9

Advanced spectroscopy (M-337) in the block structure

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Introduction

The course in advanced spectroscopy will be given in the ”block structure” in the autumn of 2010 and the course description, objectives, teaching activities and evaluation should be reviewed well in advance to make the transition smooth. This is also a good opportunity to consider improvements in the course and to test new ideas with the students at the next course (which will be the last time the course is given outside the block structure).

Problem definition

The intended outcomes of the project are:

- A suggestion of how to use the block structure to organize the course including the evaluation which currently is a three weeks project work.
- A reviewed course description.
- A poster to attract students to this elective course (and presentable at the meeting in August).

The first point, how to organize the course within the frames of the block structure, will give me an opportunity to plan a course without starting from scratch. Since I have been involved as a teacher in this course it will also fit into my portfolio. For this project I’ll consult with collogues and former students to establish the key elements of the course, if there is any perceived difficulties and how well the examination works.

Excerpts from the current course description

The course is currently worth 6 ECTS-points and running over approximately 14 weeks.

The course aims to introduce students to the practical application of modern spectroscopic methods. The course focuses on methods used to determine the structure of organic compounds, including determining relative stereochemistry and, less commonly, absolute stereochemistry.
Main course emphasis is on problem solving. The course will illustrate ways of using different spectroscopic methods to determine structure and identify small to medium size organic compounds, on their own or in combination.

The course is largely taught in double lessons so that after an introductory theoretical review, students can solve problems illustrating the theory. Computer programs for processing data and analyzing NMR spectra will be used during the course in order to provide students with deeper understanding of NMR theory. Most of the practical exercises will be done as homework assignments.

At the end of the course students in groups of two will be given a collection of spectra (typically MS, IR, UV and various NMR spectra) for an organic compound and asked to identify the compound based on these spectra to the extent possible. The NMR spectra are typically provided as raw digital data (FID's) to be processed by students in order to identify the related spectra.

Three weeks after the spectra have been provided, students must hand in a written report in which they give an account of the structural explanation for the compound. During these three weeks students may have up to 45 minutes of assistance from the supervising teacher. In order to be evaluated individually on the basis of the 7-point scale, students will subsequently be examined orally on their written report.

Teaching in the block structure

Teaching at the pharmaceutical faculty will be organized into four blocks instead of the current system of two semesters. This is an ongoing reform to increase the potential for mobility of students both within and between

the universities and faculties. It is also a good opportunity to introduce new forms of teaching and evaluation methods (Horst and Winsløw; 2004).

The block structure in itself is supposed to make the education more effective by making room (time) for longer periods of organized student group work. The teachers' role will be to introduce subjects and exercises to the students, guide the exercise and to follow up on the results. The students will learn the subject while working in groups and during the follow up. This is in contrast to today, where students are supposed to do their homework before and after lectures, combined with a few exercise classes.

	Before	Lecture	In between	Exercises
Teacher	Preparation	Lecturing	Preparation	Guiding
Student	Reading (maybe)	Listens/takes notes (maybe)	Reading, writing, calculates (maybe)	Takes notes, participates

Fig. 9.1. Traditional organization of the teaching/learning process.

	Class	Working time	Class
Teacher	Introduction of new subjects, present exercises for the students	Guides, supervises and observes students' progress	Recapitulation of difficult issues in the exercises
Student	Listens/asks questions/takes notes (checked)	Working with exercises (checked)	Listens/asks/notes/ discusses/presents

Fig. 9.2. Teaching in the block structure

Time frame

One block stretches over 9 weeks, representing 15 ECTS-points. A course covering 7.5 ECTS-points will be assigned one out of three possible schedule groups (A, B and C) each allowing teaching during a whole day

and either a morning or afternoon session per week. The maximal total time for one block will be 12 hours per week, if the morning session starts at 8:00 and the afternoon session continues to 17:00. The exact time frame can, however, be decided on by the teacher as long as it does not come into conflict with the other schedule groups (see http://www.science.ku.dk/udregler/forside/undervisningen/skemagrupper [2009-08-25]. There is still no description of the schedule groups in the block structure at the faculty of pharmaceutical sciences (www.farma.ku.dk), but they are (probably) the same for the whole university).

	Mon	Tue	Wed	Thur	Fri
Morning session -12.00	B	A	C	A	B
Afternoon session 13.00-	C	B	C	A	

Fig. 9.3. The A, B and C-blocks of the blocks structure

Teaching advanced spectroscopy in the block structure

The current organization of 'Advanced Spectroscopy' (M-337) is based on in general two hours of lectures, twice a week. At present, there are in total 19 lectures spread over approximately 10 weeks. For the time between lectures, smaller assignments are presented to the students. At three occasions during the course, a four hour guided afternoon session of computer exercises were scheduled (see Appendix A). The final exam is in the form of a project work running over four weeks. The students are given raw NMR-data and a mono isotopic mass and from this they should determine the structure of a natural product. There is a limited time, 45 minutes, to discuss the project with the one of the teachers. The number of enrolled students is 28 this year and is expected to be this size the first time the course is given in the new structure next year.

To find out more about the key points of the course and the most important and relevant subjects I arranged an interview with a few students. They

were selected based on their previous participation and their current positions as PhD-student and finishing master theses at the department. The idea was that they could pinpoint the merits of the course and have suggestions for the reorganized course. For a list of questions and compiled answers – see page 83. I have also talked to some of the other teachers active on the course and reviewed the lecture slides from last and previous years.

Organization

The block structure and the currently planned schedule group (A) include a 'short day' and a 'long day' per week. To keep the current number of lectures would require about three occasions per week for six weeks, leaving time for three weeks of final project work. Considering the workload of the teachers and students, I believe it would be best to aim for lectures twice a week as it is today. However, this means that the lectures must be more streamlined (less overlap) and with considerable less repetition compared to the current situation. By introducing group assignments or smaller projects linked to the lectures it would be possible to reduce the time spent for repetition and at the same time get control over how much the students have actually learned from the lectures.

The interviewed students expressed that it was important that the time in class was effective without too much dead time. Presentation of group work should hence not be placed in the end of a long day. Time planned by themselves, such as group work and computer exercises, could be stretched out if needed, but if they had to prioritized otherwise they could do the work without guidance.

My suggestion of a framework is two-hour lectures twice per week (separate days). The rest of the time should be used for exercises solved by working in smaller groups (with some supervision) or individually, supervised computer exercises and demonstrations/hands on sessions. Group works should be presented to the rest of the groups during sessions moderated by the teachers.

A week could start (short day) with the presentations of one or two student's solutions to previous exercises/assignments with discussions led by the teacher. After this a lecture introduces new issues and exercises to be solved in groups. The bulk of the group work is done during the 'long day' with some support from the teachers. The afternoon session starts with presentations, followed by a new lecture and exercises to be solved over the weekend (individually or in group). However, the lecture should probably

not take place too late in the afternoon so the presentation of results might be placed before lunch. Some of the 'long days' are used for the supervised computer exercises and demonstrations/hands on sessions in the instrument lab.

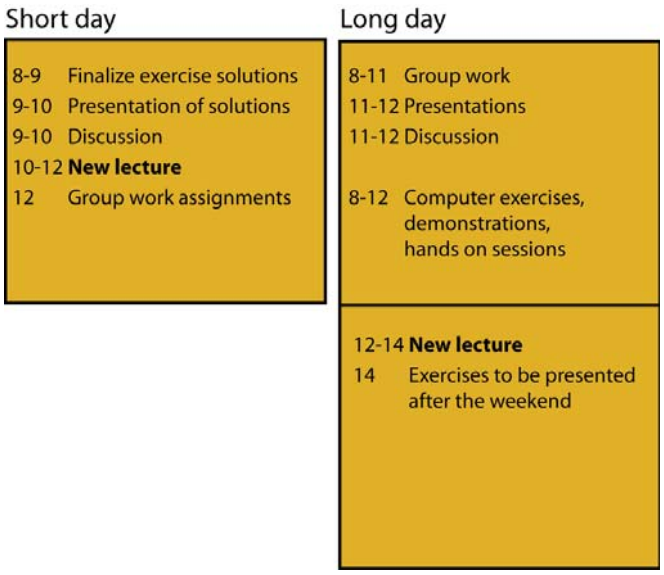

Fig. 9.4. Suggestion of framework for the organization of the course

Course outline

From the current syllabus a slightly compressed outline of the course is presented under Appendix A. The exact content depends on the choice of textbook and the teachers involved in the course.

Examination

The students were very satisfied with the final project work as exam. It was a good motivator to put a lot of work into the course and they had good use of the knowledge they gained from it.

For the reorganization of the course it makes sense to keep this form of evaluation. They expressed that the time for the project (3-4 weeks) was well suited to the problem and close to what would be required of them if it was a real problem. However, they thought there could be more 'milestones' such as "all data processed and ready for interpretation" and more guidance of how to organize the actual data interpretation.

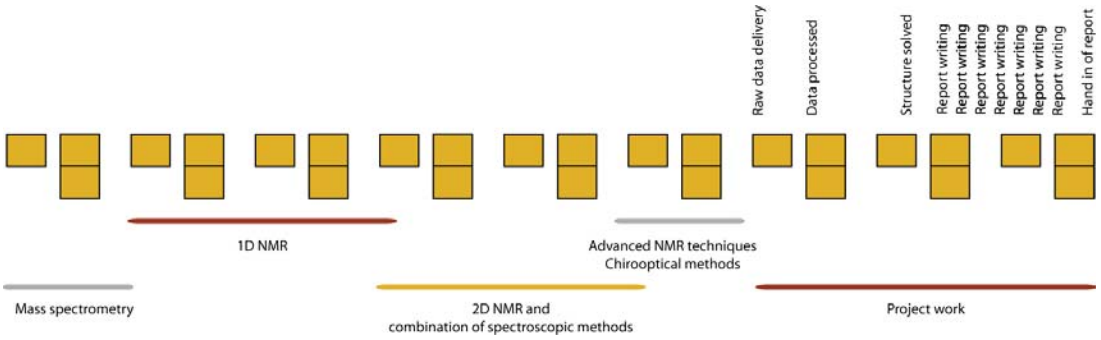

Fig. 9.5. Outline of the course. Each of the nine weeks are represented by three schedule blocks –one short day and one long day.

Course outcome

The current course outcome (Figure 9.6) is a bit outdated compared to the actual syllabus. My suggestion is presented below with verbs from 'Bloom's revised taxonomy' of intended learning outcomes (Biggs and Tang; 2007, p. 81) without the present use of prefixed "To be able to…" From the interview I learned that the main merit of the course was the *exposure* to NMR and the combination of different experiments to deduce the structures of the molecules. At this, the exam work was well aligned to the objectives of the course and the syllabus. However, the students thought there could be a larger proportion of mass spectrometry since different MS techniques (MALDI-TOF, DESI, MS^n) generally are used in real life structural determinations.

At the end of the course, students are expected to be able to use IR, UV, ^{1}H NMR, ^{13}C NMR and mass spectrometry for the structural determination and identification of organic compounds, including:

- To be able to interpret first order coupling patterns as well as simple second order coupling patterns in ^{1}H NMR spectra
- To be able to predict ^{1}H and ^{13}C NMR chemical shift values for small to medium size organic molecules and use them to solve structural problems
- To be able to intrepret homo- and heteronuclear 2-D NMR experiments such as COSY, NOESY, HSQC and HMBC
- To be able to explain fragmentation patterns in EI mass spectra and to be familiar with other techniques/ionisation forms of mass spectrometry.

Fig. 9.6. Current course outcome as described on http://www.farma.ku.dk

The students are expected to use ^{1}H NMR, ^{13}C NMR and mass spectrometry in combination for the structural determination and identification of organic compounds, including:

- Interpret first order coupling patterns as well as simple second order coupling patterns in ^{1}H NMR spectra
- Predict ^{1}H and ^{13}C NMR chemical shift values for small to medium size organic molecules and use them to solve structural problems
- Intrepret homo- and hetero nuclear 2-D NMR experiments such as COSY, NOESY, HSQC and HMBC to deduce structural fragments and their connections
- Explain fragmentation patterns in EI mass spectra and to be familiar with other techniques/ionisation forms of mass spectrometry.

Fig. 9.7. Suggested intended learning outcome

Perceived difficulties and problems with the course

Computer exercises

The handling of the NMR computer program (Topspin) took a lot of energy. The suggestion to overcome this was more guidance. Also, the actual workflow with the data handling could be more thoroughly described.

The Topspin-program is not freely available to the students after the course. It was suggested to use another program, ACD, instead. For this program we have a site license and it is regarded as more intuitive. This would require the teachers to learn this program.

It was also suggested to keep the theory of NMR and NMR-processing away from the computer exercises. They ended up changing parameters in a program they did not fully master. The adjustment of these parameters is also not that important during the exam project work (or for their theses).

Scientific writing

The interviewed students thought that a descriptive way of the reasoning leading to the structure was the best for the exam work. However, they also meant there could be room for guided reading and writing of a scientific text directed to the subject. The report could contain an ‘Experimental’ section describing the relevant parameters for the experiments.

Time for the exam project work

Teaching in the block structure means a more time compressed course and the students thought it was valuable to work during a longer period with the final project. However, it was not a solution to hand out and start the exam earlier since this should make the students to lose their focus. Also, the time frame to solve a structure in reality should not take too much time. However, it was suggested to introduce additional 'milestones' during the project, such as 'all data processed and ready for interpretation'. At present we check that the obtained structure is correct before the report is finalized.

No practical lab work

It should add value to the course if there was time to actually acquire a real spectrum. Ideally, all the spectra for the final project work should be set up and ran. It would be possible, but requires quite a lot of work from the teachers' side. A set of spectra could be acquired within hours if the sample was of high concentration and with the proper automation.

Interview of previous students in the course

Participants and year for the course: Lasse Saaby (2007, PhD-student), Rasmus PW Larsen (2008, finishing master thesis) and Jeppe Secher Schmidt (2008, finishing master thesis). They have all been using the techniques and methods taught during the course for their master theses.

1. **Was the course good or was it 'a waste of time'?**
   This is just to get them started...
   The course was regarded as a very good one. The best point was the *exposure* to NMR and the use of combined experiments to solve a problem (more than in M-25 and the whole arsenal of different experiments). The exam, project work, was also appreciated and well connected to the syllabus.
2. **Was the allocation of time for the different subjects ok?**
   MS: 3 lectures (each 2 hours)
   General NMR: 10
   2D NMR: 3
   Hyphenation and combined use: 2

Computer exercises: 3 occasions (each 4 hours)
Yes, but more MS could be included. Although, there was very little MS in the project work (just a mono isotopic mass given) but mass spectroscopy is in reality used more.

3. **Would it be possible to introduce the 2D-NMR at an earlier stage?**
2D NMR is a large part of the project work, but emerges at a late stage.
No. The focus group agreed that a logical structure of the course is important – first theory, then 1D followed by 2D.
4. **Were the computer exercises adequate?**
There were three occasions with computer exercises. The project work required use of a special NMR program.
The handling of the computer program took a lot of energy. There was two good suggestions – to offer guidance when the raw data files are delivered, and to have 'milestones' in the project such as 'All data processed and ready to be interpreted'. Also, they thought that some guidance of how to handle all the data would be good.The computer exercises should not be used to exemplify theoretical issues (such as digital resolution), only the practical steps needed.
5. **Did the lectures prepare you for the project work?**
The project work ran for a period of four weeks. From spectra to structures, and to explain the spectroscopic features.
In general, yes. But some more guidance of how to practically work with all the data would be good.
6. **What kind of problems in a more 'problem based education' would be suitable for a course like this? Give examples from your current situation in the lab.**
Teaching in the block structure is meant to be more problems based compared to traditional teaching in order to activate the students and making the teaching efficient. (Think of working in groups with problems presented during a lecture.)
Exercises from the book is ok, but some of them was cryptically, silly (tåbelig) and very theoretical. If possible they should be reworked to make them more relevant and case based.Solutions to some practical exercises should be presented by the students for the whole group. A suggestion was that all groups worked on the same problem, but only one presented the results and led the discussion of how to work with this particular problem.Also, a time limited real case, say 2 hours from raw data to identified fragments, could be used as a model of how to work with NMR and how much information could be extracted in a

short time. It was stressed that an efficient use of the long days was important. Group work with a summing up late in the afternoon might bore the students. Keep the summing up to the next occasion and give the student liberty to plan their work.

7. **What style do you prefer to use for the report?**
   Do you prefer 'the scientific description' (full structure with the spectroscopic features described) or 'Sherlock Holmes' (from spectra to fragments to molecule)? What style would prepare you the best for tasks after the course?
   The focus group liked the 'Sherlock Holmes'-style best because it gave them best possibility to write about the logical steps necessary to reach the final structure. Also, there was space to consider alternative fragments, and how to select among these.
8. **Was the long time given for the project work valuable?**
   The time from delivery of raw data files to submission was 3 or 4 weeks.
   Yes, the relatively long time was valuable to let the project settle in their minds. The block structure will mean a shorter, but more focused, time. Still, they thought it was important not to start the project work too early, before the bulk theory had been processed. It would put the students in 'exam mode' and draw attention from the theory and practicalities of the course.
9. **What new elements would you like to see?**
   The new course will be slightly longer. 7.5 ECTS instead of 6 ECTS.My suggestions: Quantitative NMR, chemometrics, other pulse sequences, MALDI-TOF MS, HPLC-MS, practical lab work, acquisition of spectra, other computer programs, scientific writing
   More mass spectrometry (HPLC-MS, GC-MS, multiple stage fragmentation, MSn, peptide analysis, other ionization techniques, MALDI, DESI) because it is a valuable technique in the analysis of natural products. The isotope pattern is theoretically important, but is not used in practice (or in the final exam).
   Quantitative NMR – yes!
   Chemometrics – introduction with practical examples to give a perspective.
   Other pulse sequences – not necessarily, but more about different variants of the used sequences (different mixing times in HMBC, different filters, phase sensitive experiments, multiplicity editing in 2D hetero nuclear NMR).
   Practical lab work, acquisition of spectra – Yes! In an advanced course

it should be time to acquire at least some simple spectra. The longer days in the block structure could be used for this.
Other computer programs – Yes! It's better to learn ACD (for which there is a site license) compared to learning Topspin (no license, not too intuitive).
Scientific writing – Yes! Maybe adding an 'Experimental' section to the project work. Also, reading of scientific articles to learn how the subject is described.

A Appendix: The schedule for M-337 2009

Advanced Spectroscopy M-337-3 Autumn 2009

#	Date, time, room	Subject	Teaching material*	Teacher(s)**
1	31/8 10.00-12.00 (U22)	The mass spectrometer, EI, the molecular ion	13.3 + 13.3a + 13.4a + 15.3-15.4b, MS Notes 1-5, Exercises in Notes	SBC
2	4/9 8.00-10.00 (U8)	Alternative ionization, fragmentation	13.3b-13-3e + 14.1, 14.2-14.6	SBC
3	7/9 10.00-12.00 (U22)	Detection, fragmentation	13.4b-4f + 14.2-14-6	SBC
4	11/9 8.00-10.00 (U8)	Introduction to NMR	2.1 + 2.2 + 2.5 + 2.6 + 2.7	NN
5	14/9 10.00-12.00 (U22)	Vector model, relaxation, pulsed experiments	2.3 + 2.4	NN
6	18/9 8.00-10.00 (U8)	Experimental methods, spectrometer, processing of NMR signal, acquisition parameters, dynamic effects	2.8 + 2.9	NN
7	21/9 10.00-12.00 (U22)	^{1}H chemical shifts	3.1 + 3.2	SA
8	25/9 8.00-10.00 (U8)	^{13}C chemical shifts	3.3 + 3.4	AY
9	28/9 10.00-12.00 (U22)	First order coupling patterns	4.1-4.8	NN
10	29/9 12.15-16.15 (D1)	**Computer exercises**	Hand-outs	NN/AY
11	2/10 8.00-10.00 (U8)	Higher order coupling patterns	4.1-4.8	NN
12	5/10 10.00-12.00 (U22)	Coupling constants and structural relationships	4.1-4.8	NN
13	9/10 8.00-10.00 (U8)	Relaxation, decoupling nuclear Overhauser effect	5.1 + 5.3 + 5.4	NN
14	19/10 10.00-12.00 (U22)	2D-NMR: COSY, TOCSY	6.1	JJ
15	20/10 12.15-16.15 (D1)	**Computer exercises**	Hand-outs	NN/JJ
16	23/10 8.00-10.00 (U8)	2D NMR: NOESY, INADEQUATE	6.3 + 5.7 + 6.4	JJ
17	26/10 10.00-12.00 (U22)	2D-NMR: HSQC + HMBC	6.2 + 6.6	JJ
18	30/10 8.00-10.00 (U8)	Spectral editing, sensitivity enhancement	5.5 + 5.6	NN
19	2/11 10.00-12.00 (U22)	Hyphenated NMR methods: theory and applications	Hand-outs	JJ
20	3/11 12.15-16.15 (D1)	**Computer exercises**	Hand-outs	NN/JJ
21	6/11 8.00-10.00 (U8)	Chiroptical methods: CD, ORD	10.1, 10.3, 11.1-11.1a, 11.2-11.2c, 11.5a, 12.2-12.2a Use of molecular model set is recommended	JJ
22	9/11 10.00-12.00 (U22)	Combined use of spectroscopic methods	Hand-outs and selected exercises from Chapter 16	JJ

*Sections in Lambert, J.B., Shurvell, H.F., Lightner, D.A. & Cooks, R.G., Organic Structural Spectroscopy, Prentice-Hall 1998. **JJ: Professor Jerzy W. Jaroszewski (responsible for the course); SBC: Docent Søren Brøgger Christensen; NN: Dr. Nils Torsson Nyberg; SA: PhD-student Sara Angolet; AY: PhD-student Ali Yilmaz

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2008-1/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/kapitler/2008_vol1_bibliography.pdf/