RÅDET FÖR HÖGRE UTBILDNING
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Project number: 071/00
Name: Jens Blomqvist
Institution: Chalmers University of Technology
Department of Applied Acoustics
SE-412 96 Göteborg
Tel: +46 (0)31 772 2213
E-mail: jens@ta.chalmers.se

Fitness for purpose - achieved by "rediscovering" the subject acoustics

Abstract

Today, teaching often means to offer the students an adjusted extract of the complete knowledge achieved during a long time period. Adjusted in regards to the student's priori knowledge, aims of the course etc. This might give access to relevant information, exercise the use of tools and give insight into the theoretical background. However, it hardly gives the chance to follow up the development of this knowledge. It does neither train the capability to model "real-life" problems, which can be considered as a main task for an engineer.

Each individual subject has its specific history of discovery. Due to observation, experiment and modelling of problems, progress has been achieved from the "birth" of the subject to its state of today. This development is logically structured due to the increase of knowledge in the subject itself and in other areas supporting research and development.

The aim is here to change from the teacher perspective to the natural perspective created by the historical development of the subject and thereby improve the ability of the students to deal with new acoustical problems in their future career.

The idea of the proposed project is for the students to "rediscover" the subject acoustics by following in the footsteps of the subject's development and remake relevant observations, experiments and modelling which led to today's state of the art in the subject. This will train the fundamental skills of modelling and setting up experiments. At the same time it will improve the fundamental understanding of the phenomena since simplifications and limitations of the theoretical background become obvious when the results are critically evaluated in different states of the development. Furthermore, the focus will be on a number of fundamental principles in the subject and in this way help the students to a better understanding of most of the acoustical applications in "real-life".

Project update

The preparation phase has now been finished and with the beginning of autumn 2002 the implementation phase will start. During the preparation phase a working group consisting of students and teachers was established. The group has mainly investigated practical aspects of the project implementation together with some general issues regarding education and perceived problems in the field of acoustics. Main matters that have been considered are:

Critical and difficult fields/topics of acoustics.
Ways to use historical key papers in acoustics.
Needed skills for an engineer to treat new 'real life' problems.
How to train these skills?
Form in which the implementation phase could be carried out.
Form of examination and presentation.

A review of historical paper has given that the path in witch acoustics has developed is far from straightforward. Often a field is developed in parallel with different ideas including strokes of genius and errors. Landmarks are made when new models or theories are introduced (often taken from a completely different field). From this point there is usually a significant development over a long time period in order to reach to the theories/models, as we know them today. This gives that in the implementation phase somewhat more recent applied papers will be used. These papers use a scientific platform where the knowledge is comparable to the status at a specific time. The important thing in the progress from an observation to a genuine understanding of the physical processes is to follow the path of the student's mind, instead of the teacher's path.

Final report

Fitness for Purpose: Achieved by "Rediscovering" the Subject Acoustics

Project: 071/00
The Council for Renewal of Higher Education
(Rådet för högre utbildning)

Jens Blomqvist
Patrik Andersson

Department of Applied Acoustics
Chalmers University of Technology
Sweden

Objectives

As teachers in an International Master's Programme, in Sound and Vibrations, we have found a serious shortcoming. Although the students have, at the end of their studies (in problem oriented courses such as Design of Silent Products), a sound understanding of the subject and good ability to apply tools provided during their studies, they are still not well able to model “real-life” problems unless they are given substantial guidance. We realised that the ability to formulate a problem, make necessary simplifications, model the problem, transfer this model to mathematical formulations, and carry out a critical evaluation of results found is not as far developed as we had hoped. This more basic knowledge or ability is here referred to as engineering skills. The idea of the Fitness for Purpose project was to encourage students to reflect and focus on these, for an engineer, crucial skills, which is not usually stressed in our traditional way of teaching. Furthermore, the intention was to do this by relating the students' learning process to how science and the field of acoustics has evolved throughout history.

History of the Fitness for Purpose project

Discussions in a working group including students

The Fitness for Purpose project started during the autumn of 2001, when a working group was put together consisting of two teachers (the authors) and five students from our International Master's Programme. This group had official meetings approximately twice a month. In the Master's Programme there are typically around 16 students who spend most of their time at the department. This fosters a close relation between students and staff; it also offers opportunities for unofficial discussions. In the beginning, these discussions revolved mainly around teaching and learning processes and the kinds of knowledge and skills our programme encourage. In the working group there was a unanimous opinion that there are distinct differences between what we learn at the university and what we are expected to do in our working life. As one of the students in the group expressed it: "The important thing to understand how you think."

Besides traditional engineering knowledge and the ability to search for needed information, the following three skills were regarded as crucial for a good engineer.

- <u>To make a problem description,</u> a generally formulated task or problem is divided into separate acoustic problems, which can be scientifically investigated by experiments (mathematical or physical).
- <u>To make a model,</u> a physical model needs to be translated into a mathematical one.
- <u>To interpret results,</u> one must translate from a model, including its simplifications, to the physical reality and draw conclusions from the results.

What the learning environment should be, to foster the desired abilities, was a recurrent topic during the meetings of the working group. In general it was considered that the optimal form was to have frequent discussions, teamwork for pairs of students, and projects of a Problem Based Learning type. Moreover, it was believed that the duration of the projects must be long. The normal duration of a course at our university (7 - 8 weeks of study) was considered to tend to promote repeating facts rather than gaining actual skills. It was interesting to find that not only were the students in the working group well aware of the procedures needed by a practising engineer, but they also wanted to use these procedures for learning. This is closely related to the original idea of the project, rediscovering acoustics by following the historical evaluation of the field.

One of the main ideas in our project plan was to use some classic acoustic papers in order to "rediscover" knowledge and, thereby, obtain a more genuine understanding of the physics and methods needed to deal with new problems. Accordingly, 10 papers, generally accepted as benchmark studies, were examined. These papers ranged over widely divergent aspects of acoustics such as experiments on sound propagation speed, statistical views on sound energy in rooms, and vibrating strings. Some papers were experimental, while others were more mathematical; the authors came from somewhat different fields of science. Next, different ways of making use of these papers were discussed and the following five approaches were identified.

- Reproduction: Repeating experiments to better understand conclusions;
- Historical correction: Examining the errors in the papers by investigating what went wrong and why;
- Scientific anachronism: Using up-to-date theory to explain early publications;
- Historical evolution: Investigating how experiments within the field of acoustics have developed and identify the changes that have led to improvements; and
- Evolution of ideas: Examining how some of the fundamental acoustic concepts have evolved to reach their final form.

After considering the nature of the historic papers and various ways to use them, the working group decided to abandon this approach. The reason for doing this can be summarised as follows. When reading these papers, it is quite clear that the idea of clean breakthroughs that suddenly reveal a new understanding is a fiction. Instead, there existed several alternative ideas and models simultaneously. Although these included useful ideas, from a modern point of view, they also had significant flaws and errors. Often the theories that we experience today as being close to "the truth" were first presented by "hard core" mathematicians who were usually greatly influenced by other areas of natural science. These mathematical descriptions are often given without much explanation, perhaps because it was considered unnecessary since everything was encompassed by mathematics. Another thing that makes the interpretation difficult, and which is worth noting, is that the approaches to and ways of viewing problems were very much influenced by the ideas and theories available at that time. The students considered most of the papers to be somewhat otherworldly, and the working group concluded that, if we want to nourish "true" knowledge, the students must encounter their own problems to gain experience.

Another idea, which arose from the original project description, was the use of a logbook as an historical document. This form of tracing thoughts and ideas was believed by the working group to be a good way to record the information and, at the same time, to relive the method of the working process.

After the use of classic papers was abandoned, attention was turned to ways of implementing the good learning environment outlined above and to supporting this by the use of logbooks. The working group found that a course called Individual Preparation Course (IPC) could be transformed, by implementing discussions, by teamwork for pairs of students, and by Problem Based Learning projects in a period of 16 weeks. The outcome of the discussions on implementing a good learning environment and how logbooks can be used is given below in the description of the IPC course.

Description of implementation of ideas in the Individual Preparation Course (IPC)

In the Individual Preparation Course (IPC), given 2002, projects were implemented based on the ideas of the Fitness for Purpose working group. The IPC projects attempted to let the students go through the crucial steps in the engineering process. The crucial steps of implementation were specified in more detail as; observation, formulation of the problem, making a controlled experiment, evaluation, modelling, verification, parameter study and conclusions. The course description that was handed out to the students at the start is given in Appendix 1.

The students worked for 16 weeks, in pairs, with their individually chosen projects and was guided by a tutor from the department. The topics of the IPC projects were chosen by the students themselves to achieve a higher motivation and interest; in the first lecture they were asked to find the record of an observation of an acoustical phenomenon they would like to investigate further during the project.

The tutor's role was to guide the partners through their work and help them with support and information when needed. Examples of such support are to help the students in their decisions by providing: suggestions on where to find information, limitations when it comes to available money, equipment and manpower, and if needed, suggestion on aspects to investigate. The idea of the logbook was introduced and implemented as a basis for the contact between the students and the tutor. The instructions for of the logbook, which was handed out to the students, are shown in Appendix 2.

There were, in addition to the tutors, two teachers for the course (the authors). Their role was to formulate an engineering process to apply to the student projects and to provide background knowledge. The teachers worked with their own observation (the sound from a coffee cup, when the bottom of the cup is struck, changes dramatically just after instant coffee has been stirred into hot water) in parallel with the projects of the students. Since the teachers did not know beforehand why this phenomenon occurred, they had to go through the same process as the students. Time was scheduled each week for the progress of the projects to be presented and discussed. Some of the time was also used to give lectures on general engineering topics, such as how to conduct an experiment, the art of science, the field of thermoacoustics, and on specific background knowledge for the projects, such as how to use software for mathematical modelling.

To keep attention on the process, rather than the final results, the reporting was done as short oral presentations and discussions periodically during the course. The logbooks were used not only for writing down findings and thoughts, but also as the basis of the discussions and presentations.

Evaluation

Overview

Three methods were used to evaluate the ideas of the project in general and those implemented in the Individual Preparation Course (IPC) in particular.

1) Questionnaires for Master's degree students to answer about their master thesis work; answers from students of the year 2002 who had participated in the newly implemented IPC projects were compared with those from students of 2001 who had not participated.

2) Interviews with the teachers of a course called Design of Silent Products. In this course the students have to go through the same kind of process as in the IPC project. The teachers' assessments of the students' abilities year 2002 were compared with those of the previous year. Students of year 2002 had participated in the newly implemented IPC projects while students of year 2001 had not.

3) Evaluation of how the students' IPC projects in 2002 were reported in the logbooks.
A more detailed description of the three evaluation methods and their outcome follows.

Questionnaires for Master's degree students to answer about their master thesis work

For the students participating in the Master's Programme, the final part of their studies consists of their master thesis work for which they should independently (although with some supervision) to solve an engineering problem. This usually includes problem definitions, a literature survey, measurements, mathematical modelling, evaluation of results, and writing a full report. The duration of the project corresponds to half of an academic year. Since this requires the students to work in an engineering type situation, it was considered to be an opportunity to evaluate whether the abilities we tried to foster on the IPC course had in any way succeeded. Two groups, of 10 students each, were studied. The students in 2001 group were experiencing an IPC course, for which they carried out an short individual project; they also had supporting lectures on aspects of acoustics. The students in the 2002 group were taking part in the IPC course previously described, which emphasised the stages in an engineering process.

A questionnaire consisting of two parts was sent out to the two groups of students. In the first part they were asked to rate their own abilities, while in the second part there were questions that led them to reflect on their work and experience during the thesis project. In the first part they were asked to rate the following statements from 1 (totally disagree) to 10 (totally agree) in regard to their thesis work

1. My mathematical background is sufficient.
2. My knowledge of acoustics is sufficient.
3. I have the ability, independent of my supervisor, to identify and formulate the questions to be solved.
4. I find it easy to mathematically formulate the acoustic problems involved in my thesis.
5. I find it easy to understand and/or interpret the results of my calculations and measurements.
6. I have a clear focus on the goal and on how to get there.

The results from these questions are shown in Figure 1 where the results from 2001 are given in blue and from 2002 in red. To illustrate the confidence level of the results the ±1 standard deviations are also plotted.

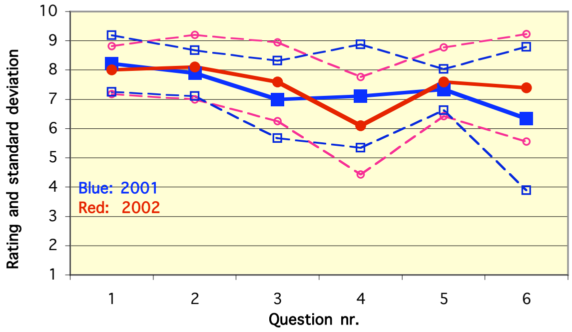

Figure 1. Results from the first part of the questionnaire: Students' rating of their own abilities.

Although such a plot can be interesting, this one shows primarily that there are apparently no significant differences in how the students rate their abilities in 2001 and 2002.

In the second part of the questionnaire, the answers were groped in categories: only those with significant variations are reported. The response to the question on problems experienced during the thesis work indicates that in 2001 organisation and communication were the main problems while in 2002 the emphasis is more on poor equipment, such as computers, and analysers. A reason for this could be that the students in 2001 were one to two months further along in their project when the questionnaire was sent out. Issues related to the engineering process also seem to be somewhat more problematic during 2001 than in 2002. Furthermore, the students in 2002 seem to think that the problems they are faced with in the thesis work are things they have to deal with themselves, rather than something caused by shortcomings in their programme.

The students in 2002 also consider themselves to have a clearer idea of what is expected of them in their final project. It is also interesting that students in 2002, on the question of what they believe to be the main purpose of the thesis work, mostly state engineering skills (problem solving, evaluation of results) while in 2001 the answers have more to do with applying their knowledge.

In dealing with new acoustic questions and problems, students in 2001 say they find making mathematical models to be the most difficult part, while in 2002 the defining of the actual problem was considered to be the most difficult.

Interview with teachers in the course Design of Silent Products (DSP)

A second strategy to evaluate the ideas implemented in the Individual Preparation Course (IPC) was to interview the teacher of a course called Design of Silent Product (DSP). In this course the students are training their ability to solve independently an open technical question related to acoustics. Hence, the students have to go through the same kind of process as in the IPC project. The students of the year 2002 did participate in the IPC project focusing on the engineering skills, while those of the year 2001 did not. The teachers comments, on the students' actions in and reaction to the DSP course for these two years, are used here to evaluate whether the students have benefited from the ideas implemented in the IPC project. Below, the course is described in more detail and is followed by a summary of the interviews.

The DSP course is given in the last term of the International Master's Programme in Sound and Vibration, just before the final thesis work starts. The course lasts about 7 weeks and about 10 students participate. Excerpts from the course description are given below.

> "This course might appear somewhat different from other courses. Therefore, I decided that the course description should also be different. This course is one of the last in your education as a specialist in sound and vibration. There are just a few months left until you will work in real life as an acoustic engineer. You will experience a substantial change when you exchange your well organised educational situation for a working life, where you have to work by your own, without the guidance of teachers.
> This course is a first step in this direction. There will be not the typical teacher/student situation, but we will work together in small groups towards one goal. This goal is to learn how to design a silent product and to demonstrate our knowledge with an example. ...
>
> I know that these steps are quite ambitious and they will demand substantial initiative, energy and work from you (and probably also from me).
> In the course schedule there are very few hours fixed as lecture hours. We will certainly need more time, which we will allocate during the course. You will also have do substantial part of the work on your own. ..."

It should be noted that the course was taught by different teachers in 2001 and 2002, due to a personnel change at the department. Hence, first each teachers view on the course was investigated.

Each years a noisy machine (a chain saw in 2001 and a dishwasher in 2002) was given to the students and they had to answer the question: Could this machine be treated or reconstructed to be less noisy? Both teachers stressed in the interview that for the student the idea of the course is to learn to more independently handle a new problem, by simulating a typical engineering task. Both explained that this course significantly differs from a traditional course: in the DSP course the students are free to independently try to identify and formulate the problems to solve. Both teachers described their role to be that of a resource, guide or adviser to whom the students could turn when needed, for guidance, answering questions, or giving lectures on specific topics. Both years the students were divided in small groups which, from the beginning of the course, focused on different problems. In addition to the work done in groups, lectures were also given on topics such as general design strategy, and various acoustic and technical matters, to improve the background of the students. The two teachers had a very similar view of the course, which is not surprising, as the ideas from the course in 2001 were supplied to the second teacher.

The teacher in 2001 felt the students lacked the following at the start of the course: self-confidence, initiative to ask from missing knowledge, ability to formulate a problem and turn it into an engineering task, and the courage to interpret results. The teacher in 2002 said that in general the students were well prepared for the course but lacked initiative and the willingness to ask questions. Both teachers felt that they had to retreat from their original concept of the course, since the students did not ask for information, even though they seemed highly motivated and engaged. After some weeks, the teachers had to take the initiative to suggest lectures that after some discussion were accepted by the students.

The students on the other hand realised after some time that they had to take major initiatives on their own. Here, it seems there was a change after the first year: the teacher of year 2001 felt that the students started to take initiative "in the end of the course", while the teacher of year 2002 felt that the initiative from the students came "after the middle of the course". At the end of both courses, the teachers felt that most of the students were motivated, engaged, asked questions, and wanted to continue to examine the object assigned and to test new ideas.

Both teachers admitted that they had doubted whether one can expect students to take their own initiative in a process that they never been through before. Maybe the students have to be guided the first time? One of the teachers made the analogy of being a beginner in a new language: you don't immediately start talking to people; rather, you stay keep quite, try to listen and learn, and after a while take some small initiatives. The other teacher pointed out clearly that it is hard for the students, as they are not used to the this type of course; they do not know what they are expected to do in the course, they do not know what knowledge they lack, nor do they know what demands they can put on the teacher.

A primary conclusion drawn from the interviews reported above is the confirmation of a student's lack of ability to tackle the process of an engineering task on his/her own. It was this lack that was the starting point of the project. It is also interesting to find that both teachers independently arrived at the same doubt as to whether the students can be expected to take their own initiative in a process that they never experienced before. This suggests that the students need training in this type of learning process before they can actually fully benefit from it.

To summarise, two indications that the IPC projects were beneficial were found. First, according to the teachers, the students of 2001 started to take initiative at the end of the course, while those of 2002, who had followed the IPC project, started to take initiative in the middle of the course. Second, the teacher of 2002 expressed somewhat more satisfaction with how the students were prepared for the course.

Evaluation of logbooks

The working group considered the logbook to be an interesting tool, not only for recording the research project but also as a means to illustrate the scientific process. Therefore the decision was taken to attempt to evaluate the student logbooks. However, the students were not told that logbooks were being evaluated until after the project was finished.

The evaluation was made by two independent judges and rated on a five-point scale on the basis of how understandable and extensive the log was. This rating of the logbooks was then compared with the average mark that each student had received in their courses in the Master's Programme during their final year of studies. All of these courses treat different aspects of the field of acoustics. The number of finished courses varied between 4 and 8, while the average of the number of completed courses was 5.2.

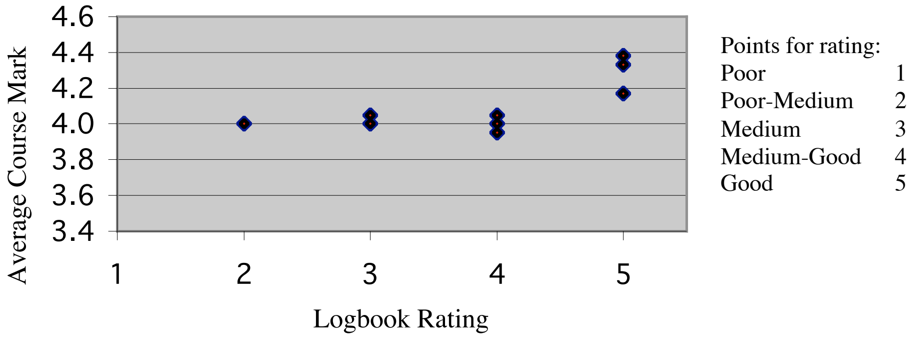

Figure 2: Relation between logbook rating and average course grade for nine students.

Due to the small number of logbooks the statistical reliability is very poor. However, the results show a clear relation between writing a good logbook and obtaining a high average grade in the courses (Figure 2). This does not show that writing a good logbook is a means to obtaining good grades. It could just as well signify that a good student, write a good logbook and also obtain good academic results. It is also interesting to note that there does not seem to be any link between the average course grade and obtaining grade 2 - 4 in the logbook evaluation. This suggests that all students who are entering the Master's Programme are highly motivated, while their abilities, interest or other reasons for writing a logbook, vary widely. The most positive interpretation in favour of writing the logbooks well would be that, if the students could master the writing of logbooks, this would also lead to good academic results.

Conclusions

The aim of this project was to improve what we have called engineering skills such as the ability to formulate problems, transfer the physical reality into mathematical model, investigate results from the model, and translate these into conclusions about the physical reality. Discussions with a working group including students have shown that they are well aware of what is required of them as engineers. A problem is that it is difficult to assess whether students acquire these skills, especially if the number of students in the study is small. However, our experience is that changing the teaching and the working procedure of the student, while at the same time concentrating more on engineering skills, did have a positive effect. Evaluations show that other teachers have observed this and that students start reflecting about the process during their work.

Both teachers and students have expressed a very positive attitude to the use of logbooks in their work and the logs is something we have concluded should be used more extensively in our Master's Programme. It is a straightforward way to structure the work and emphasise the whole process from an observed problem, to a mathematical model from which conclusions can be drawn. It is however clear that we cannot just give the students a description of a logbook and hope that this will make a significant change; we have to frequently discuss the use of the log with the students. In the evaluation we found a correlation between obtaining high overall grades and writing a "good" logbook.

In retrospect it is clear that one of the major obstacles to overcome in a mixed group of teachers and students is to achieve a consensus of problems, the meaning of formulations and the goals. In the beginning it was often frustrating for the teachers that the work did not seem to progress. It is important to realise that it takes time to find a common language before you can really benefit from all the knowledge in the group.

If we want to improve the subtle skills referred here to as engineering skills, we must change both the teaching and learning processes, which requires endurance. If we just "add on" a course or tasks, the students are unlikely to regard these as any different from previous ones. Our experience is that it is advantageous to have a continuous discussion of how we learn, and we have found that students are very interested in these questions.

An idea from the original application was to concentrate on the engineering skills by following the scientific evolution of the field of acoustics by redoing classic experiments and theoretical formulations in papers commonly regarded as benchmark papers. This would be possible but in this case we found that this was not a good means to improve the understanding of the field of acoustics. This is because nomenclature, conventions, and the approach at that time were far too different from those of students today.

Finally, to strengthen engineering skills requires time and effort, from both teachers and students. This could sometimes be hard to motivate both financially with the present reduction of resources and in relation to the rest of the educational system. The idea of a project where the students formulate their own problem and make an investigation is still a part of the Individual Preparation Course, but the time is limited to seven weeks and the tutors give closer guidance to the students. The concept of logbooks is still introduced to the students at the start of the Master's Programme, and the logbooks are used during their studies.

Whenever possible, it is recommended to implement the ideas presented in this report. This recommendation is based on the positive effect found in the evaluation and the clear positive attitude and acceptance of these kinds of ideas from both teachers and students.

Acknowledgements

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APPENDIX 1

Tentative course description given at the start of the Individual Preparation Course

Action		Agenda
1	Each group (4 - 6 students) is assigned find some observations. These observations should be clearly described and identified. Together with a tutor, choose one experiment to study in pairs.	Weeks 1 - 3 Presentation week 3
2	Individual software exercise (Matlab).	Weeks 2 - 5
3	Formulate a hypothesis of how the phenomenon studied works and design and carry out an experiment to test it.	Weeks 4 - 8 Presentation week 9
4	Formulation of how an experiment is set up and examination of the errors. This would then be a guideline for how a hypothesis is validated or discarded.	Week 9
5	Try to set up a mathematical model of the phenomenon described in the software Matlab.	Weeks 9 - 12 Presentation week 12
6	Search for models in the literature and try to implement them.	Weeks 11 - 14
7	Describe the process of translating a physical model into a mathematical model.	Week 15
8	Parameter study Final Presentation	Week 16

Study week	Calendar week	Date	Activities
1	Week no. 36	3/9	Course introduction (and the coffee cup problem)
1	Week no. 36	5/9	Repetition of background
2	Week no. 37	10/9	Lecture: Matlab exercise
3	Week no. 38	17/9	Presentation
4	Week no. 39	24/9	Lecture: The art of science
5	Week no. 40	1/10	Lecture: Favourites in acoustics
6	Week no. 41	8/10	Lecture: Acoustic modelling
7	Week no. 42	15/10	Lecture: How to conduct an experiment
8	Week no. 43	24/10	Free week (exams in other courses)
9	Week no. 44	31/10	Presentation of experiments
10	Week no. 45	7/11	Lecture: ...
11	Week no. 46	14/11	Lecture: ...
12	Week no. 47	21/11	Presentation of mathematical models
13	Week no. 48	28/11	Lecture: ...
14	Week no. 49	5/12	Lecture: ...
15	Week no. 50	12/12	Lecture: ...
16	Week no. 51	19/12	Free week (exams in other courses)
			Final Presentation

Description of a logbook

(Log: a record of performance, events, or day-to-day activities)

During your research investigation it is essential to record your thoughts, ideas, attempts, useful formulas, why some formulas are not useful, your experimental set-up, failures, results (both positive and negative), and conclusions. This may be done in a logbook, where you write notes about your work as you do it.

By looking at your logbook you should be able to remember what you have found (or not found), and how this came about. Thus, the logbook may be used to assist your own investigation.

Further, it should be possible to use the logbook when you communicate with others, including friends, students, course assistants, and examiner. The important thing is when somebody asks you something about your investigation, you should be able to give the answer right away or to find it in your logbook, instead of answering "I don't know" or "I don't remember".

Every now and then during the course, you and the examiner or teacher will have discussions about your investigation, such as what you have found (or not found) and how you are working. The logbook will then be the basis for these discussions.

At the end you might like to conclude your work with an oral or written report. You would then go to your logbook (where everything of interest is summarised), pick out the parts you would like to present and compose the report with appropriate words.

As general rules of thumb, it is better to write too much than too little in the logbook, and it is wise to write the notes in chronological order. Exactly what should be included and how it should be written is your own choise. Remember to write the logbook for yourself and not for anybody else.

Recommendations

- Mark your notes chronologically (note the date).
- Use a binder instead of loose papers.
- Always have the logbook available.
- Make generous notes.
- Write your name and address in the logbook.