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Challenges in planning a course with multiple teachers and independent experimental projects

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Introduction

For the past two years I have been giving a lecture on powder X-ray and neutron diffraction as part of a course titled “Structural Tools in Nanoscience”. The course is taught by several teachers each an expert in a particular experimental technique. The intended learning outcome (see the full course description in Appendix A) is that the students shall became familiar with a number of experimental techniques used to characterize materials with structures on the nanometre scale and be able to choose techniques suitable to characterize samples of their own choice. I became interested in analyzing the challenges of running a course with many different teachers and which puts a lot of responsibility on the students to form the experimental part of the course. This report will consist of my thoughts and initiatives to modify the latest (block 4, 2012) course based on student evaluations from 2010 and 2011 as well as my own experience with the course. I became involved in the course quite late and since I am not formally responsible I have not had the capacity to change the course description or the exam form. In this report I will discuss the ideas for improving the course and the factors limiting the practical implementation.

The challenges are to ensure that teachers of the course provide coherent teaching, which inspires the students and gives them sufficient background for performing an experimental project independently. Apart from the challenge to make a coherent schedule for the lectures it is also challenging to plan the experimental part in relation to the lectures as it is up to the students to decide which experimental techniques they will use and when.

Methods

The ideas for the initiatives to modify this year's course were obtained from an analysis of the standard evaluation forms filled out by students taking the course in 2010 or 2011, from one semi-structured interview with a student from 2011 and from discussions with other teachers on the course. The ideas for improvements of the course were partly implemented in the 2012 course. Finally, evaluation schemes made from students following the 2012 course and semi-structured interviews with three students served to evaluate the course structure of 2012.

The questions of the semi-structured interviews, shown in Appendix B, were grouped into questions concerning the lectures, the experimental work, coherence between lectures and experiments, and study material. Furthermore, the 2012 students were also asked questions about student participation. Audio files of the interviews can be obtained upon request (henning.osholm@gmail.com).

Results

Analysis of the course years 2010-11

The standard evaluation schemes used by the university administration to evaluate the course served as the first source of information of what students felt about the course. The analysis is based on seven students taking the 2010 course and three students taking the 2011 course. In the following I have tried to extract general conclusions from the students' individual responses.

Lectures

The key importance of lectures in this course is: (1) to introduce the students to a pamphlet of experimental techniques, (2) to make the students aware of the benefits and pitfalls, (3) thereby to enable the students to make educated decisions on their project, and (4) to motivate the students by having dedicated teachers giving examples of the possibilities of the technique, hopefully with exciting examples from their own research.

One of the special features of this course is that the lectures are performed by several different teachers. The basic idea is that experts within the different techniques are best at presenting the techniques and not least are engaged within their field of expertise which hopefully shows in the teaching situation. This feature also seemed to be appreciated by the students:

> "Underviserne er engagerede og venlige" (The teachers are engaged and friendly) (Student, 2010).

The more negative remarks are related to lack of coherence between the teaching of the different teachers:

> "Many different teachers – basics are repeated quite often" (Student, 2010).

A similar remark was made in an interview, where it was mentioned that lectures were presented well but they lacked continuity. This is unsurprising as it takes a lot of collaboration between the teachers to align their lectures such that they do not repeat each other – especially because some of the techniques are based on the same underlying physical principles. On the other hand, repetition can also serve the students to give them a sense of knowing the subject and thereby be more motivated to follow the lecture. Motivation is of course a prime factor for students to get deeply involved in the course and its material. It is up to the teacher to motivate the students, this is best done by involving them in the teaching, instead of giving the classic one-way lecture. This quality might have been lacking in some of the lectures.

> "The lectures were sometimes a bit boring. Some of the lecturers should engage the students in discussion, in order to make the class a bit more interesting" (Student, 2010).

Experimental work

A very important part of the course is the experimental work. The students should independently, in groups of three or four, find a sample which they find interesting, and decide which of the techniques presented in the course they can use to characterize the sample. The students find that the experimental part is very important and in that way they learn to compare techniques. Furthermore, the course enables them to judge what kind of experiments to perform in order to get insight into their material. But a common comment was that they feel that they are not involved enough in the experiments. On the question: Did you feel involved in the experimental work? The answer was:

> "Not quite, there is a tendency that the experiments are rushed (maybe in 1 to 2 hours) and mostly performed by the supervisor. Maybe because we only have to use the instrument once during the course. Lacking hands on experience." (Interview with student, 2011).

Similar remarks were made by other students.

Intended initiatives for 2012

From the analysis of the evaluation of earlier courses it is clear that the four-block structure of the teaching year is challenging for a course with the present ILOs: the students have to learn about a number of potentially new techniques, the physics behind them, the benefits and limitations of the techniques, before being able to make an educated decision on which techniques they intend to use on their samples. Since there is only about eight weeks for the course it is not, in the current state, possible to get through all the techniques before the students have to decide, which techniques they intend to use and make arrangements to use the relevant instruments.

In a planning meeting which most of the teachers attended I presented my ideas, based on the evaluations of earlier courses and the interview, for revisions to the course. We discussed the ideas and how to implement them. In the following I will present the initiatives taken.

It was decided to structure the list of lectures such that the techniques most likely to be chosen by the students were taught first etc. Though this may sound simple, it was a difficult task to accomplish because many of the teachers were engaged in other activities during the course period. Another initiative was to minimize the overlap between lectures. This also meant that additional constraints were put on the order of the lectures. To minimize the overlap, two new sets of lectures were introduced: (X-ray) Scattering and Crystallography were made separate themes as they are an important part of several techniques.

In the lectures we wanted to engage the students more and make the lectures more closely related to the experimental part of the course. It was also suggested that teachers should be more aware of pedagogical principles like introducing the ILOs for the lecture before starting, and conducting teaching-learning activities (TLAs). Suggestions for each of the particular techniques are specified below:

Atomic Force Microscopy (AFM): Introduction of a new TLA – doing a AFM experiment and exercise on paper, and including a tour of the instrument (half toured the instrument while the other half did the assignment, and vice versa).

Scanning Electron Microscope (SEM): The SEM talk was moved to an early stage of the course and an instrument visit was included.

Small Angle X-ray Scattering (SAXS): A practical computer exercise was added to complement the theoretical part.

Scattering techniques and Crystallography: The Scattering lectures were also to be taught differently – it was to be performed in dialogue with the students with small buzzing exercises. In the Crystallography lecture more TLAs were introduced.

Powder diffraction: buzzing exercises and tour of the instrument were introduced. One of my ideas for more student involvement was for a discussion of a scientific paper to be part of the presentation of the techniques. The paper was given to students in advance, and they were expected to read it before the lecture.

Experimental part

Some initiatives were conducted relating to the experimental work. The first was to postpone the group formation until after the first three sets of lectures to avoid students forming groups with those whom they knew beforehand rather than with those having a different background but with whom they might have a common interest in particular samples.

The students had also pointed out that they feel there is a lack of hands-on experience in the experimental work. It was therefore suggested that there should be more focus on making the students involved in the experiments.

Discussion

??? It is easy to wish and envisage how the ideal course should be. Unfortunately, in reality there are many constraints and obstacles. Constraints are issues like the structure laid out for the teaching. At the University of Copenhagen, Faculty of Science this means a nine-week teaching period of which the last week is often used by the students to prepare for exams. This structure puts a lot of pressure on a course like the one analyzed here. It would be optimal if the students had been introduced to all the techniques before they have to perform the experimental part of the course. Until recently I have found that to be difficult. For the past years there have been two double lectures per week (subtracting all the weeks with holidays). To get through all the techniques the lectures were spread more or less over the full eight weeks. In 2012 the structure was generally retained. In order to ensure that the students could start early in the course period to chose techniques for their project which they knew about, the order of the lectures series was designed such that the techniques with the highest possibility of being chosen for the experimental work were covered first. Unfortunately there was an obstacle to this plan – coordinating the teaching schedule with the schedules of the teachers. An additional constraint was that the basic lectures (Scattering and Crystallography) should be given before the lectures on techniques based on these. Those constraints meant that some techniques normally used by many of the groups ended up rather late in the course. This was far from ideal. Two students interviewed after the 2012 course suggested that all the lectures could be presented in the first part of the teaching period. The benefits of doing that would be (1) the techniques could all be taught before the experimental work, (2) because the lectures are concluded before the experimental work, students can avoid making arrangements to conduct experiments during lectures (3) because of points (1) and (2) and the fact that class attendance is normally higher in the early part of the course, the general attendance would probably rise.

> "Stort set alle kurser er ikke så intense i starten, men er meget intense til sidst." (Almost all courses are not that intense in the beginning but very intense at the end.) (Interview with students, 2012)

The downside is that the lecture programme would be very compact and the time for students to prepare would be less.

How to include the basic physical principles

One of the initiatives was to minimize the repetition of the basic physical principles in the lectures. This has historically happened as many principles are common to several techniques. In practice this was solved by introducing separate lectures on the common basic principles. It seemed to work well as no one mentioned problems with overlapping lectures until I specifically asked for remaining overlaps. One student mentioned that a little bit of repetition was still present. The example given was that in electron microscopy two different techniques are presented and the principles behind the generation of electrons etc, which is common to both, are taught in detail twice. One interesting comment made in the interview with the students was that they prefer lectures to focus on the applications and the research rather than the physical principles because, as they put it: “the physics we can always look up by ourselves”. One challenge in this respect is that the backgrounds of the students attending the course are quite diverse, e.g. this year students from physics, nanotechnology, chemistry and earth science attended.

More TLAs in the lectures

One focal point this year was to introduce more TLAs to get the students more motivated and involved in the theoretical part. In the SAXS lecture a computer exercise was introduced. The students should learn how to analyze data and determine object shapes and sizes from the data. In this way the students learned how to analyse one type of SAXS data, but they also learned of possible pitfalls in the data analysis. Furthermore, possible misinterpretation was discussed. Despite this, in my opinion, rather positive outcome of the exercise, there were critical remarks by some students. The criticism targeted that the exercise was based on determining the shapes of proteins in solutions. They felt that this was too far from their own research interest in nanoscience, partly because specialized software was used. I believe that the students learn a lot from this type of TLA, but to really engage the student the case needs to be closer to an application suited for the type of materials to be studied in this course.

Experimental part

The experimental part of the course is expected to be carried out independently in groups. The students have their own projects, for which they are responsible: they decide the techniques to use for gaining the information they need and they make arrangements with researchers to help them perform the measurements. Therefore the projects mimic a real research situation. Hence this is a very good example of what problem-based learning should achieve (Biggs & Tang 2007, p. 154). The independence of the groups to design and perform the project also creates a challenge for the course planning. You never know ahead of time which group will choose which technique. One year everyone might decide to use one particular technique, another year no one will use it. But it is exactly the independence of the groups to define their project and decide which experimental techniques to use that makes the present course so distinctive. This aspect of the course is also clearly what makes it popular amongst the students. The challenges of the planning also make the project very realistic and make them aware of the difficulties of performing a general research project.

> "Learning practical research. This is something that makes this course worthwhile. The insight in applying knowledge to real problems." (Student, 2011)

The negative remarks of former students about how groups formed early in the course often led to groups of people with similar background and gender, was considered for the 2012 course. The group formation was postponed a couple of weeks in order for the students to become more familiar with each other and to have time to discuss ideas about projects. This initiative was partially successful – groups were formed of students with diverse backgrounds, but the gender separation still remained.

Another issue raised by former students was the lack of hands-on experience during the experiments. Before the 2012 course the teachers discussed this aspect and we agreed to aim at involving the students more in the practical work wherever possible. According to the student interviews we did not succeed in achieving this goal. One of the reasons for the limited direct participation of the students in the actual measurements is that the students generally only use each technique (the one they choose) once, therefore it is more time consuming if the students themselves should perform all the experimental steps. The time aspect in this respect is important because the instruments are the work horses of the research groups and are often paid for by grant money. This means that the instruments are used quite heavily and at the same time several student groups might want to use the equipment. Again the short block structure of the course limits the time which can be used for these measurements. Apart from the time constraint, the limitation of hands-on experience is that the instruments are complex and fragile, and inexperienced operators might harm them. This could mean that the research groups will have difficulties fulfilling their obligations to the funding agencies. That said, we still have to make a better plan for how we can improve the involvement of the students in the experiments. Part of this could be through improved course material. Presently the course material is limited to electronic reproductions of books or articles as well as PowerPoint slides[1]. Without too much effort we might prepare some specific documentation for each technique, covering the basic operations of the instruments, which would enable the students to have a better basis for taking part in the experiment. Alternatively we could improve the communication and make them aware that they are the managers of the project, and therefore they need to know the techniques, but they are not expected to perform the experiments, rather they will be guiding the experiment in collaboration with a skilled technician.

Conclusions

It is clear that challenges still remain in planning a course of the present type with many teachers and a high degree of independent experimental work. The analysis of former courses and experience with adjustments made to this year's course showed that improvements can be made to increase the coherence between lectures but also more adjustments could and should be performed. The TLAs introduced this year were generally successful, but from the student evaluation is was also clear that the TLAs should be closely aligned with the real experiments in order to be meaningful for them. Planning a course of this type is limited by a number of constraints, e.g. the busy schedules of the teachers. Another limitation is that many teachers are not on a university salary, but funded by grants etc., thereby limiting the time they can spend on the course. The same reasons limit the time that can be spent on the experiments. So even with the best of intentions and ideas of how the course could be planned and what teaching material should be available, we are unfortunately limited by resources. If I were responsible for the course next year, I would try the model of running all the lectures in the first three or four weeks and dedicate the last four

[1] In the semi-structured interview there were also questions regarding the course material. In order to keep the focus of this report an analysis of the course material has been omitted from this paper.

weeks to the experimental work. Furthermore I would put more emphasis on making TLAs with clear relevance to the experimental part.

A Information on the course

Information from SIS on the course Structural Tools in Nano Science

Udgave: Forår 2012 NAT

Point: 7,5

Blokstruktur: 4. blok

Skemagruppe: A

Uddannelsesdel: Kandidat niveau

Kontaktpersoner: Robert Feidenhans'l (robert@fys.ku.dk)

Andre undervisere: Erik Johnson (johnson@fys.ku.dk)
Susan Stipp (stipp@geol.ku.dk)
Tue Hassenkam (tue@nano.ku.dk)

Skema-oplysninger: Vis skema for kurset
Samlet oversigt over tid og sted for alle kurser inden for Lektionsplan for Det Naturvidenskabelige Fakultet Forår 2012 NAT

Undervisnings-periode: 23. april til 15. juni 2012. Eksamen i perioden fra d. 18. – 22. juni 2012

Undervisnings-form: lectures and exercises in groups.

Formål:

The purpose of the course is to give an introduction to modern charactisation tools in surface and nano science. The tools include STM, AFM, electron microscopy, x-ray scattering based techniques plus a range of chemical analysis tools like X-ray photo-electron spectroscopy. The students will work in groups of about four people and choose their own set of samples which they will characterise with a subset of the techniques presented in the lectures. The students will learn about the applicabities of the techniques and learn how to use them in practise.

Indhold:

In the course we will discuss some of the most important experimental tools for advanced structural characterisation in nano science.The tools could include:
(i) scattering methods based on x-rays and neutrons (small angle scattering, reflectometry, EXAFS, diffraction)
(ii) Scanning and transmission electron microscopy
(iii) Scanning probe methods including STM and AFM
(iv) chemical characterisation tools (XPS, contact angle, TOF-SIMS).

The course will give a thorough understanding of the physical basis of the techniques and of their strength and weaknesses. Local experts from other institutions and companies will be invited to give highlight examples and excursions will be arranged for demonstrations. A large part of the course is experimental, where the students will use the techniques on their own samples and learn about their applicability the hard way. The course is evaluated by a written report and a poster session.

The course will also include an excursion to a company or institution, which uses advanced characterisation tools in nano science.

Målbeskrivelse:

The goal of the course is to give the student knowledge about modern characterisations tools in surface and nano science. The student should know the basics of a range of techniques that will enable him/her to evaluate what kind of structural information a given technique can provide and what not. This could be information about atomic or crystalline structure, mesoscopic structure or chemical structure. The student will also be able to judge the applicability of the techniques concerning the form of the sample, whether it is single crystal, powder, flat or rough.

The student will be able to use the techniques in practice. The experimental part is very much student driven. The student be able to organise the lab work working in a team, keeping a logbook, arrange laboratory time and seeking information about the interpretation of results, etc.

Finally, the student must be able present the result in a written report and also to present it as a poster.

Lærebøger: Noter uddelt ved forelæsningerne.

Tilmelding: Via Selvbetjeningen

Faglige forudsætninger: Bachelor indenfor en naturvidenskabelig retning.

Eksamensform: Passed/failed, internal censorship. Written report + an oral poster presentation.
One report and one poster is made pr group.
Participation in the experimental activities and contribution to a written rapport and a poster are required before the students can participate in the examination.
Re-exam: Oral examination.

Eksamen: Mundtlig prøve den 21. juni 2012.
Reeksamen: Mundtlig prøve den 23. august 2012.

Undervisnings-sprog: Engelsk

B Questions asked in the semi-structured course

Questions asked in the semi-structured interviews.

Teaching type and coherence between presentations of the techniques?

- What is your thoughts on the way the techniques were presented?
- Was the physics behind the techniques teached at the right level?
- How would you suggest the teaching was organized:
  - Is it better to have all the physics behind each technique presented with it?
  - Or is better to collect the physics in one lecture (set of lectures) and then refer to that in the presentation of the individual applications with a short reminder?
  - Was there too much overlap between lectures?

Coherence between presentations and experimental work

- Did you feel that the lectures gave you the background for performing the experiments?
- Were there too many techniques (sub-techniques) presented compared to what was actually possible to perform experiments with?

How did you find the experimental work?

- Was there enough time allocated for the experimental work?
- Did you feel involved in the experimental work?

Study material

- Was the expected study material available?
- What is your opinion on the material?
- At one lecture (at least) a paper was distributed to the students for preparation and was supposed to spawn a discussion about the benefits and possibilities of a method. Do think such an initiative is useful?

Student participation

The participation for the lectures were generally low (~50% in average)

- What was your participation?
- What was the reason for your amount of participation?
  - Do know whether other participants had similar reasons?
- What would it take to increase your level of participation?

Expectations and outcome

- Did the course cover the expected subjects/methods

- Do you think the learning objectives laid out for the course was met?

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:

http://www.ind.ku.dk/publikationer/up_projekter/

kapitler/2012_vol5_bibliopgraphy.pdf/