EINDHOVEN UNIVERSITY OF TECHNOLOGY

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Author(s)	Danqing Liu Betty van der Ceelen Daian Saman

Final Report 6EMA62

Device integrated responsive materials

Department of Chemical Engineering and Chemistry

1. Introduction

This document contains a report of the implementation of the cross-disciplinary course **"Device integrated responsive materials"**; this report contains the evaluation of the first run of the course, based on this evaluation several improvements will be proposed and implemented for the next run of the course.

Our initial goals for 2025 in education can only be achieved by acknowledging, stimulating and providing incentives to our educational talent. Furthermore, the course **"Device integrated responsive materials"** brings our faculty a step closer to achieve TU/e initial goals. Therefore, the challenges and lessons learned from this implementation will be shared in one of our next Educational Days, in order to promote and stimulate other teachers to undertake more projects like this.

2. Background and project motivation

With rapid advances in science and technology, new functional/ responsive devices are emerging in our society with every increasing rate. For example, soft robotics which are constructed from compliant materials and can bend, deform and adapt their shape showing promising application in field of medicine, biomedical engineering and manufacturing. In virtual reality, communicative materials that provide feedback are required to make the virtual environment more realistic. Also, the dynamic environment where privacy can be introduced on demand is discussed. As we are now entering 5G communication, photonic data exchange technique are developing for ultra-fast data transfer. Smart devices are made from smart materials. However, traditional chemistry education focuses on molecular science such as synthetic organic chemistry. How to translate and magnify deformation and motion on molecular level to device function on macroscopic level is becoming important given the current development in technology and science. Therefore, the aim of the course is to fill the gap between molecular sciences and device engineering. In order to understand smart devices or develop smart functions, one needs to have combined knowledge on various fields. Chemistry is needed to synthesize and characterize functional molecules, applied physics is used to deduce the underlying principle, mechanical engineering involves in analysing and further enhancing the device performance, many devices are driven by electricity and therefore electric engineering is required, and of course all devices start with design. For these reasons, we propose a new cross-departmental course on 'device integrated responsive materials'.

The aim of the course is to bring together material properties and device design. It hereby fills the gap between molecular sciences (Synthetic Organic Chemistry, Physics of Soft Matter) on one hand and device engineering and applications on the other hand. The course will illustrate this by means of existing products, such as displays, smart windows, and microfluidic devices, and future developments such as soft robotics, electronic paper and interactive coatings and paints.

As such the course bridges the knowledge from different disciplines with aspects from chemical engineering, mechanical engineering, electrical engineering, physics and industrial design. Where needed an extension will be provided to the knowledge acquired in previous years in the present curriculum.

The course topics are in par with the research direction at TU/e: strategy 2030 to bring **multi-discipline sciences** together. The teaching method also aligns with the **'challenge-based learning'** at TU/e. The philosophy of the course is that students are learning from the expert by joining the lectures as well as learning by working on the projects and doing the experiments on their own. At the end, students will also make a step further from academia approaches towards industrialization to learn how the devices are massively produced.

Although primarily aimed for students of the department of Chemical Engineering and Chemistry, students from the other engineering sciences (electric engineering, mechanical engineering, and

applied physics) as well as Industrial Design will be stimulated to enrol. We are opting for stude nts with different backgrounds that are evenly distributed. During the course, students from different backgrounds will be grouped to complete assignments.

2.1 Alignment with strategy 2030:

2.1.1 Cross-disciplinary research and education

The course connect chemistry to other scientific fields, and link different sciences (chemistry, mechanical engineering, electric engineering and applied physics) together. It illustrates a path from molecular design, material formulation, device processing and characterization by giving the examples of the existing devices (displays), and the emerging smart devices (soft robotics, smart windows).

2.1.2 Challenge-based learning

Students with different background will be grouped to accomplish projects. In a typical project, students are expected to start with an original idea on device design, then they will make the devices in the laboratory with the help of teaching assistants, and eventually they will characterize the performance of the device. This in turn reflects the cross-disciplinary education as student group needs to acquire and master knowledge from various disciplines. Furthermore, students need to learn how to work and communicate with their peer-colleagues coming from different background.

2.2 Objectives and outcomes of the project

The teacher collaborated with the project team to:

- Design and implement a diagnostic test to determine the level of the students.
- Design and implement pre-knowledge modules for all involved departments.
- Design and implement a standard assessment in a cross-disciplinary learning environment.
- Design, plan and implement coaching sessions to guide students and teams on the project.
- Design, plan and implement lab sessions with hands-on support for students and teams.
- Plan the coordination activities between departments and Teachers.

Additionally, we would expect the following desired effects:

- We hope that this course can also inspire the lectures from other faculties on establishing cross-disciplinary education.
- The course will strengthen the collaboration between different departments within TU/e and eventually in a broader scope.
- In a longer term, the course should in turn promote the cross-disciplinary research at the university and deliver researchers that are prepared to challenge the cross-disciplinary research projects.

2.3 Risks and success factors

- The teachers should allocate sufficient time.
- The teaching assistants should have sufficient knowledge on the topic and timely guidance on the content.

- Standard evaluation criteria should be composed to standardize process and assure the grade being objective. Teachers, post-doc assistant will work together to formalize this.
- Prior knowledge on basic thermodynamics, polymer physics, polymer chemistry, and responsive materials will be available on the website before the lectures starts. Post-doc will help lectures to sort out materials.
- To guide the student groups throughout the project, each group is assigned with a mentor to provide sufficient and timely advice.
- TA will plan the lab work time and provide hands-on help to students with their experiments.
- 11 lectures are involved in the course. It is essential for lectures to have an overview on all the topics and promote a connection of a specific topic to the other topics. The post-doc will coordinate this.

3. Evaluation and results

3.1 Structure of the course

The course consists of two distinguish aspects: learning from the experts (lecture session) and learning by doing (practical session).

Lecture session: the course covers 11 topics ranging from existing technologies to emerging technologies and ends with from academic ideas to devices. 12 lecturers coming from different background including academia lecturers and experts from industry gave the lectures. The detailed course topics is given in the Appendix 1.

Practical session: 4-5 students formed a student team to work on a project. The topics were discussed in the lectures prior to the practical work. Student teams were given the option to choose their own topic of interest. Each team has an own mentor and two teaching assistants were assigned during the period of the course to guide and help all the students' projects.

Exam: There were several graders for the different components of the final grade; several teachers agreed in the grades of the teams for presentation, report and lab work. The final exam consisted of different sub-sets of questions per topic, which were provided by an expert in the field; therefore, the final exam comprised the most relevant topics of the whole course with questions appropriate to the level of the course. The components of the exam providing the final grade are:

- Presentation (15%)
- Report (15%)
- Lab work (20%)
- Written exam (50%)

3.2 Course preparation

Prior to the course, we organized special training with drs. Harry Wouw from Dienst Personeel en Organisatie to the teaching assistants. The training was designed to focus on the following aspects:

- Interview students to find out what they want to produce;
- Give them an advice about the most appropriate equipment and processing procedure to use;
- Demonstrate and explain the principle of this equipment or processing with special attention for safety matters or refer to an expert;
- Supervise the lab sessions in a proper way;
- Involve also quiet students in the group work;
- Grade each student individually during the lab work using a rubric.

The training was high valued by all participants who think it sheds light on how to work with students that might not completely understand their project. We are considering this training also to the next run of the course in 2020.

3.3 Results and conclusions

The evaluation of the course is carried out by several means. (**1**) Follow-up group consisting 6 students with various background (chemical engineering, physics, industrial design, mechanical engineering, mathematics) was formed to give timely feedback every three weeks during the period of the course. The responsible lecture (Danqing Liu), course coordinator (Daian Saman) and the quality assurance officer (Betty Ceelen) were present during the meeting. (**2**) Also, survey about the course was filled out by the students at the end of the course. (**3**) Lectures including guest lectures and co-lectures gave feedback on the course.

Based on the evaluation results, we conclude that overall the course is very well received by the students who value working in a multidisciplinary group for the project and learn various perspective of the technologies.

In summary:

- Students were highly motivated. The selection process ensures that only students who truly wanted to participate in this course were the ones selected. Additionally, student teams were given the option to choose their own topic of interest, this setup provided to students with freedom and independence to analyse which topic they were truthfully interested in.
- The lecturers find it is a pleasure and also a challenge to work with student team coming from different background.
- Teaching assistants are necessary for the course. Although the general goals/ topics are given by the lectures, teaching assistants help to fill out the details. Furthermore, teaching assistants play a main role in the lab work to guide the students with practical terms.

Suggestions to improve the course.

- Most students like the practical work especially in a multidisciplinary group. They express the wish to increase the ratio of lab work. Students suggest in the future extend the course divide it in two parts, a more theoretical part followed by the practical part.
  - This suggestion we should consider for further discussion.
- If the course kept the same, then the lecture hours might be shorten. The lectures should focus on the topics directly related to the projects, for example, in this quartile, soft robotics and smart windows. Other topics on displays and piezoelectricity might consider to remove.
- Students feel the exam load is somewhat heavy. Especially the written exam, we should consider either remove it or replace it with oral exam next year.
- Students mention that not everyone contributes fairly in the project team. We should take some measures to evaluate this.
  - We considered to create an evaluate form between peer students. But this needs further discussion.
- Both teaching assistants are coming from chemical background. We are considering to include a teaching assistant from mechanical engineering or applied physics.

- So far the facilities in the chemical engineering are used for students' projects. We should explore using labs/ equipment from other departments, e.g. mechanical engineering or physics next year. This can be also partially solved by appointing a teaching assistant from those department.
- We observed that the lecture on intellectual property rights is well received which inspires the students to consider the innovation items in their project. We consider encourage the students to write patent on their achievements in their projects in the next year.
- The lunch meeting of the follow-up group is very helpful. The lectures are encouraged to participate in this meeting next year.

3.4 Dissemination of the lessons learn

- Share the experience in the Onderwijsdag (education day at the CEC department)
- On request of the Teacher Support chain at TU/e
- On request of the 4TU committee

4. Appendix

- Follow up group meetings X3
- Survey
- Topics discussed in the course

Introduction	Materials processing
Liquid crystal displays	Smart windows
E-paper	Device design
Soft robotics	Upscaling
Material design from industrial perspective	Dielectricity
Intellectual property rights	Piezoelectricity

6EMA62 Device integrated responsive materials, meeting 1, 22 May 2019

Present: students, D.Liu, D.G. Saman Yan, E.M. van der Ceelen.

General

Students work on either Soft robots or Smart windows. This course fits in the 2030 MDP strategy.

Lectures

The lectures are interesting, however not all lectures are relevant for all projects. Danqing suggest to offer students web lectures for this course. The students present would like that because if there are web lectures you can choose which video is relevant for your course. Some lectures should stay, because students wouldn't like watch long hours of web lectures.

The content of the lectures was interesting and in a way students would like to get to know more about certain subjects, but there isn't enough time. Subjects named in the meeting:

- Some more Microsystems, to take it a step further
- Display could be less, although it was interesting
- The lectures about electricity were relevant, but for some students it had overlap
- A introduction about sensors would also be interesting, if there was more time

The 2 guest lectures were also interesting, but both lecturers used too much slides.

Laboratory work

In practice, the planed lab hours is not much, not all students have laboratory experience and therefore loose time with getting acquainted with working in a laboratory.

Before students start working in the laboratory it is important that students know what they are going to there. One of the groups had a meeting before they started to work in the laboratory, they suggest that it will be helpful when there is already time reserved for such a meeting preferably in the lecture hours, so everyone can attend.

Danqing what the students think about a slightly different set-up: first two weeks laboratory work for everyone, to get to know the basics, such as liquid crystals. After the basics students can go on with making a sample. The students present think that this might work.

Working in a multidisciplinair team

The students enjoyed working together with students from other departments. It was nice to hear different ideas from different angles, all students come with their own specializations and interests. For example students from Industrial design are interested in the final product, students from chemical engineering and applied physics are more interested in the science behind the product and less in the application.

The chemical engineering students in the groups know the most about working in a laboratory especially with practical things, such a cleaning and waste deposal.

It is valuable for the future to experience that each departments uses slightly different language and expressions. Mostly one of the students takes the lead regarding the terminology.

The students see the advantages for their future for this is what they are going to do when they are going to work whether it is in industry or in a PhD position.

The only point of concern is the planning; because the student are from different departments and have different courses scheduled it can be hard to arrange a meeting to work together.

The lecturers were also from different backgrounds, the lecturers from industry focusses more on applications which is different angle for some of the students. There were quite a lot of chemical engineering lecturers, for one of the chemical engineering students who attended the meeting this was fine, the other student would rather like to see more applications.

The number of lecturers was no problem for the students, there are more courses with multiple lecturers.

Assessment

This year there is a written examination, for next year Danqing wants to change that and do an oral examination.

The students feel that an oral exam would be more appropriate for this course because of the research nature of the course. For this year the students would like to have examples of examination questions because at the moment they don't what to expect and especially what they should do to obtain a high mark.

Scheduling

Now students have the lectures first, followed by laboratory work, this makes it sometimes hard to plan the laboratory work. Next year there will also be laboratory timeslot available at different times.

The course is scheduled in the fourth quartile which is rather late. The fourth quartile is less suitable for the applied physics students because the fourth quartile is attended for going abroad.

For other departments the fourth quartile is for optional courses which makes for example quartile 2 and 3 less suitable.

If the written examination is cancelled there will be some more time available, maybe double timeslots could be used for this course, to have more time available. This might be hard to arrange because of the shortage of available spaces for education.

Maybe in future this course could be extented. If the course could be extended then it could be one large course or the course could be split in two parts, a more theoretical part followed by the practical part of the course.

Anything else

It is not always clear who students can contact if they would do something extra or outside the standard facilities. For next year the lecturer will appoint a teacher assistant who can help students with this.

Action points:

For this year:

- The lecturer will provide practice examination questions

For next year:

- Next year there will be an oral examination instead of a written examination
- A slightly different set-up to have more room for the laboratory work, with first two weeks of basic laboratory work and some of the lectures available as web lectures
- There will be time reserved for the first meeting of the groups before they start the laboratory work.
- Timeslots for laboratory outside the scheduled hours for the course

Points to consider for the future

- Spreading the course over 2 quartiles
- Make it an extended course over two quartiles
- Make it two independent parts, first theoretical part followed by a practical part

6EMA62 follow-up group 2

The interaction between the different groups.

For most groups there was not much exchange, although some groups did have some interaction.

This meeting took place in the 6th week, Danqing asks the students if they will be able to complete this course in time. There will be sufficient time, but the students would have liked to have had more time available for the project.

The students had sufficient knowledge, and if there were any questions lecturers were nearby and the chemical engineering students are acquainted with the lab and the people. There was also a former graduation thesis available.

The students liked working in the chemical lab and the students experienced it as different from working in for example the physics lab. Mostly not all group members are present at the lab at the same time, only if it needed, for example if there is something specific to be made.

Working in a multidisciplinary team

Danqing asks what is important for the students to successfully participate in this course.

For one of the students present it is important to be patient; not all group members have the same background and knowledge, when you explain something make it as easy and clear as possible and don't expect that they understand it at once. The other students agree: communication is the key word.

In this course the students noticed that students from different background have a different view, the chemical engineering angle is different from an electrical engineering view.

The lecturers present ask about the design side, is a design student able to contribute sufficient to the projects?

One of the students present is an industrial design student, he felt that for some projects it is difficult to contribute as a designer. One of the students has shown an example of a moving wire. The trouble with the wire is, that after ten times it doesn't move anymore. For a designer it would be difficult to come up with an application because for now there is no end-product. The technology is there but it isn't ready for designing yet.

He has noticed that for this project it is useful to have a basic understanding of the chemical processes, but he also thinks that not all designers will be that interested in the chemical process.

His suggestion for the future would be to give future design students the opportunity to choose the project which would suit best themselves.

Dr. Broer used to work in the industry and the designers he dealt with were there to give ideas and suggestions for applications.

The technical staff developed something and the designers came up with ideas to use the new technology. With the suggestions for applications, problems will occur which need to be solved before it can be used in practice. With that knowledge the technical staff moved on, it was a reciprocal process. For example with the moving wire; the designers will give suggestions to use it, the technical staff will try to solve the problem with the limited ability to move.

Danqingadds that at the moment aren't that many applications for Soft Robotics, and before it can be used hard robotics will have to be involved, but there could be applications for which hard Robotics can be too hard.

Any other businesses:

The students would like to know what to expect for the final exam:

Danqui will provide examples but for now students can expect questions about:

- Laboratory
- Microprocessing
- Smart windows and soft robotics
- And a design question

Students don't have to have much knowledge about the other group projects; for the exam only basic knowledge is needed.

6EMA62 follow-up group, meeting 3

The quartile is coming to an end and at the moment most students are busy with analyzing data. They now sometimes discover that some data wasn't as expected, and with hindsight that they have made mistakes. It is more than just obtaining data.

Danqing points out that it is expected that faults will be made, it is part of the learning process and this will also occur in real life, the difference is that in real life there is time to redo the measurements or adjust them. For this course there is a limit of time and this is not possible.

At the moment most students are practicing their presentation. The presentation is supposed to be 25 minutes, the students feel that is a bit too much because there is not much to be told about the results. Most students now have a 10-20 minutes presentation

Both the teacher support, Daian and Danqing don't agree. Danqing believes that 25 minutes is not that long, Students have to show first a bit of the background explain what your project is about why you show for something and not for something else, justify your choices explain your results, although they might faulty or different than expected and tell what you've learned.

The basic background is the same for everybody and the students don't feel it is necessary to tell about the background again, one of the groups only shows a small recap. One of the other group doesn't have that much specific background, because their topic was quite new.

Daian points out to the students that they have to add reflection on the process. Students need to add some reflection about their learning moments, what went wrong, what should have been done differently. The presentation is not as much about what you have achieved but, about what the students have learned. The result is not the real goal of the presentation, the learning curve is.

The students suggest for next year to have two presenters, because 25 minutes is a bit much for 1 person.

Agreements:

The lecturers will publish the requirements for the report on Canvas

To consider:

To have a minimum length for the presentations of 15 minutes

To add to the information on Canvas that reflection should also be part of the presentation

To have to students do the presentation instead of 1 student

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Survey results for the course

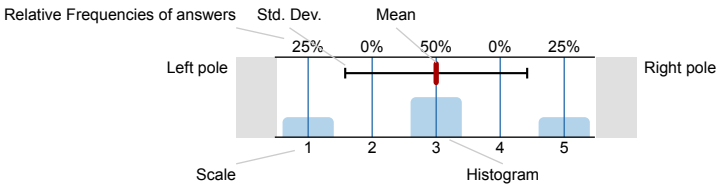
6EMA62 - Device integrated responsive materials 2018/2019 B4

Total number of recipients: 20
Number of responses: 8
Response rate: 40%

Survey Results

Legend

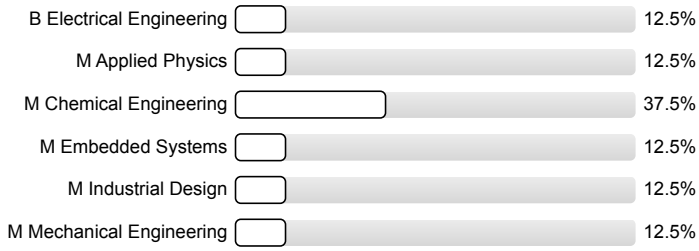
Question text



n=No. of responses
av.=Mean
dev.=Std. Dev.
ab.=Abstention

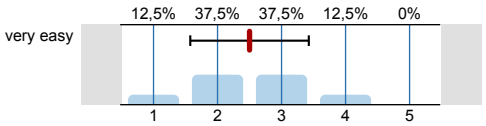
1. General Questions

1.1) Please select your bachelor's or master's degree program:



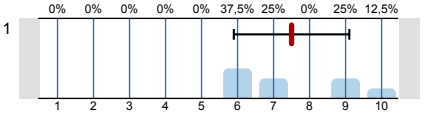
n=8

1.2) Overall, how would you describe the level of difficulty in this course?



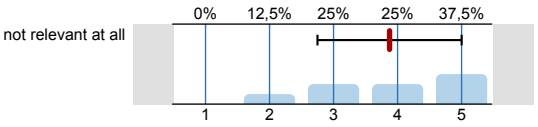
n=8
av.=2,5
dev.=0,9

1.3) On a scale of 1 to 10, how would you rate this course (with 10 being “excellent”) ?



n=8
av.=7,5
dev.=1,6

1.4) How relevant was this course for this study program?



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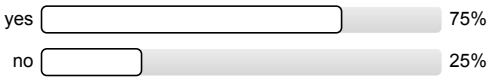
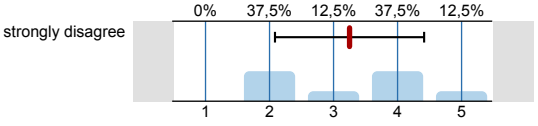
av.=3,9
dev.=1,1

1.5) Did you have sufficient prior knowledge and/or skills to follow this course?



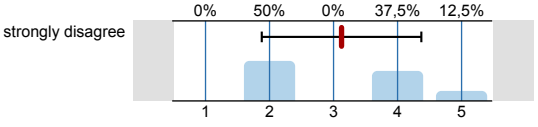
n=8

1.7) The educational setup (e.g. structure, content, teaching/learning methods, level, and coherence) worked well and was suitable for this course.



n=8
av.=3,3
dev.=1,2

1.8) The course was well organized (e.g. availability of lecturers/supervisors, availability of information, scheduling, and planning).



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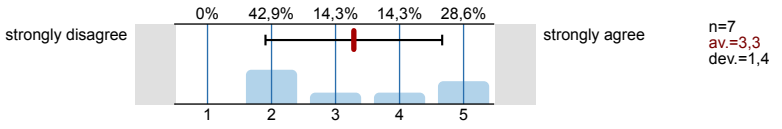
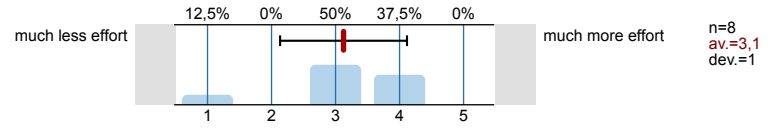
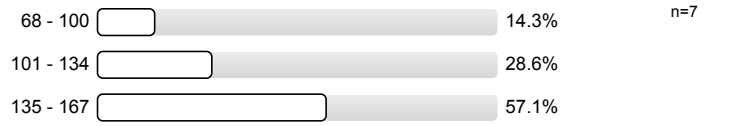
1.9) The course material was clear and motivated me to study for this course.



1.10) The effort I applied to complete this course corresponds with the number of credits (5 ECTS = 140 hours).

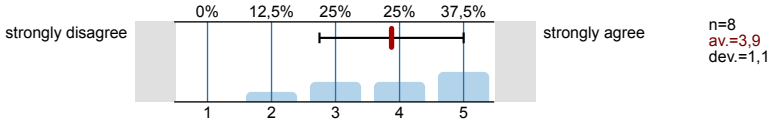


1.11) How many hours did you spend on this course in total? Note that 1 ECTS is equal to 28 hours of work.



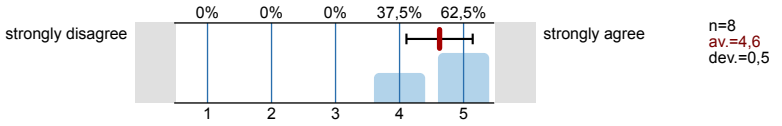
2. Educational form: Lecture

2.1) The lectures were clear and effective.

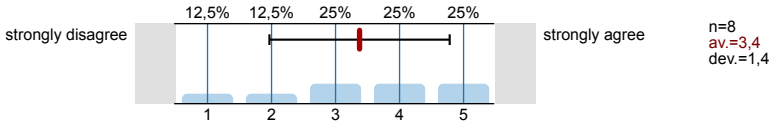


3. Educational form: Practical work

3.1) This educational form contributed to my understanding of the subject matter.

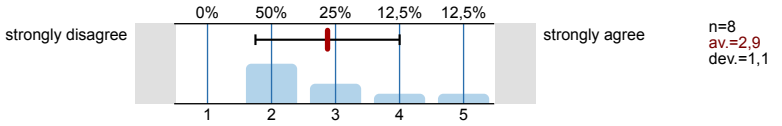


3.2) The feedback I received was sufficient and useful.



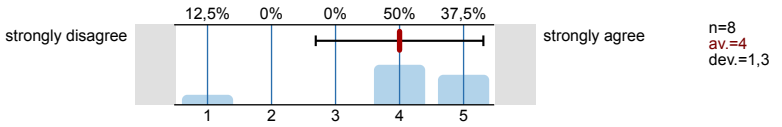
4. Assessment as a whole

4.1) The assessment of this course was appropriate (e.g. methods used, relevance and clarity of the questions/assignments).

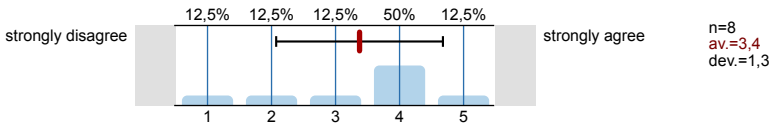


5. Assessment (Final Test): Written examination

5.1) The final test of this course was appropriate (e.g. methods used, time to finish, relevance and clarity of the questions/assignments).

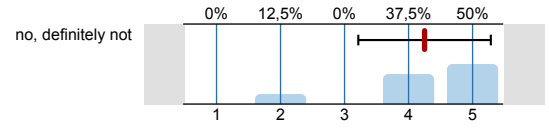


5.2) The final test accurately represented the subject matter.



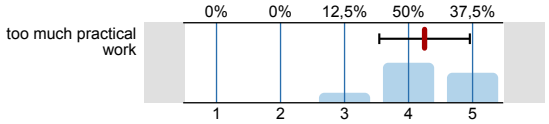
6. Teacher Selection

14.3) Did you receive sufficient support/coaching in this project? (e.g. did you knew who you could contact, was the help you received adequate, were you motivated by the input of the lecturers etc)



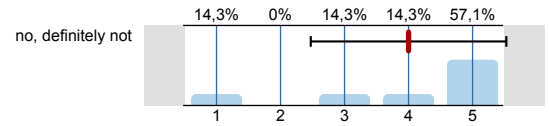
n=8
av.=4,3
dev.=1

14.4) What is your opinion about the amount of lectures compared to the amount of practical work in this course? ("3" is just right)



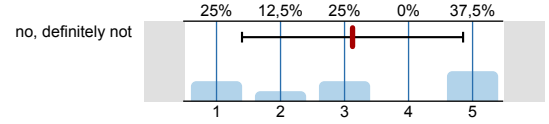
n=8
av.=4,3
dev.=0,7

14.5) The multidisciplinairy nature of this course added value to my study program



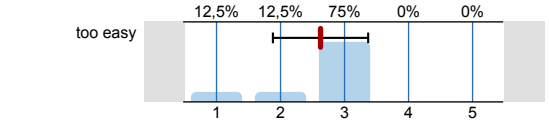
n=7
av.=4
dev.=1,5

14.6) All group members brought their own expertise with them and made a useful contribution to the project



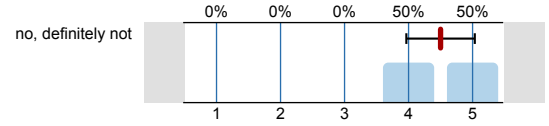
n=8
av.=3,1
dev.=1,7

14.7) What is your opinion about the level of difficulty of the final exam? ("3" is just right)



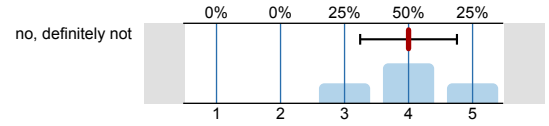
n=8
av.=2,6
dev.=0,7

14.8) Did you enjoy the course?



n=8
av.=4,5
dev.=0,5

14.9) Are you satisfied with the knowledge you've gained in this course?



n=8
av.=4
dev.=0,8

Comments Report

1. General Questions

1.6) If your answer above was no, please explain:

- It's a course provided by the Chemical engineering department, and is about liquid crystals, which I have no relevant knowledge. I just select this course as my free selection, as I want to know something I didn't know before.
- The chemical stuff was sometimes to specific for not having a very scientific background

13. Open-ended Questions

13.1) What did you like about this course/project?

- I chosen this course purely because that I would like to learn some responsive materials. And in this course, I get both theoretical knowledge and hand-on lab experience about liquid crystal. I think this course reached my expectation.
- I liked the course because i thought you could learn a lot from the students from other faculties. However, the lectures where mostly company-focused and the project was very chemical. The chemical students really had to lead the project. The other students helped where they could. It wasn't really a benefical way of teamworking for both.
- I liked the way you had to work with different disciplines to get to the final project. The cross-departmental course definitely thought me to think in a different way
- I liked working together in multidisciplinary groups a lot. The guest lectures were interesting as they have a whole different story and perspective. In general it was a course I enjoyed taking!
- I really liked the practical work in the lab.
- The different perspective for technology
- The project should be the major part of the course, as this is what it is really about and how it is advertised. For me, learning some of the larger scale/older techniques for closing the gap with my micro/nano knowledge was very interesting.
- the multidisciplinary team work

13.2) What would you like to improve in this course/project?

- For the chemists this course was really easy, try to make it more difficult for them. The communication to the students was often late and unclear. For next year make a study guide with all info (planning, the way the different parts are set up, deadlines etc). Try to minimize changes when the course has started and when it changes send a message. (This was not done with the change in exam setup which was confusing for the people that were not present in the follow up group). The change came very late, i was happy with it, but i had already been studying quite a bit and this was just lost time now.... Try to add a peer review system to the project work.
- I would OR focuss on the project for the course, OR focus on the exam. Because it had a lot of lectures and the spare time was filled with practicum, it hadn't really a point to focus. I personally would do lectures in the first 2 weeks, and after that focus on the practicum. Because there wasn't so much time at the lab, and the practicum had to be finished early to give the presentation you have to work very quickly. We couldn't give a good answer at the research question, due to time reasons. You had only the time to measure a few samples.
- Increase the amount of practical work and skip the written exam.
- Maybe decrease some lecture content, which is too much. And for the lab sesseion, maybe prepare proper chemical compount ahead of time, as most students care more about the application of the chemical compounds.
- More project hours, fewer lectures, as many of them were not relevant for the project.
- No examination needed....
- The exam was not needed, we had a presentation report and exam+ lab work for 5 credits
- While the course was very interesting, it is clear this is the first year of them giving this course. It was a bit messy in the organization, and time seemed too short to deliver a proper final product

14. Course specific questions

14.10) Thank you for completing the survey so far! If you have any additional comments about any of the course components (e.g. the lecturers, the teachers (interim) exam, study material etc.), you would like to share , you can place them here. We really appreciate your feedback!

- The course schedule was not visible in our personal schedules. Try to fix this for next year to avoid confusion. I really enjoyed the course. Good luck organizing it next year!
- When labtime started, there where always people that are late. I would get consequence for that, because it can really annoy the group (and the people that are there on time).