 0 min, (b) 15-30 min, (c) 30-60 min, (d) 60-120 min, (e) >120 min
2	How well prepared for conducting today's exercise did you feel? (a) poorly, (b) not so good, (c) so, so, (d) well, (e) really well
2	To what extent did you feel that you understood the theoretical background and procedure of the exercise before the conduct of the exercise? (a) poorly, (b) not so good, (c) so, so, (d) well, (e) really well
2	How did you think the individual walk-through of the exercise with the supervisor proceeded?
3	What do you expect to learn today?
3-5	What would you like to talk about for the individual team discussion session today? (recurring)
4	How did you benefit from the plenary discussion on spectroscopy?
5	Which elements of the spectroscopy assignment did you find challenging?
5	Did the team finish the practical part of all exercises? What remains?

B Focus group interview guide (translated)

Overall evaluation

• How do you evaluate the laboratory course overall?

• How do you evaluate the interplay between the laboratory course and the lectures?

• Did the laboratory course fulfill your expectations? Which expectations did you have?

Evaluation of elements of the laboratory course

• The freedom to select exercises and planning of course days was intended to motivate students and allow students to take ownership in the teaching and learning activities. Did that make you feel motivated? (pros and cons)

• In your opinion how are students motivated for this type of laboratory course?

• Peer supervision. What did you think about that? (as supervisor/pupil)

• Do you feel that it is important to understand the theoretical background of the individual exercise before/during the conduct of the exercise? Is it OK to postpone this to the writing of the student reports at the end of the course?

• Do you think it is a good idea to keep the technical language style of the laboratory manual?

• Team discussion sessions – How was your personal benefit? How could it be improved?

• How do you evaluate the influence of the laboratory course (specifically the team discussion sessions) on your overall learning outcome within the areas (i) reaction mechanisms, (ii) NMR spectroscopy?

• Pedagogical questionnaires and discussions – How did they work out? (pros and cons)

Future course development

• Please describe some positive experiences from previous laboratory courses?

• The laboratory manual was evaluated negatively at the course evaluation. How do you think a better manual could be created? As a “cook-book”?

• Would you prefer more ”open” or more ”closed” types of exercises?

• Would it be a good idea to instigate questionnaires before the conduct of exercises (pre-lab)?

• Other suggestions for course improvements?

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Use of formative assessment to improve student motivation and preparation for exams

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Introduction

I am one of the teachers on the course "Speciel patologi og fjerkræsygdomme" (Special Pathology and Poultry Diseases) which was held for the first time in 2011/12. The course is taught in the third year of the veterinary degree programme and is mandatory for all veterinary students. The course replaced, after a restructuring of the overall plan for the veterinary curriculum, a previous course which was placed on the master's degree level. At the same time, the course was reduced from two weeks to one week of practical training, and the final evaluation of the students changed from an oral examination to a practical written examination. However, the structure of the course – including learning objectives, teaching and learning activities and curriculum – remained the same. In the new format of the course the percentage of students failing the final exam increased from approximately 4 % to 20 %.

When evaluating the answers from the practical written exam it is clear that the students were not well prepared for the theoretical contents and form of the final exam. There could be several reasons for this including: the structure of the course (theoretical and practical teaching are separated by up to several months), the placing of the course in the veterinary curriculum (bachelor versus master students), and the motivation of the students to participate in the course (poultry is not the most appreciated animal species among veterinary students).

These are all matters that are worth considering as possible areas of improvement, but these are also issues that are dealt with on a higher adminis-

trative level. Therefore, in this project I have chosen to focus on a didactic method that can be used within the existing format by evaluating the use of formative assessment to improve: students' motivation for learning and their understanding of the contents, level and form of the final exam, and as a method for the students to be aware of their own skills within the course.

Method

Students attending the practical part of the course in May 2012 were given a quiz with ten questions covering some of the topics included in the course curriculum. The questions were designed to have broad answers and in a form that could be used in the final practical written exam. After 45 minutes of work with the questions, either individually or in groups, all questions were answered in plenum with input from the students on each question and final validation by myself. In addition, all students were requested to answer a questionnaire before the quiz and after the plenary session. The questions regarded the students' perception of their motivation, their work during the course and their possibilities to pass the exam.

Result

The sample of students who participated in the quiz and answered the questionnaire consisted of four males and twenty-two females, all veterinary students participating in the course for the first time. All students had participated in the teaching more than 80 % of the time. Furthermore, only two students answered that their motivation for participation in the course was below average, while the remaining stated that their motivation was average (n=20) or above average (n=4).

The number of answered questions were seven or above (Fig. 4.1A) and only one student answered only one question. The numbers of answers corrected after the plenary session (Fig. 4.1B) were fairly evenly spread from one to ten questions. However, the degree of correction was not referred in the questionnaire, which could be a useful parameter for the students' knowledge of the topics.

Before the quiz, three students were not motivated for learning and no students had the highest score for motivation. After the quiz, the motivation moved up on the scale, showing that the quiz and plenary session brought

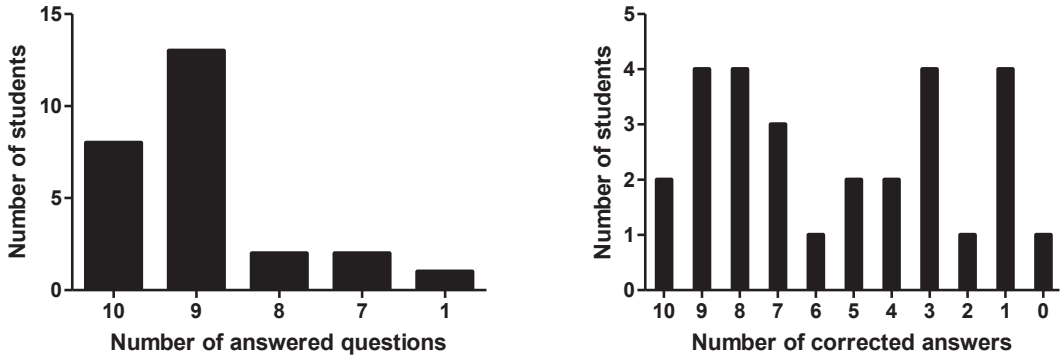

Fig. 4.1. A: Number of quiz questions answered. B: Number of answers corrected during the plenary session.

an increase in motivation for learning (Fig. 4.2). The students' perceptions of their understanding of the contents of the course before and after the course remained unchanged by the quiz (Fig. 4.2).

A slight change was found in the students' perception of passing the exam in both positive and negative direction, as both an increase in score 4 (Good chance of passing exam) and score 1 (Some chance of passing exam), together with a fall in score 2 (Fair chance of passing exam) was found.

Score*	Motivation for learning		Perception of understanding of course		Perception of possibilities of passing exam	
	Before	After	Before	After	Before	After
1	3	0	0	0	0	0
2	11	8	3	3	6	8
3	12	14	19	18	18	14
4	0	4	4	5	2	4

*: Score: 1: None, 2: Some, 3: Fair, 4: Good

Fig. 4.2. Motivation for studying, perception of understanding of course and perception of possibilities of passing exam before and after quiz and plenary session among 26 veterinary students.

All students participating in the formative assessment session passed the course at the following exam.

Discussion and perspectives

Formative assessment is a teaching and learning activity that can give students information on their progression in learning the course and help to improve their next performance (Askham 1997, Biggs & Tang 2007). The feedback given by formative assessment gives the students an opportunity to reflect and improve their learning (Gibbs & Simpson 2004, Biggs & Tang 2007).

Through a quiz consisting of ten questions, the students participating in this present KNUD-project gained a higher motivation for learning. Furthermore, students can increase their awareness about their own likelihood of passing the exam and thereby this helped them to prioritize their work in preparation for the final exam. The number of questions answered was high and, even though many answers were corrected after the plenary session, this indicates that the students participated willingly in the exercise. Furthermore, the final (summative) exam will be a more familiar and known format through practising during the course by using this form of formative assessment.

Using formative assessment during the course gives me as a teacher the opportunity to adjust the planned teaching. Almost all the students misunderstood or did not answer two of the ten questions, and thereby this have us an indication that these topics need more attention in lectures. Furthermore, this can be a method to bring the theoretical aspects of the course closer to the practical parts. The two parts of the course are now separated by an interval of one to five months. Bringing more theoretical questions in to a practical setting will help the students to focus on both parts of the course, also those topics not used during the practical hands-on part of the course.

In conclusion the present project shows, that formative assessment is easily implemented in the course “Speciel patologi og fjerkræsygdomme” in the existing format of the course and can lead to an increased motivation for studying and learning in the students.

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2012-5/

The bibliography can be found at:

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