10

How Students Evaluate the Laboratory Exercises in Pharmaceutical Physical Chemistry

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Introduction

I am taking part in teaching the course of Pharmaceutical Physical Chemistry course at the Faculty of Pharmaceutical Sciences (FARMA). In addition to teaching pure physical chemistry principles at the undergraduate level, the course aims to provide insight and to develop deeper understanding in different topics that are important for the students to learn due to their pharmaceutical relevance. It should be pointed out that the physical chemistry course is a prerequisite for admission to different interdisciplinary courses on the advanced level in the faculty. The Pharmaceutical Physical Chemistry course consists of large class lectures, small exercise classes and a laboratory course. In this project, I will focus only on evaluating the laboratory course of the Pharmaceutical Physical Chemistry (see below for a short description of this course). Here, my main concern is how to lead the students to be efficiently engaged (the required active participation) and to fully understand the laboratory exercises. In general, there are different factors (Hahn & Polik; 2004) that may affect the overall degree of success in teaching physical chemistry. I believe that the following four issues are among the most important factors that we need to consider as teachers in pharmaceutical physical chemistry in order to help students to achieve the intended learning outcomes of the course and to obtain a higher degree of success: (1) the low preparation level of some students for the laboratory exercises, (2) the lack of scientific interest to learn, (3) the difficulties in understanding the basic principles, and (4) the difficulties in solving phys-

ical chemistry problems in the reports, which are typically described with mathematical expressions.

My main purpose is to evaluate and to understand students' perceptions of the learning difficulties, to learn from their proposed improvements, and to avoid obstacles or difficulties when performing the exercises and also when writing the reports.

The following main questions guided the present report:

1. Do we need to improve the written text of the procedures of the laboratory exercises and the underlying theory? Are there any points that are not clear in these two parts?
2. How do the students evaluate the provided aids (the theoretical background, the experimental procedures, and the mentioned relevant chapters of their textbook)?
3. What part of the exercises does the students like/dislike?
4. How do the students evaluate the safety issues in the laboratory?
5. Are there any general recommendations from the students to improve the course?

Details of the laboratory course

Before describing laboratory course in detail, I will briefly present the three following main teaching activities in the Pharmaceutical Physical Chemistry course: large class lecturing, small class teaching on exercises, and the laboratory course. The relationship between these activities and the written exam is well established.

Large class teaching

The 45-minute lecture course deals with various topics including thermodynamics, electrolyte and non-electrolyte solutions, states of matter, chemical kinetics etc. Here, it is important to mention that the lectures are designed to make a link between the concepts being taught and the relevant laboratory exercises and the pharmaceutical relevance.

Small exercises class

Different chemical behaviours are explained by mathematical expressions and learning them is very important tool for predicting students' performance in solving problems. The students have the opportunity to work in

small teams for problem-solving on different topics described in the large class lectures. The students interact more with the teacher than is possible in the large class.

The laboratory exercises: Active participation and reports

In the laboratory course, the students work on exercises in pairs or in a few cases, groups of three. The students carry out twelve different practical exercises in major topics of physical chemistry that were presented in the lectures. The course is structured to have eleven meetings in total during autumn to perform the exercises, which are designed to ensure active participation and direct student-teacher interaction, and to develop students' skills in performing the experiments by using different techniques as well as in reporting the experimental data obtained. Active participation means that all experimental exercises are satisfactorily performed within a four-hour period, and the reports with data analysis and answers of relevant questions are submitted at time and must be approved by the teacher. Each group is expected to complete the lab report which is due at the beginning of the next laboratory period. As the teacher, I circulate among the students while they perform the exercises to discuss their experimental data and to check their level of understanding level of these exercises by asking related questions. This leads in many cases to me asking the students to report on their experience while performing the exercises and helping if there are any problems or any points which are not clear.

Questionnaire

In order to give the students the opportunity to evaluate the practical exercises in the laboratory course anonymously, I prepared a short questionnaire consisting of ten multiple-choice questions with eight of them rated on a 5-point scale and six additional free-response questions (the questionnaire is given in Appendix A). The last two narrative questions were on evaluating the overall course. It was important to formulate the questions to be specific to the lab exercises. The questionnaire was reviewed by other teachers who were involved in this course and also by our KNUD teacher Camilla Østerberg Rump. The contribution of both Camilla and my colleagues was very helpful in shaping the final form of the written questions. Among other things, this questionnaire was designed to shed light on the

difficulties/obstacles on learning at the lab course and to focus on how to improve the learning environment after analyzing the students' answers and their comments/suggestions. Some of the specific questions were related to the written reports; therefore, it was important to ask the small groups (two or three students per group) to complete the questionnaires cooperatively (team reflection) after finishing their reports. The participation of the students in this project was voluntary. The selection of the five laboratory exercises was based on either their pharmaceutical relevance or the observed degree of difficulty students experienced in writing their reports. These lab exercises cover different physical chemistry topics including colligative properties, calculation of partition (P) and distribution coefficients (D), electrochemical processes, specific acid and specific base catalysis, and diffusion process.

We evaluated the responses to 75 questionnaires. In this project, we focus only on discussing the average responses given to the ten multiple-choice questions for the five laboratory exercises and the summary of responses of the six additional free-response questions. It is worth mentioning that the responses to every specific exercise will be discussed with the teachers of the course. In general, the students' responses on the different exercises were similar. Therefore, it is worth reporting here on the data analysis of the average responses given to the five exercises.

Results and discussion

The students' responses to the multiple-choice questions

Pre-Laboratory Preparation: Of the 75 responses, 60% of the students spent only 15-30 minutes on the pre-laboratory preparation including reading the experimental procedure with specific instructions on how to operate each instrument and the theoretical background (Fig. 10.1a), while 33% spent 30-60 minutes. Such a low preparation level is remarkable and surprising, especially in that 4% did not prepare at all, and only 3% spent 60-120 minutes on the pre-laboratory preparation. The efficiency of this preparation within the mentioned time periods is also an important issue but it is a difficult task to evaluate and therefore it was not tackled in this project. As presented in figure 10.1b, 31% of the students felt that their degree of preparation for performing the exercises was good, and 47% were neutral. 22% indicated either a poor or fair degree of preparation. Only 1% of the

students felt that they were well-prepared. Here, the lack of motivation of some students could also significantly affect the preparation level. It was reported that the lack of motivation in physical chemistry courses could be attributed to the abstract nature of concepts in these courses and the high level of mathematical knowledge required (Hahn & Polik; 2004; Sözbilir; 2004; Tsaparlis & Gorezi; 2005). Pre-laboratory preparation is highly important for the deep understanding of the laboratory exercises (Johnstone & Al-Shuaili; 2001; Rollnick et al.; 2001). As Johnstone and Al-Shuaili (2001) observe:

> "investigation is very knowledge dependent and cannot take place in a knowledge vacuum".

Clearly, there is a need to increase the level of students' preparedness to ensure a higher degree of understanding and active engagement in the laboratory. Rollnick et al. (2001) reported on the importance of adequate student preparation for the laboratory and discussed the different degrees of preparedness found between prepared and less prepared students. It was also easy to distinguish between these two different groups in this laboratory course. Three aspects of the pre-laboratory preparation which are helpful in achieving the successful completion of a practical were identified (Rollnick et al.; 2001):

1. A "bird's eye view" of the practical. This can be achieved by asking the students to prepare a half-page synopsis of their lab exercises, which includes the aim of the exercise, background and procedural information including the important experimental elements such as specific reactions, relations, or substances.
2. Prerequisite knowledge required to perform the exercises. This can be achieved by including a set of pre-laboratory questions. In our course, there are few written questions on every exercise included in the laboratory manual. To increase the pre-preparation level, I suggest preparing a few additional multiple-choice questions that the students have to complete before performing the exercises. There is need also to have more pre-laboratory discussions with the students.
3. A detailed understanding of the experimental steps. Asking the students to prepare a flow diagram is one method that can be used.

These aspects and the proposed suggestions will be discussed with other teachers of this course to see what can be changed to increase the degree of preparation. In particular, after the analysis of the students' responses (Fig.

10.1(c)) to the question of how they evaluate their degree of understanding the written laboratory manual before the exercises, only 25% felt that their degree of understanding was good whereas 50% felt that the degree is either poor (15%) or fair (35%). According to Rollnick et al. (2001):

> "It is the next tier down that obligatory preparation benefits most those who willing in spirit but poorly organized or those who would skip preparation because of the load of other academic work".

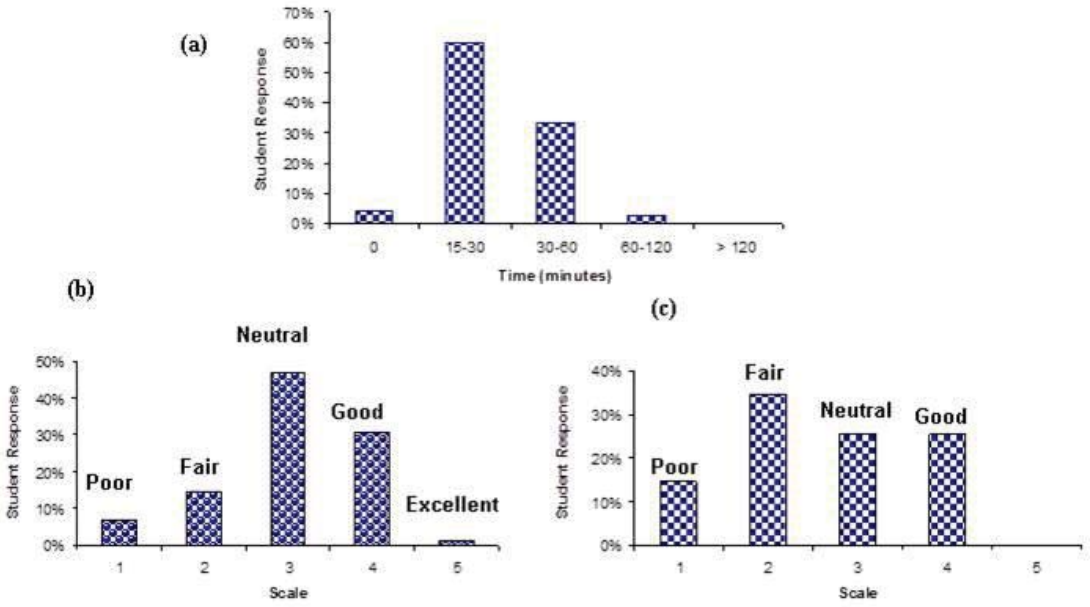

Fig. 10.1. The students' responses to how much time they spent on the pre-laboratory preparation (a), the degree of their preparation (b), and their understanding of the written laboratory manual (c).

Writing the report

The time needed to complete the reports and to answer the included questions is dependent, among other factors, on the number of tasks involved, the questions and the degree of difficulty in understanding the experimental exercise. Among students, this time would vary from group to group. For instance, it took relatively more time to complete the reports for the two experimental exercises on the colligative properties and the electrochemical processes, which some students find relatively difficult and which demand

more time to answer the questions related to the experimental data. Also, it generally takes more time for less well prepared students to complete their reports. In general, the approval of their reports by the teacher also requires more time than for well prepared students. As indicated from the students' responses, most students completed their five reports within 1-3 (36% of the students) or 3-6 hours (31%). 22% completed their reports within 6-9 hours and 7% needed more than 9 hours (Fig. 10.2a).

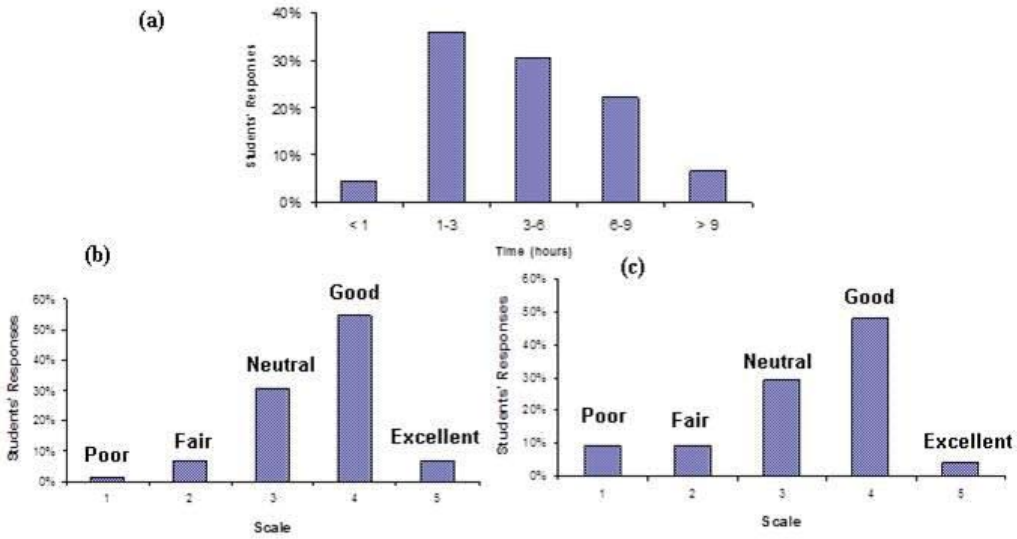

Fig. 10.2. The students' responses to how much time they spent after the exercise on writing the report (a), the degree of understanding the exercise after writing the report (b), and their rate to the provided aids.

The students' response to the question on the degree of understanding the exercises after writing the report was positive and encouraging (Fig. 10.2b). 62% of the students felt that their understanding was good (55%) or excellent (7%), although some of them had a neutral response (31%). Figure 10.2c and 10.2b indicates that the laboratory experience is very effective in teaching physical chemistry. The presented data indicated a significant improvement in understanding the topics after performing exercises and writing their reports due to the active student-student and student-teacher interactions and also due to the involvement in the practical activities. I believe that increasing the level of the pre-laboratory preparation by considering the suggested changes is an important step that can be helpful in improving to an even higher level of understanding physical chemistry in the

laboratory. The provided aids including the laboratory manual (the theoretical background and the experimental procedure) and the mentioned chapters of the used textbook in this manual were rated 4 or 5 from 5 by 52% of the students (Fig. 10.2c). The written theoretical background and the experimental procedure in the laboratory manual were rated 4 or 5 by 69% and 78%, respectively (Fig. 10.3). Some students indicated that it was hard for them to understand the written theoretical background in some of these exercises. The main reason was performing the experiments before learning the relevant topic in the lectures (the lectures and the laboratory course are offered in the same semester). There were also some students who felt that the mentioned chapters of the textbook were not very helpful in understanding and writing the reports of some of the exercises. Here, the students should take advantage of the direct student-teacher interactions in the laboratory and the pre-laboratory discussions to improve the understanding of the relevant topics. But such interaction is not efficient when some students are not motivated or not well-prepared to perform the experiments.

Subject	Scale of Rating				
	1	2	3	4	5
The theoretical background	7%	7%	17%	57%	12%
The experimental procedure	1%	5%	12%	55%	23%
The safety at lab	1%	5%	9%	31%	53%
The overall learning outcome	4%	11%	17%	64%	4%

Fig. 10.3. Learning outcome from the exercises.

Most of the students highly agreed (53%) or agreed (31%) that they did not experience any safety issue during performing the exercises (Fig. 10.3). This was very positive evaluation of the safety of the laboratory.

The overall learning outcome

The learning outcome from the exercises was rated 4 or 5 by 68% of the students (Fig. 10.3). This indicates that the practical laboratory work is efficient tool in learning physical chemistry. The students have a good opportunity to examine the presented experiments, to develop their awareness on the frequently used methods when performing the experiments and how to use them, and to comprehend the basics of different physical chemistry

topics. The positive evaluation of their laboratory experience is described below in detail.

The evaluation of the free-response questions

The free-response answers of the students to questions 11-13 including the most positive and most negative aspects of the laboratory exercises, are summarized in Figure 10.4. Among the most positive aspects, the students mentioned the important role of teachers in helping with both the practical exercises and the reports. We recall here the research study of Herrington and Nakhleh (2003) reporting on how the chemistry laboratory instruction, which is different from that in the classroom instruction, is important to consider for developing successful and effective teaching of chemistry in the laboratory. The mentioned negative aspects were mainly related to difficulties in understanding the exercises and writing the reports. There were also various suggestions from students (answers to question 14) for changes that could be made to improve some exercises. To avoid repetition, these suggestions are summarized below with other changes suggested by the students for improving the overall course. In general, most students were very satisfied with the course. As an example of an answer to question 15, one student group mentioned:

> "Overordnet er kurset rigtig godt. Vi får meget ud at lave rapporterne. Der har dog været nogle af øvelserne, hvor vi har forstået teori bag under udførelsen af øvelse. Rapporterne har hjulpet på forståelsen."

The students' suggestions for improving the overall laboratory course

The students mentioned a number of improvements that might be made. The main given suggestions were:

1. To improve the written theoretical part in the laboratory manual for some exercises. Some students commented that they felt that this part is difficult to understand and/or included irrelevant information. It was suggested to write it in a simple manner.
2. To improve the written experimental procedure in a few exercises. Some students suggested writing this part in more detail and writing it in a simple manner with short and simple sentences.

What were the most positive aspects?	
1. Efficient for learning and understanding the theory given in the lectures 2. Developing practical skills in performing experiments and using techniques 3. The exercises are linked to the written exams. Understanding them leads to good performance in the exam 4. Good supervision from the teachers at the lab 5. Good technical support from the technicians 6. The pharmaceutical relevance of some exercises 7. Learning how for first time to use different techniques	8. Exercises which easy to perform and to understand 9. Reports of some exercises that were easy to write. 10. Team work in the students' groups 11. Safe exercises 12. Enjoyable experience when the exercises were well understood 13. The detailed experimental procedures of some exercises 14. The overall knowledge gained when combining the exercise with the written report 15. The techniques and the substances were ready to use
What were the most negative aspects?	
The theoretical part: 1. Difficulties in understanding the theoretical part 2. Not understanding the exercise and the obtained results 3. Performing the exercise before learning the theory 4. Difficulties in understanding the mathematical expressions in the theoretical part 5. Feeling in few exercises that the theoretical part includes points that were not relevant to the exercise and the report 6. Feeling that the theoretical part is not helpful in answering the questions and the report **The exercises:** 1. The need for more detailed experimental procedure in few exercises 2. Feeling that the pharmaceutical relevance is missing in few exercises 3. Some students disliked that one of these exercises is very easy and fast	4. Difficulties in using the techniques 5. Technical problems during the exercise 6. Difficult time at the lab without pre-laboratory preparation 7. Exercises that involve many experimental parts 8. Consuming long time in performing some exercises 9. Long waiting time in some exercises 10. Consuming time in few exercises for both cleaning and setting up 11. Not understanding if the obtained results were acceptable or not. 12. Not sufficient information in the first day of the course 13. Having only one teachers at the laboratory 14. Not enjoyable one exercise or more for some students **The report:** 1. Difficulties in writing some reports 2. Reports that include many and/or difficult questions 3. Consuming long time in writing some reports

Fig. 10.4. Summary of students' free response answer

3. To include more images/cartoons in the laboratory manual. These cartoons help the students to understand the exercise and the experimental procedure during their pre-laboratory preparation.
4. To insert more examples of the pharmaceutical relevance of the exercises. Some students felt that few exercises are irrelevant to their pharmaceutical education. We need to consider in more depth the need of highlighting the pharmaceutical relevance of these exercises.
5. To improve the written questions for some reports. Some students felt also that there were too many questions in a few exercises.
6. Some students commented that it would be helpful to consider having more than one teacher in the course. The students felt that they did not need to wait so long for having support in the first two weeks when two teachers were in the laboratory. However, it is difficult to have more than one teacher due to the limited financial and teaching resources. In addition, the students have to wait only a few minutes to get the required support from the teacher.

Conclusions

The evaluation of the students' responses showed that the majority of them were satisfied with the course. Their responses indicated that they felt that the laboratory course is an effective learning tool. This is an indication in itself of a successful course. One important finding was the low level of pre-laboratory preparation among students, meaning that only a few students were ready to perform the exercises. In an attempt to address this problem, we suggested few changes that could be adopted the course. In addition, the students offered a number of suggestions for improving the laboratory work. These suggestions and the mentioned changes will be discussed with other teachers of the course to check what we can do to improve the learning environment.

Acknowledgments

I would like to thank the members of the teaching team of the course: Jesper Østergaard (the course coordinator), Henrik Jensen, and Susan Weng Larsen for their valuable suggestions and comments. In addition, I would like to thank Camilla Østerberg Rump for improving the questionnaire. I also thank the students who took part in this project.

A Questionnaires About the Laboratory Exercises

Questionnaire about the Laboratory Exercises

A22-2: Pharmaceutical Physical Chemistry

The main purpose of this questionnaire: our main goal is to provide you with an excellent learning environment for achieving the intended learning outcomes of this course as described in the following link: http://www.farma.ku.dk/index.php/Farmaceutisk-fysisk-kemi-oeve/6110/0/). In this regard, your feedback will be important to improve these exercises. This questionnaire is designed to provide accounting of how you reflect as student on these exercises and what to do to improve them in order to meet the intended learning outcomes of the course.

Please note that the questions mentioned in the sections I-IV are related to your feedback on the specific exercise and the questions mentioned in the section V are on your overall experience of the laboratory course

I. How did you prepare at home before the laboratory exercise?:

1. How much time did you spend preparing at home before the laboratory exercise? [Minutes]

0
15-30
30-60
60-120
> 120

2. To what degree did you feel prepared and ready for performing the exercise?

Poor	1
Fair	2
Neutral	3
Good	4
Excellent	5

3. To what degree did you feel that you understood the written theoretical background and the experimental procedure before the exercise?

Poor	1
Fair	2
Neutral	3
Good	4
Excellent	5

II. How much effort and time were invested during writing the report?:

4. How much time did you spend after the laboratory exercise on reading the material, analysing data and writing the report altogether? [Hours]

< 1
1-3
3-6
6-9
> 9

5. After having written the report, to what degree do you feel that you understand the exercise?

Poor	1
Fair	2
Neutral	3
Good	4
Excellent	5

6. How do you rate the provided aids (the theoretical background, the experimental procedure, and the mentioned chapters of your textbook) as being of use for writing the report?

Poor	1
Fair	2
Neutral	3
Good	4
Excellent	5

III. Rating Your Laboratory Exercise:

Please circle the number that corresponds to your level of satisfaction* (with the following aspects of your laboratory exercise as follows):

*Please focus on how you find the provided materials (the theoretical background and the experimental procedure) to be particularly important during performing the exercise and reporting on the experimental data and how they affect overall your understanding level.

7. The written theoretical background: I found that the written theoretical background is very helpful in understanding what the exercise was about

Highly agree	5
Agree	4
Neither agree nor disagree	3
Disagree	2
Highly disagree	1

8. The written experimental procedure: I found that the written experimental procedure is very helpful in understanding what the exercise was about

Highly agree	5
Agree	4
Neither agree nor disagree	3
Disagree	2
Highly disagree	1

9. Safety issues in relation to the exercise: I did not experience safety issues during the exercise that had not been addressed in the written experimental procedure

Highly agree	5
Agree	4
Neither agree nor disagree	3
Disagree	2
Highly disagree	1

10. How do you rate your overall learning outcome from the laboratory exercise?

Poor	1
Fair	2
Neutral	3
Good	4
Excellent	5

IV. Narrative Questions on the Laboratory Exercise:

11. What were the most positive aspects of your laboratory exercise? (or what did you like most in your exercise?)
12. What were the most negative aspects of your exercise? (or what did you dislike most in your exercise?)
13. Please give your comments on the laboratory exercise
14. Where do you feel improvements could be made?

V. Narrative Questions on your overall experience of the laboratory course:

15. How do you evaluate the laboratory course? Please mention the reasons for your satisfaction or dissatisfaction?
16. Do you have any suggestions for improving the overall laboratory course?

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2010-3-1/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/kapitler/2010_vol3_bibliography.pdf/