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Teaching competences within a foreign discipline – Introducing protein science to pharmacy students

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Background – why should students at a School of Pharmacy learn about proteins?

In September 2011, I joined the Department of Pharmacy and in addition to my other teaching assignments I was appointed to a faculty work group in charge of producing a report that surveyed and critically assessed the current status of teaching within biological or protein-based drugs (biopharmaceuticals) at the School of Pharmaceutical Sciences (van de Weert et al. 2012). While working with the work group and attending the University Pedagogic Course, I started thinking about the inherent problem of introducing the complex topic of biopharmaceuticals to pharmacy students who had little or no prior background in protein science. How does one minimize surface learning and ensure that students attain actual competencies within such a challenging new discipline?

Teaching at the department of pharmacy has traditionally revolved around the pharmaceutical science of small molecule drugs. In the last two decades there has however been a dramatic increase in the number of large molecule drugs coming to the market. Most of these are based on naturally occurring protein macromolecules (biopharmaceuticals). At present, about 25 % of newly approved new drug entities are biopharmaceuticals and their proportion in the global pharmaceutical development pipeline is steadily increasing. Thus, they comprise a significant number of the present and future novel drugs reaching the market. This means that students in pharmaceutical sciences should not only be aware of their existence, but also know

about their properties as drugs, how they are discovered, analyzed, developed, modified, formulated and approved. Simply put, the students need to know everything worth knowing about proteins from a pharmaceutical perspective. Currently, however, there is insufficient teaching about proteins at the School of Pharmacy and in particular no course deals with attaining practical competencies with proteins in a laboratory setting.

From a teaching standpoint, learning and attaining practical competencies with protein drugs represents a significant paradigm shift relative to small molecule drugs. Proteins require a fundamentally new knowledge base, a different set of practical skills, in short, a different scientific culture. My thoughts on this subject were inspired by (Wood 1996, p. 132-7):

> "To learn to use tools as practitioners use them, a student like an apprentice, must enter that community and its culture."

Thus, in order for pharmacy students to learn real-world competencies with protein-based drugs they needed to adopt or at least understand a different way of thinking, a way of thinking embodied by the discipline of protein science. True in-depth understanding of the pharmaceutical development of biopharmaceuticals thus required the students not only to learn about a new topic but also embrace a foreign scientific culture.

From a practical viewpoint, this presented a significant challenge. As the newest addition to the faculty, I had only limited sway to make changes in the existing course programme and even less room for manoeuvre concerning the introduction of new courses. I therefore decided initially to survey the status quo of teaching in biopharmaceuticals at the department (attached in teaching portfolio) and use select teaching assignments to gain first-hand experience with the challenges of teaching proteins to pharmacists and use any attained knowledge to guide further steps.

Starting small: new lectures in existing courses

Plan

I identified two scheduled double lectures that I was to teach on two different existing courses. I judged that these offered a good opportunity to introduce key theoretical aspects of protein science to students and evaluate the outcome of my teaching. In both cases, the lectures had been added to the existing courses upon my own initiative and generously accommodated by

the person responsible course. The first teaching event was a double lecture in a PhD course entitled, "Analytical Methodologies in Protein Formulation". The second teaching situation was a set of lectures on related topics in the PhD course, "Mass Spectrometry Coupled to Separation Techniques" in Bioanalytical Chemistry.

I aimed to introduce the discipline of protein science in the lectures by the following teaching strategy:

- Be approachable: As I was a guest lecturer at the existing course, I would take five minutes at the beginning to clearly introduce myself, encourage students to ask questions anytime and also to contact me after the lecture if curious for more information.
- Why am I here? I would spend the first three slides directly identifying why this topic was directly relevant to the student attending this particular course. Studies show that the first 20 minutes of a lecture is the time frame where students are attentive (Middendorf & Kalish 1996). It was therefore critical that my first slides would get students curious to the new topic at hand by outlining the relevance of the material to their background.
- Be succinct: For each lecture, I made a set of 70-80 slides concerning the subject matter. I then spent a considerable amount of time looking over the slides and removed about half of them. This was done to ensure that each individual slide was justified as need-to-know material and not just nice-to-know material. It also ensured that I could spend more time on select parts of the material that were key for deeper learning.
- Use practical real-world examples: I would go to great lengths to identify and use real-world practical examples that were relevant AND representative of how the students could apply this new discipline in a pharmaceutical setting.
- Student activation and peer instruction: Each 15 minutes I would introduce a slide with a quiz (see Appendix A for examples) to break up the lecture into shorter segments, to shift the focus and enable students to participate. The students were given five minutes to discuss the question or come up with a solution with the person sitting next to them. Then I would ask if any had an answer and hopefully try to start a discussion.

Evaluation of outcome

Through a well-defined focus coupled with the use of peer instruction and student activating exercises as inspired by Mazur (1997), I aimed at initiat-

ing deeper learning processes. I hoped that I could achieve this goal despite (1) having only the short time frame of two lectures and (2) being tasked with teaching a discipline that was foreign to the students. To evaluate my teaching and specifically to gauge my success in inspiring students' interest and some degree of deeper learning, I attained a copy of the course evaluation sheet for one of the courses. This evaluation sheet was however written in advance by the course responsible and had not permitted a specific evaluation of my two lectures. Irrespective, I did find that 43 % highlighted my lectures in the evaluation form and of this subgroup all were in positive and enthusiastic terms. To evaluate if I had managed to do more than spark student curiosity, however, I emailed all the students on the course exactly one week after my two lectures and asked them to fill out a very simple questionnaire (Appendix B). The sole purpose was to specifically assess if the students remembered the correct answers to the three quiz events during one of the lectures. As these three quiz questions had been designed to sum up the most important parts of the combined lectures, the ability of the student to still remember the answers would be a somewhat crude indicator of the degree of deeper learning I had managed to induce in the students. I note in this context that such a simple approach is not the exhaustive evaluation needed to accurately assess deeper learning outcomes. Also this would be difficult to achieve based merely on two lectures. My evaluation merely served to gauge whether students achieved a more relational understanding of the subject matter, with an ability to explain and analyse causes as per the hierarchy of learning outcomes described by Biggs & Tang (2007). I managed to get replies from eleven students (approximately 40 %). A few had some suggestions for me to improve the lecture and 90 % appeared to have found the lecture both interesting and stimulating despite the foreign topic (see Appendix C for one example). Naturally, such conclusions should be taken with a grain of salt as they were replying directly to me and not in an anonymous manner. Thus I focused instead on evaluating their answers to the one week-old quiz questions. The results are shown in figure 10.1.

More than 80 % of the students were able to give the right answer to Quiz 1 and Quiz 2, even a week after the course. I was somewhat surprised by these finding. I had expected something closer to 50 % or perhaps even lower. Notably almost all correct answers also included a correct rationale for the answer, as detailed in their emails. This latter is also an important finding as this indicates that some degree of deeper learning was achieved. It appears that quiz questions can, if carefully considered, be an excellent stepping-stone for students to start to embrace the core concepts of a new

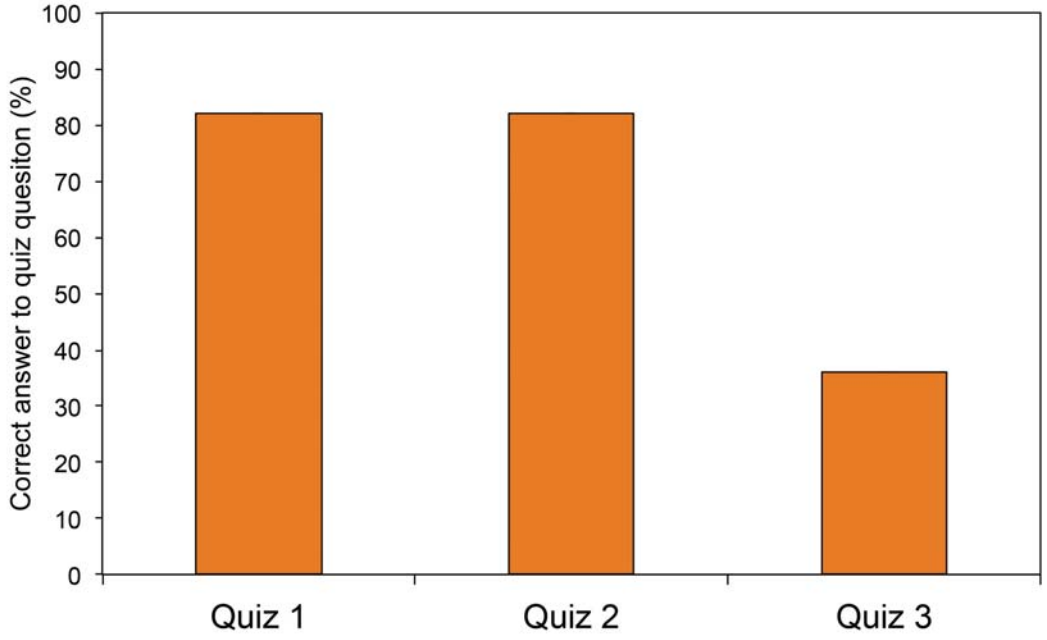


Fig. 10.1. Evaluation of the extent of deeper learning in a lecture. The chart indicate the number of correct answers in percent to quiz questions one week after the lecture.

and foreign discipline. This was supported by my evaluation of this lecture event. This has subsequently inspired me to use quiz questions as a component in all future lectures in particular to underline the key take-home messages within a new topic. Notably, less than 50 % of the students recalled the correct answer to Quiz 3. This is probably because this quiz was not so general and conceptual but rather relied on students having absorbed specific knowledge imparted to them earlier in the lecture. It may also be that this quiz was held at the end of the double lecture and thus the students found it harder to become activate and assimilate my teaching. Regardless, I will in the future use only simpler, conceptual quiz questions at the end of the lecture (perhaps replacing Quiz 3 with three more simple quiz questions thus dissecting the central point covered in Quiz 3 into smaller more digestible bits).

Starting small: new laboratory exercises in existing courses

Action plan

Laboratory work represents a crucial practical competency within most types of science including pharmacy. To my mind, practical lab exercises provides a unique venue for illustrating and setting theoretical knowledge in a scenario and context that encourages deep learning. I therefore welcomed the opportunity to design, implement and evaluate a new laboratory exercise on basic protein science that was accommodated into the bachelor's degree project of third-year pharmacy students. At the time, there were very few other laboratory exercises at the School of Pharmacy involving work with proteins. Thus this new exercise served as a timely opportunity for me to test, evaluate and refine future laboratory teaching concerning proteins within the Department.

To help the introduction of the new laboratory exercise I decided on the following teaching plan:

- Stimulate student interest: For each group (3 or 4 students) I would hold a 30 minutes pre-meeting where they were introduced to the background and relevance of the laboratory exercise. This pre-meeting also provided the chance for the students to ask questions and served to display gaps in student knowledge concerning proteins. I made several schematics and figures that explained the background of the exercise and the equipment used and hung printed copies of these on the wall in the laboratory for easy inspection by the students during the exercise.
- Make the students take ownership: Each group of students was encouraged to prepare samples of their own choosing that could be produced using a variety of basic experimental protocols. Experimental work in the lab centered on analysis of these unknown samples, which had not previously been analyzed by me. The results were therefore not predetermined. Through this approach, I hoped to enhance student interest in interpretation of the results from the lab exercise. To further empower the students, they were also given the opportunity to read original literature and to come by my office if they needed aid in interpreting results.
- Real-world relevance: The instrumental setup and work flow I designed for the laboratory exercise was implemented to closely mimic work flows in use in a real-world pharmaceutical research laboratory. It was emphasized to the students that while some of the equipment in use was

somewhat outdated the principles and procedures used in the lab exercise were very relevant to real-world applications. I also introduced the students to two software tools that are used routinely in professional protein analysis labs and encouraged the students to try to use this software independently to interpret their own results.

Outcome and student evaluation

To assess and evaluate my teaching and the design of the laboratory exercise, I had the students fill out an anonymous evaluation form after completing the laboratory exercise (Appendix D). I was very pleased to find that the students found the laboratory exercise very interesting as I had spent a considerable amount of time designing it for the same purpose. In the evaluation, several mentioned that the exercise had made them more interested in learning more about proteins and their role as drugs. Almost all students emphasized that the material was clearly and well explained to them with ample time to ask questions. Some mention that it would have been nice if the laboratory exercise had been part of a larger context, for instance, a designated course on protein science (at the time it was merely an add-on exercise to the bachelor project of pharmacy students). Only about 50 % had prepared prior to the exercise and thus many solely relied on what knowledge was provided to them during the pre-meeting. The considerable value of the pre-meeting on overall learning outcome was thus made apparent. I did however take up quite a lot of my time to meet separately with each group. If a larger body of students were to perform the lab exercise I would probably have to do the pre-meeting in the form of a lecture or tutorial for all groups. Further, to make students prepare more for the laboratory exercise, next year I plan to provide them with an assignment which needs to be completed by the pre-meeting and introductory lecture. The assignment will then be discussed at this meeting and the students will be expected to provide answers and participate. This assignment will be based on the use of the two software tools that the students will also use in the lab to interpret their own results. Thus, by introducing an assignment before the lab exercise the students will not only be forced to think about the lab exercise before hand but also become familiar with some of the tools that they will ultimately need to interpret results obtained during their ensuing lab work.

Going big: planning a new master's degree course

As a member of an inter-faculty work group on biopharmaceutical education, my coauthors and I produced a report in early 2012 on the status of education within biopharmaceuticals at the School of Pharmaceutical Sciences, University of Copenhagen (van de Weert et al. 2012). This report recommended increased teaching within practical aspects of pharmaceutical work with proteins and suggested the introduction of a new elective master level course that included a significant number of laboratory exercises.

The need for a designated practical course in protein science was also alluded to by some students in the evaluation form of the new laboratory exercise. To my mind, one can only achieve so much by patching one or two lectures or laboratory exercises into existing courses. While this is sufficient to familiarize students with the general principles of the new discipline of protein science, it will not be sufficient to fully equip pharmacy students with the competencies required to tackle tasks they will confront if they are to work with protein-based drugs in their professional career. Furthermore, it does not adequately illustrate the myriad practical challenges of working with large biomolecules in a laboratory setting. I have therefore begun over the last six months to plan how I may stitch my experiences from teaching within the last year into the seams of a new tentative master's degree course. This course will have the title "Purification and Analysis of Peptides and Proteins" and has tentatively been proposed as an elective course for master's students.

The planning of this course is still at an early stage and much work still needs to be done. I have set upon following the guidelines provided by Jakobsen (1999) with an emphasis on addressing, in turn, the following key points during the planning: (1) Teaching goals and competencies, (2) Student backgrounds, (3) Structuring of teaching material, (4) Structuring of learning processes, (5) Choice of evaluation and exam. I will herein only detail how I plan to make use of my recently acquired experience with teaching protein science to optimize teaching goals and competencies and the structuring of teaching material in this new course. The primary aim of this new course is to teach the hands-on skills and competencies required to work with proteins in a laboratory setting, an element that is currently lacking in the study programme of pharmacy students. To meet this goal, the course needs to be a practical course and will be built around a series of laboratory exercises. I have decided on an overall format for the course that

builds closely upon practices gained from introducing lectures and laboratory exercises in existing courses described earlier. Every laboratory session will be introduced by a lecture immediately beforehand to properly introduce and thoroughly go through the background of the laboratory exercise. To ensure that students prepare for each such grouped lecture or lab session, assignments will be given beforehand which will be quizzed and discussed during the lecture. I plan to organize and implement the lectures according to the guidelines outlined earlier in this report with emphasis on (a) student activation and (b) the relevance of the lecture to the ensuing lab exercise and real-world applications. For the laboratory exercises, students attending the course (estimated approximately 20-30) will be separated into groups of four or five students. Inspired by my experience from designing the previously discussed laboratory exercise, I will encourage student ownership and involvement in the practical work by giving each group an unknown unpurified protein sample at the beginning of the course. The basic overall goal of the practical course is thereafter to use the laboratory exercises to purify and find out as much as possible about the protein in their sample, using a range of experimental methods and techniques. As the course progresses, the students will be introduced to increasingly advanced methods and have the opportunity to apply these methods in a practical setting during the ensuing laboratory exercise. As each sample is different and unknown, it is hoped that the students will more easily identify themselves with their laboratory work and engage in motivated, critical thinking processes, instead of just following a preset sequence of laboratory protocols which is a pit-fall of some laboratory-based teaching (van de Weert et al. 2012). A further benefit of this particular structuring of the laboratory exercises, is that it quite closely reflects the real-world work procedure of a pharmaceutical scientist working in an analytical research lab. It is hoped that this laboratory course will impress on the students a list of specific highly relevant competencies within the broader discipline of protein science and additionally give the students basic know-how to tackle real-world challenges encountered during the development of biopharmaceuticals.

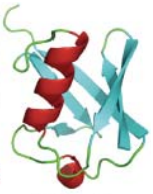
Perspectives

Planning a new master's level course is a momentous task and much work still needs to be done concerning crucial aspects of the design of the new course. However, I strongly feel that by evaluating my teaching practices

over the last year, I have become better equipped to be able to design and plan a good course. In addition to my own evaluation, the extensive feedback from both colleagues and my pedagogic supervisor upon supervising my teaching has greatly helped me to critically assess various teaching events. Most importantly, this has provided me with the basic tools to continually improve my strategy for encouraging deeper-learning processes in the students that I teach. I have become convinced that deep-learning processes, more than any other single teaching parameter, is critical to make students absorb the key aspects of a new foreign discipline and attain actual competencies within this discipline.

A Quizzes

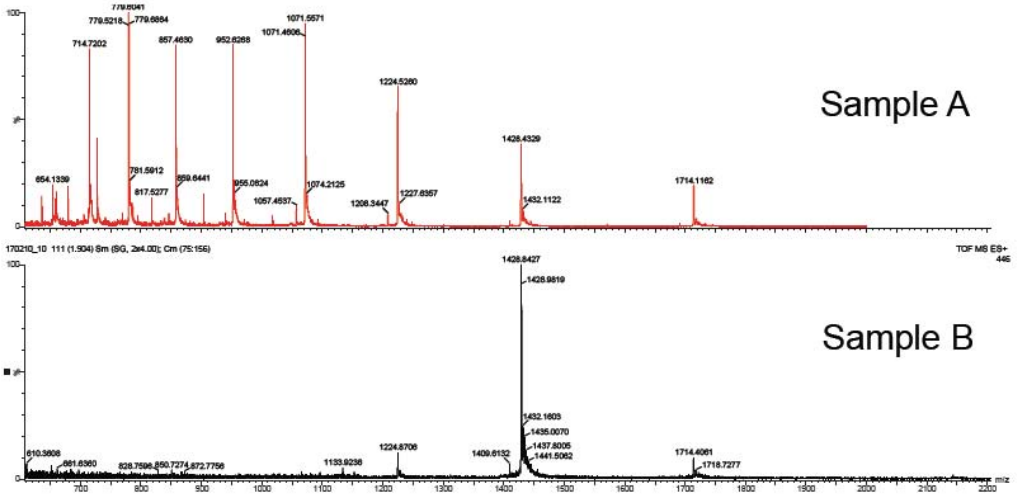
QUIZ 1 – REAL WORLD EXAMPLE



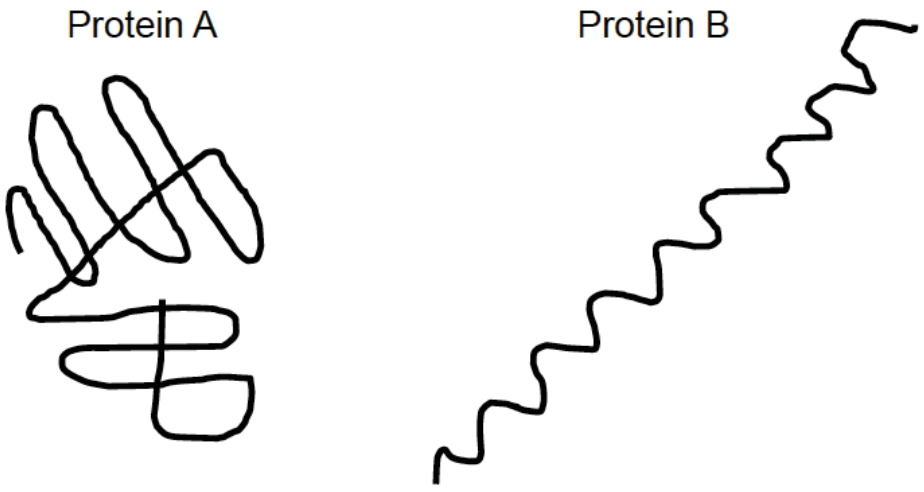
Ubiquitin (76 res)

ESI mass spectra of the protein Ubiquitin from two different samples.

Q: Which sample contains Ubiquitin in its a) folded state and b) unfolded state



QUIZ 2 – Protein ion mobility?

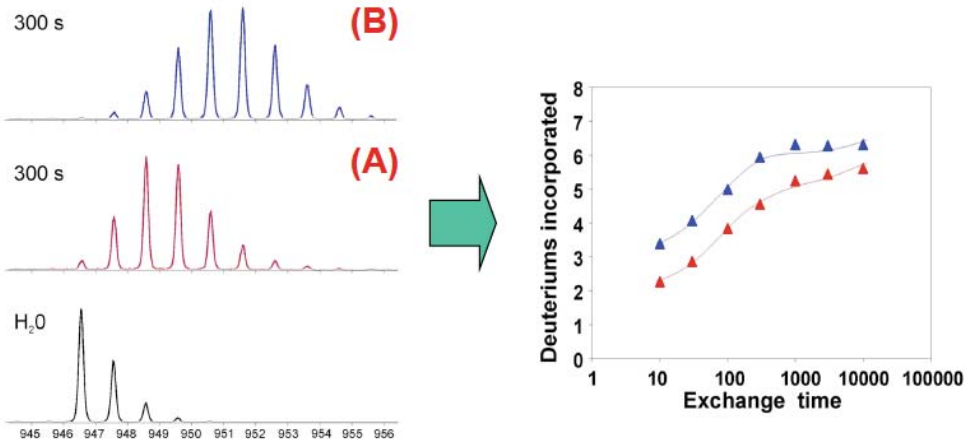


M = 12000 Da
Z = 12+

M = 12000 Da
Z = 12+

Q: Which protein has the highest ion mobility?

Peptides used to monitor H/D exchange of the protease domain of FVIIa: (QUIZ 3)



Q: Which mass spectrum (A) or (B) corresponds to a peptide of FVIIa after the FVIIa protein has undergone H/D exchange (300s) while bound to its cofactor protein Tissue Factor (TF).

B Questionnaire

Dear attendees at the PhD course in Mass Spectrometry Coupled to Separation Techniques in Bioanalytical Chemistry

In light of your recent completion of the PhD course, I am now conducting an evaluation of parts of the course and it is very important that I receive some brief feedback from you.

You may recall that I gave the last two lectures on the last day of the course (Friday 20/1) concerning the topic Analysis of protein conformation by MS. Since then a week has passed. Presently, I am interested in evaluating (a) your opinion and (b) your learning from three quiz session in my lectures.

Please take 5 minutes to answer the questions below. Just press reply to this mail and type your answers directly after each question and send the mail back to me.

Use only your memory to answer the questions below and do not use the course material or anything else. Your answers will be used solely for internal evaluation purposes and nothing else and naturally will be fully confidential. To help you remember the actual quiz questions, I have attached the three slides that I used to present Quiz 1-3 during the lectures.

Question A: Do you remember the correct answers to Quiz 1? If so, what are they?

Question B: Do you remember the correct answer to Quiz 2? If so, what is it?

Question C: Do you remember the correct answer to Quiz 3? If so, what is it?

Question D: Did Quiz 1, Quiz 2 and Quiz 3 help you to improve your understanding of the main subjects covered in the two lectures?

Question E: Do you have any additional comments you would like to share?

Thanks in advance for your time, I greatly appreciate your feedback. If anything is not clear then feel free to contact me.

Kind regards,

Kasper D. Rand

C Answers to questions A-E

Question A: Do you remember the correct answers to Quiz 1? If so, what are they?

Yes, I remember the answers. Sample A = unfolded; many chargeable sites exposed. Sample B = folded, most chargeable sites are masked in the tertiary structure.

Question B: Do you remember the correct answer to Quiz 2? If so, what is it?

I am not sure that I remember the correct answer. I remember discussing this in a small group and I remember some of the arguments from when we discussed it with you in the large group. However, I do not remember for sure if these arguments were correct or incorrect. I think protein A has the highest ion mobility.

Question C: Do you remember the correct answer to Quiz 3? If so, what is it?

Yes, I remember the answers. Mass spectrum A corresponds to the protein bound to the cofactor. The binding results in less H/D exchange and accordingly the m/z values are lower than in spectrum B, where higher D content increases the m/z value.

Question D: Did Quiz 1, Quiz 2 and Quiz 3 help you to improve your understanding of the main subjects covered in the two lectures?

Yes, absolutely. It improved my concentration and interest in the topics that I actively had to apply the introduced concepts.

Question E: Do you have any additional comments you would like to share?

It is an ungrateful task to give the last lectures on Friday afternoon. Initially, my level of concentration was very low at this point of the course. It had been a long and interesting week with lots of learning and Friday afternoon my head felt full. Furthermore, I do not work with protein/peptide MS, nor do I plan to, so I do not have an inherent interest in the topic. In essence, my motivation for listening and learning was minimal. However, your lectures managed to capture my attention to much greater extend than I had expected. The quiz questions and the associated short group discus-

sions were important contributors to this.

However, the examples of biological applications towards the end of the lecture did not manage to keep my attention. So if you have to cut the lectures short, in my opinion, this last part is far less important and interesting than the quiz questions.

D Evaluation form

Evaluering af øvelse i massespektrometrisk analyse af et protein i forskellige farmaceutiske formuleringer:

1. Havde du forberedt dig til denne øvelse? hvordan?

2. Var laboratorieøvelsen interessant? Hvorfor/hvorfor ikke?

3. Har denne øvelse givet dig lyst til at lære mere omkring proteiner og deres rolle som lægemidler?

4. Syntes du at du lærte noget som var relevant for dit a) bachelorprojekt i farmaci og b) din videre uddannelse på FARMA

5. Adskiller denne laboratorieøvelse sig fra andet laboratoriearbejde du har foretaget dig i løbet af din uddannelse på FARMA indtil nu? Hvis ja, hvordan?

6. Havde du væsentlige forståelsesmæssige spørgsmål som du ikke fik afklaret under øvelsen?

7. Var der rigeligt tid sat af til at du kunne stille spørgsmål?

8. Har du andre kommentarer til denne laboratorieøvelse?

9. Har du andre kommentarer til min undervisning omkring denne øvelse?