INTERDISCIPLINARY CASE-BASED TEACHING OF ENGINEERING GEOSCIENCES AND GEOTECHNICS

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ABSTRACT

The complete restructuring of the 4-year Professional Bachelor programme in Arctic Technology at the Technical University of Denmark in 2007 has provided the perfect framework for implementing CDIO-based courses with focus on a holistic and interdisciplinary approach.

In this paper we present our experiences over four years teaching one such course, *11821 Site Investigations*. The goal is to teach the students to conduct site investigations in connection with construction work in arctic areas. It covers technical skills and competences from several different branches of engineering in an interdisciplinary course. Course elements comprise the understanding of relevant geological processes and deposits, tools to examine and map these deposits, as well as the use of Global Navigation Satellite Systems (GNSS) and Geographical Information Systems (GIS) to collect and organize spatial information. Environmental aspects and cultural heritage screenings are also covered as well as group work and report writing. The course is constructed around a real world case, e.g. the construction of a specific road segment, and the students have to produce a realistic site investigation report based on field and laboratory investigations as well as theoretical considerations.

The interdisciplinary structure of the course combined with the real-world case and just-in-time teaching applied has resulted in more motivated and hard working students, and as teachers we receive better and more interesting reports to read. However, the inter-disciplinary and practically oriented nature of the course poses special demands on teachers and instructors. Among these are more complex coordination among course elements, and difficult adaption of the curriculum.

Based on written and oral feedback and our own teaching experience, we conclude that the new course form is an efficient and challenging way to teach engineering with good learning outcome over a broad spectrum of the CDIO syllabus.

KEYWORDS

Geoscience teaching, real-world case, interdisciplinary, personal and interpersonal competences, just-in-time teaching.

INTRODUCTION

Arctic Technology is a 4-year Professional Bachelor programme at the Technical University of Denmark (DTU). The programme is special in many ways; primarily because the first 1½ years of the education, the students live in Greenland, where they study at the DTU micro-campus at the Building and Construction School in Sisimiut. Since most teachers come to Sisimiut from Denmark to teach the students for periods of typically 1-3 weeks, courses have to be taught intensively, one course/subject at a time, rather than in parallel as is the practice at the main DTU Lyngby campus in Copenhagen.

These boundary conditions have supplied perfect framework for implementing CDIO based courses, when the education was completely restructured in 2007 [1]. The restructuring allowed us to change the focus from mainly core scientific and technical knowledge to a holistic and interdisciplinary approach focussing also on the personal, professional and interpersonal skills.

In this paper, we present our experiences obtained over four years of teaching the course *11821 Site Investigations* with a case-based, interdisciplinary, hands-on and just-in-time teaching (i.e. lectures are given when they are needed for the students to continue with the case, thus assuring they are highly motivated for learning) approach.

BACKGROUND

Previous to 2007, courses given at the Greenland campus were small intensive courses of 2-3 weeks duration; or longer courses split up into teaching sequences of 1-2 weeks distributed over the 3 semesters. The courses were organized and based on subject matter and professional content. Typically one teacher was in charge of and teaching each individual (part of a) course.

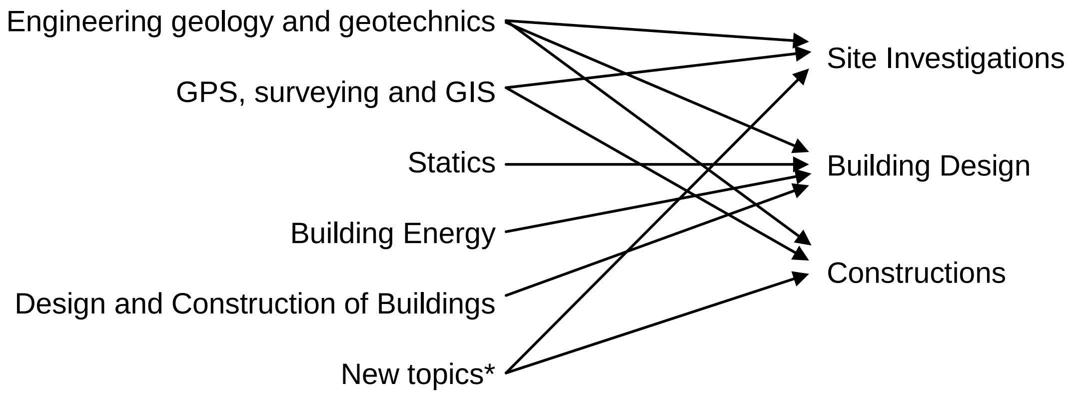
The reason for restructuring the curriculum was the study habits of the Greenlandic students, which were not suitable for the standard way of teaching at DTU. The students had a low activity in class, often did not show up and were accordingly in danger of dropping out – not because of academic skills but low engagement.

With the restructuring of the education [1], focus was put on producing an active learning environment initiating high motivation based on real-world cases. Therefore most of the new courses were implemented as "composite courses" – i.e. large interdisciplinary courses organised by teacher teams with teachers from all the fields of engineering involved in a course. Experts from the teacher team are present in turn, organising field work and giving lectures comprising all technical and professional elements necessary to solve the problems encountered during the work with the case. The students work in fixed groups during a course, and the students are assessed partly on individual work during the course and partly on the group report handed in at the end of a course.

This resulted in a major reorganization of courses and course elements as exemplified in Table 1 for courses related to geosciences. The focus has therefore changed from *the subject* of pure knowledge and technical skills to *the objective* of producing a certain outcome, e.g. a site investigation report, a proper foundation design, or a properly dimensioned road embankment.

Table 1
Example of relationship between old and new courses

Old Courses	New Courses



*) Environmental screening and cultural heritage screening was introduced in the Site Investigations course, and road construction in the Constructions course.

This shift in focus induces better motivation, as the students experience the applicability of what they learn immediately, and additionally it becomes more obvious to include in the curriculum not only the mathematical/technical skills, but also the professional, personal and social competences as specified in the CDIO syllabus [2].

The composite courses are designed to fully live up to the relevant CDIO standards [3] at the course level:

Standard 1 - *The Context*: The use of real-world cases put the education in the relevant context right from the start.

Standard 2 - *Learning Outcomes*: All learning objectives are specified in the course descriptions and given in an operational form with action words [4]. And the formal course descriptions are now being supplemented by additional detailed information on implementation and progression in personal, professional and interpersonal skills.

Standard 6 - *Engineering Workspaces*: The DTU micro-campus in Greenland is situated right in the relevant engineering workspace for arctic engineering. The arctic conditions are just outside the door, and Sisimiut is a small but self-sufficient town in most ways due to the difficult infrastructural situation in the Arctic. Thus the societal side of engineering is there as well – and we use it intensively in the composite-courses.

Standard 7 - *Integrated Learning Experiences*: This is exactly what composite-courses are about – integrating all the engineering disciplines necessary to solve a specific case problem.

Standard 8 - *Active Learning*: The inductive teaching method and active learning environment is based on cognitive constructivism as exemplified by experiental learning methodology with the basic assumption that skills and understanding cannot be given to students – they must be obtained through experience [5].

Standard 11 - *Learning Assessment*: The learning is assessed as part of the teaching – not as an add-on after the course de facto is finished like the case with a traditional written exam; i.e. both formative and summative assessment is obtained. The learning is assessed on selected work during the semester and the final report – this is in full agreement with the axiom of constructive alignment [6].

DESCRIPTION OF THE COURSE "SITE INVESTIGATIONS"

The course *11821 Site Investigations* is a 12½ ECTS points course of 7½ weeks duration from the beginning of September to the end of October, and is given as the very first course on the Professional Bachelor programme in Arctic Technology.

The overall goal of the course is to teach the students to conduct site investigations in connection with construction work in arctic areas, especially Greenland. It therefore covers technical skills and competences from several different branches of engineering in an interdisciplinary course.

The learning objectives of the course as specified in the official DTU course description are given in Appendix 1. With respect to the CDIO syllabus, we target specifically the following paragraphs of section *2 Personal and Professional skills and attributes*: *2.1.2 Modelling – 2.2.3 Experimental Inquiry – 2.3.1 Thinking Holistically.*

Although the objectives for personal, professional and interpersonal skills are stated rather superficially in only one out of 10 learning objectives, they are not later added appendixes, but integrated into the course objectives from the start. As part of the iterative convergence of the course elements, the learning objectives will be reworked for the next update of the course description with more specific objectives especially for team work.

Course structure, teaching styles and core technical content

In this course, the students acquire an understanding of the relevant geological processes and deposits, as well as tools to examine and map these deposits with a technical focus. They are taught the use of Global Navigation Satellite Systems (GNSS) and Geographical Information Systems (GIS) to collect and organize spatial information in relation to the investigations. The students are also introduced to environmental aspects and cultural heritage screenings.

The course is developed based on an inductive approach, where a case problem (based on a real situation) is introduced in the beginning of the course. Each individual part of the course uses the case problem for application of the methods taught. The idea is that the students develop an understanding of the case problem and techniques to explore/solve it throughout the course, and the main evaluation of the student learning process is the final project report as well as evaluations in the individual parts of the course. The content of this report is developed throughout the course, as the main content and theoretical background is written/prepared during each course element. In the last part of the course, some time is allocated to ensure continuity in the report between the different elements, and develop conclusions, perspectives etc. Figure 1 gives a general overview of the course structure, where topics one by one are treated theoretically, in parallel with work on the case project, field work, analyses and interpretation.

The case is always based on a real-world problem, preferably a real project from the municipality of Sisimiut, e.g. site investigations for the construction of a road in a specified area of town. In this way we impose realistic conditions on the project. All groups work with the same case, but are assigned different parts of the field site for their data collection. In their final reports they will, however, synthesize and discuss the entire collective data set. In this way they are capable of covering a relatively large area and get a realistic picture of the variability in the geological conditions.

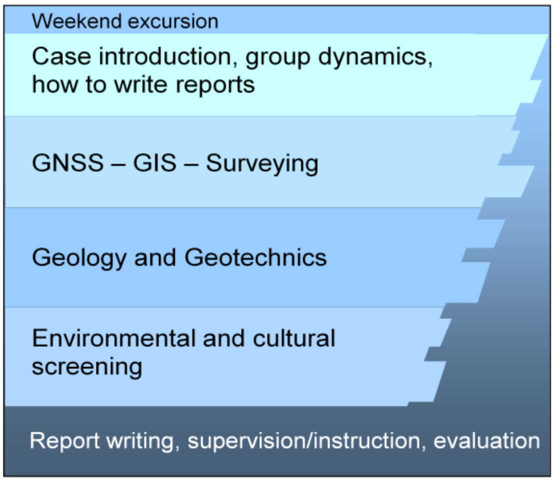


Figure 1: Overall structure of the course. The case problem is used throughout the course as the fundamental scenario, and elements of the final report are produced successively throughout the course.

To give an example of the type of case problem the students are faced with, we present the 2008 project case. The students were asked to produce and report on a site investigation for a new road connection between two parts of Sisimiut. The road was to pass a sedimentary area affected by the presence of permafrost (ice rich soil). Based on the planned placement of the road (information supplied by the municipality), the students were to produce a digital elevation model of the area through GNSS measurements and evaluate surface elevation changes relative to previous models. They were to conduct geological investigations through the drilling of boreholes along the suggested road, and classify obtained samples and measure their mechanical properties. Geophysical measurements were to be collected using geoelectrical and georadar methods in order to provide 2D information about geology and permafrost distribution. They were asked to evaluate the environmental impact of the future road connection as well as to identify any remains of historical interest that might be present in the affected area and which would have to be handled during the construction phase.

Due to this being an early course in their education, and on an introductory level, the students were closely guided in the planning of the field work. However, all measurements, laboratory analysis, data treatment, modelling, interpretation and synthesis were done autonomously by the students under our supervision.

Figure 2 shows an example of the synthesis of an engineering geological model for the area the road is to pass through, produced by students on the course.

After the completion of the student reports, the road project has become a reality, and at the time of writing, the construction of the road embankment is well under way.

Using the inductive form in this way at the course level, and using a real-world problem/case to illustrate the different topics in the course seems to work very well. First of all, it motivates the students, who often comment that it is more interesting working on a realistic project than constructed class exercises. However, it also ensures that the students work with the subject matter at several learning levels (knowledge, application, evaluation, synthesis – with reference to Bloom's taxonomy [8]), depending on the project formulation.

An anchor point of this course is that the students work with real data, and should collect those data themselves. This gives them hands-on experience, and a better understanding (and thus motivation) of what they are doing and why. As in this course we are working with

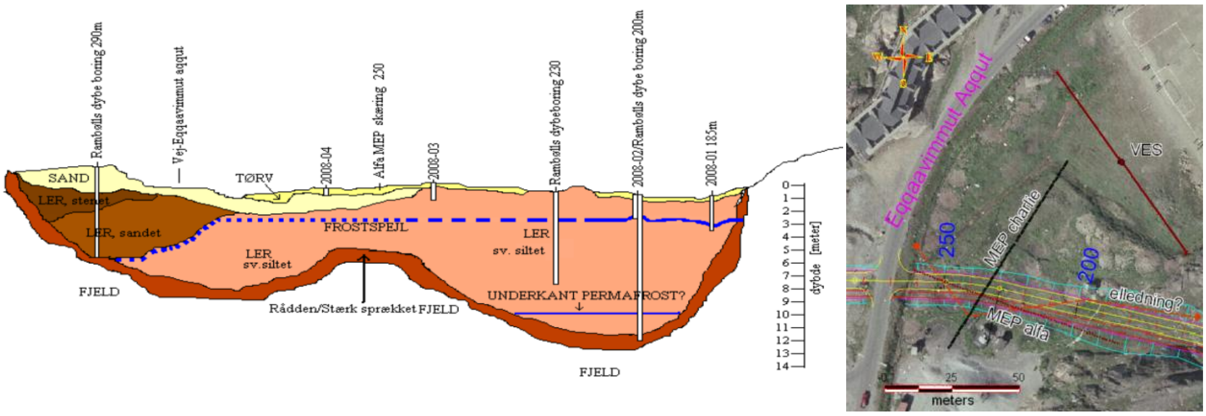


Figure 2. Examples of illustrations from a student report. Left: an illustration of the engineering geological model synthesized from classification of samples from shallow and deep boreholes combined with interpretation of geophysical measurements. Right: outcrop of a map produced to show the projected road trace in combination with the location of geophysical measurement profiles. [7]

very practical geoscience related subjects, nature is our engineering workspace. In order to understand the technical challenges and solutions to foundation and construction problems – the target of a site investigation – the students must first obtain an understanding of the geological materials and the processes that created them. We mediate that by taking them out in nature, to show them the different processes in action. In that respect we are fortunate to have the campus situated in Greenland. We have all the relevant processes – glacial, fluvial and marine – occurring within reach of a short excursion.

Measurement techniques and instrument handling (geophysical measurements, drilling of boreholes, GNSS measurements for creation of a Digital Elevation Model, etc.) is taught in the field, at the case-site, on real world complex geology/topography. Drill cores and samples are brought to the laboratory for further analysis by the students. Supporting lectures are given throughout the course on a just-in-time basis. However, the practical and experimental nature of the course allows for much direct interaction between teachers/instructors and the students and thus is automatically driven by student needs.

Including field work as teaching method is potentially very rewarding for a practical course like this, however it may also pose some dangers and require very meticulous planning. Bottlenecks may easily occur in a suboptimal reality, where multiple equipments are not always available, and different measurement systems operated simultaneously may bias the measurements or render them unusable. Furthermore, working in nature, all parameters are not as easily controllable as when working in the lab, and thus unexpected results are often encountered. If this is not dealt with and explained “real-time” without delay in the field, students feel frustrated, unsuccessful and lose motivation. These are the great risks and challenges when including field work as teaching method. However, when overcome, we find that this is one of the most rewarding teaching styles for this type of subject. Field work should of course always be followed (possibly the next day) by data treatment and interpretation/analysis, and some kind of presentation, either as classroom discussion, oral presentation, or as part of a report to assure sufficient student reflection. This last step is the most difficult and most often neglected in experiental learning [5] – if not sufficient care is put into this, the experience obtained by the practical work will not be transformed into understanding.

One of the main challenges is to get the team of 7-8 teachers from four different departments and an external expert to work as a team. Teachers from DTU are not used to this kind of cooperation. It takes careful planning, a lot of discussions and strict coordination to make the course a whole - freely flowing from one teacher to the next. But it is possible with engaged teachers, and makes in the end quite a positive difference to both students and teachers.

Personal, professional and interpersonal competences

We find it very important to support the students in their personal development and supply them with the proper tools to successfully complete the main tasks of the case study. In compliance with the CDIO syllabus [2], we therefore focus much time and attention to certain aspects of the professional, social and personal competences described in the syllabus.

The following list comprises such skills and competences which have been selected for special attention in course *11821 Site Investigations*:

- Teamwork and project management [CDIO syllabus 3.1]
- Communication skills and report writing [CDIO syllabus 3.2 (& 3.3)]
- Critical thinking skills [CDIO syllabus 2.4.4]

<u>Teamwork</u>: We wish the students to develop skills of constructive teamwork. This has en extra dimension here, since we form groups to include Danish as well as Greenlandic students, so intercultural problems also have to be addressed. For this reason, a certified coach is part of the teacher team, and helps the students understand group dynamics and write up group contracts, regulating their relations and work ethics.

<u>Project management</u>: Although we guide the students through their project work in this course and follow them closely, we intend them to start familiarizing themselves with the necessity of proper project management in order to produce an acceptable result within a limited time frame.

<u>Communication skills and report writing:</u> Writing a large and complex technical report is very different from the essay-style reports often used in the high school. As this is the first course, we train the students in writing basic technical reports throughout the course, with exercises targeted specifically at report writing skills, as well as individual and group assignments on technical matters to which the students get specific written or oral feedback, also related to the reporting style. Especially some of the Greenlandic students usually have great difficulties communicating in the Danish language, especially when it comes to professional terms. They are therefore offered help from a teacher specially trained in teaching Danish for foreigners to rewrite non-acceptable answers.

<u>Critical thinking</u>: Students coming from the high school need to adjust their mindset to solving real life problems instead of learning facts and methods. This part is addressed by using a real life construction project as basis for their project work. As the problem is not constructed, we don’t know the answer in advance and this forces the students to develop critical thinking skills in their work on solving the problem. This is stimulated through continuous discussions and feedback on their work.

STUDENT EVALUATION AND QUALITATIVE FEEDBACK

At the end of all courses at DTU, students are filling in the standard DTU course evaluation questionnaire, which has three sections: A general evaluation of the course, an evaluation of each teacher and a section for additional comments. The students give *11821 Site Investigations* good evaluation as shown for the last year in Appendix 2, but this quantitative evaluation will only be commented very shortly here, since a more elaborate evaluation have been applied as discussed in the next section. The qualitative results from the third section will be discussed later.

The most interesting questions in section 1 are the first 'I think I learn a lot in this course' and the last 'Overall I think this course is good', which on a score from 1 (completely disagree) to 5 (completely agree) in 2010 scored respectively 4.4 and 4.3, which are very good scores. The most difficult question for a large interdisciplinary course is 'I think the teacher makes a good connection between the different teaching activities', which with a score of 3.9 is more than acceptable.

Quantitative evaluations

For two years we have implemented an extended evaluation scheme based on the Course Experience Questionnaire (CEQ) [9]. The questionnaire has been adapted to the DTU course environment by LearningLab DTU: Two of the original categories – *Appropriate assessment* and *Emphasis on independence* – has been replaced by two new categories – *Generic skills* and *Motivation*. In this process the number of questions has also been reduced from 30 to 22, and the questionnaire augmented by an extra question to evaluate the use of Information Technology (IT) in the courses – see Appendix 3.

The modified survey's questions are answered on a scale from 1 to 5, where 5 means "I definitely agree" and 1 is "I definitely disagree". The answers are processed according to the topic of the individual questions and collected in five groups evaluating different elements of the teaching, where a higher score is better. The results for 2008 and 2009 are summarized in **Error! Reference source not found.**, and are all above average. Especially high scores were given on the *Good teaching scale*, the *Motivation scale*, and *IT*.

Table 2
CEQ Evaluation of Course 11821

	Average	2009	2008
Number of questionnaires		14	19
Good teaching scale	3.84	3.94	3.74
Clear goals scale	3.44	3.43	3.44
Appropriate workload scale	3.32	3.55	3.10
Generic skills scale	3.75	3.93	3.57
Motivation scale	3.92	3.97	3.88
IT (The use of IT in the course)	3.99	3.93	4.05

The lowest scoring scale is the *Appropriate workload scale*, indicating that the curriculum for the course maybe was too large, especially in 2008. Due to the time needed for working with the cases and teaching/acquiring new skills such as efficient report writing, less time is available for traditional class teaching. It is quite a complex process to adapt an entire education to a new structure, due to the inter-course dependency of skills and competences. And even after four iterations, there is still room for improvement.

Qualitative evaluation and feedback

The third section of the DTU standard evaluation has room for both positive and negative feedback and suggestions for improvements. Furthermore an oral evaluation session has been conducted every year by the head of the study program, without attendance of the course teachers to allow the students to speak more freely of any problems and concerns.

Both written and oral feedback about the course is in general very positive. Phrases such as "Exciting and challenging" and "I learned a lot" are typical throughout the evaluations.

The practical focus is mentioned as a motivating factor. Both in terms of the overall case, to which each course element is attached:

> *"Good coherence in course – logical progression"*, [oral feedback, 2010]
> *"Good balance between practice and theory"*, [DTU course evaluation, 2010]

and with specific reference to practical exercises and excursions in the field and the main fieldwork collecting data for the site investigation report:

> *"It was good that we conducted fieldwork, it made it more interesting"*, [DTU course evaluation, 2009]
> *"Nice with exemplification through field excursion"*, [written feedback, 2008]

Although the course comprises six elements taught by different teachers from four different engineering departments (one is external lecturer), it is our intention that the course should be coherent and appear as one continuous progression to the students. The feedback from the students indicate that we have come quite far in this regard, but there are still weak points in tying some of the elements properly together. Unfortunately, these points are very apparent to the students, who also reflect on them in their feedback:

> *"The course structure is good, but I miss a little more coherence between the geodesy and geology elements"*, [DTU course evaluation, 2010]
> *"It felt like the teachers had not discussed the purpose of some of the exercises, and some things were repeated in connection with GPS/GIS"*, [DTU course evaluation, 2010]

This is certainly a point to improve on in the future.

In the oral feedback session of 2010, one student commented that the teacher in each element ought to do more to "try to prepare for the next theme". We find that this is an excellent observation. Although the course responsible has been the recurring face throughout the course, starting the course, teaching a central part approximately half way through, and rounding off the course, it is not possible to have him/her available at all transitions during the course. There has probably been a tendency for the individual teachers to focus more on their individual elements – following the coordinated strategy the team has prepared together for that particular case – and not so much specific focus on tying that element on to what came before and what will come after.

From time to time we also observe critique of deliberate choices made in the course planning. Often this critique is caused by the different teaching style the students have been used to during secondary and high school:

> *"At times, too many things were going on at the same time, which meant that each student used much time on some parts, but did not become acquainted with the other experiments"*, [DTU course evaluation, 2010]

Since we are treating a real world complex case, many things need investigation. We have tried not to sacrifice the complexity of the real case for simplicity in teaching and coordination in class. The course has thus been structured such that in each group they will have to distribute tasks among the group members, working in pairs or individually on some parts and then report the findings back to the group. It is actually one of the learning objectives of the course to introduce them to efficient team work in an engineering setting. This is the reason for having a certified coach in the teacher team. The involvement of the coach is seen by the students as good support:

> *"Good thing with the coach – although too short"*, [oral feedback, 2008]

Acquiring such skills early is of course of great importance, as many of the courses they will encounter throughout the education is based on group work, and not least because once educated engineers, the students will have to engage in interdisciplinary cooperation with people of many different professions.

TEACHER'S EXPERIENCES

One of the experienced teachers involved in the education from the very beginning, has been teaching geodesy and GNSS both before and after the restructuring of the courses. He pinpoints the very difficult problem of restructuring a well established curriculum in engineering education:

> *"However, the composite courses introduced a serious pedagogical problem … because the elements needed for site investigations, which with the new structure of the education were to be taught in the very beginning of the education, were the most theoretical and calculation-heavy within our profession"*, [Keld Dueholm, personal comm., 2011]

With the same overall time frame for the education, and more focus on the professional and personal skills, there has been an ongoing discussion about the influence on student learning:

> *"Since the time available for the technical content was significantly reduced in connection with the composite courses, I never reached the same technical depth and engagement with the students as previously"*, [Keld Dueholm, personal comm., 2011]

This is backed by Lars Stenseng, who has been teaching the geodesy and GNSS element for the past 2 years following Mr. Dueholms retirement. He explains that due to the focus on process, there is less time for the traditional teaching of core theoretical basis, compared with similar courses at DTU [Lars Stenseng, personal comm., 2011].

He concludes that although his students in Denmark obtain a deeper theoretical understanding, it is still not sufficient to be operational for e.g. research or development purposes. On the other hand they lack the practical knowledge and experience that the students obtain in the composite courses, through the interdisciplinary application in the case project work.

> *"I think this way of teaching better fits a professional bachelor engineering education",* [Lars Stenseng, personal comm., 2011]

Especially this positive effect on the learning process through the link of different disciplines is noticed by many teachers in the team:

> *"I see the composite courses as a good tool to create a link between the subjects under the teaching conditions present in Sisimiut"*, [Keld Dueholm, personal comm., 2011]

"The fundamental case in the course gives a better more natural flow and progression in the learning process", [Lars Stenseng, personal comm., 2011]

The results are quite evident to another teacher, who has been teaching the engineering geology and geotechnics element from the start of the education, at which the location of all samples and geophysical measurements were measured with measurement tape relative to recognizable points in the terrain, in order to produce crude maps for the reports:

"The reports we have received from the students in the last few years are much better than previously. The students show deeper comprehension of the technical content, and their writing and data presentation has also improved. This is a direct effect of linking the geotechnical and the GNSS and GIS elements in one course", [Niels Foged, personal comm., 2011]

However, he thinks that the cultural heritage and environmental elements are not in their full context coordinated with the above topics and may complicate the students understanding of societal relations to the factual investigation results.

The course structure and especially the basic case project also improve the students' ability and willingness to take charge of their own work:

"With the new course structure, the students have become better at taking initiative of their own field measurements – based on a predefined plan", [Niels Foged, personal comm., 2011]

We speculate that this is due to the understanding of the overall context of the measurements they are to perform. This is a general observation not only linked to the field and laboratory work, as the teacher in the GIS element explains:

"The case project makes the students more mature in their approach. I see them more motivated - They just want to learn!" [Darka Mioc, personal comm., 2011]

The ones who are there, she goes on to add, because there are problems with students not showing up for classes. Such problems, however, are even bigger in Denmark, she concludes. This difference is probably due to the practical and real world case used in Greenland:

"The way we teach in Greenland is much more motivating than how the same topics are taught in Denmark. It is being used in the end – the road actually gets built!" [Darka Mioc, personal comm., 2011]

"Even those who don't really care for a specific element, become motivated to learn through the further application in other course elements", [Lars Stenseng, personal comm., 2011]

One challenge with intensive, full time, courses is that there is no time for self reflection, and thus it is more difficult to obtain the intuitive understanding of the technical content. This is typically observed in the short intensive three-weeks courses that are part of the DTU Denmark semester plan, but a real-world approach could help the student to think out of the box:

"It is my impression that the more practical approach based on a real-life case helps the students obtain the understanding in spite of the time pressure." [Lars Stenseng, personal comm., 2011]

Although the technical content is not directly comparable to what Darca Mioc teaches in Denmark, it is evident from her comments that she is happy with the course and the student outcome:

> *"The course is really very good! … I feel comfortable teaching in this way … I think they learn much more in Greenland"*, [Darka Mioc, personal comm., 2011]

CONCLUSIONS

During restructuring of the Professional Bachelor programme in Arctic Technology in Greenland, the CDIO concept was incorporated in the course structure, and educational elements of individual courses were reorganized to form interdisciplinary courses on specific engineering relevant topics.

The interdisciplinary structure of the course *11821 Site Investigations* combined with the real-world case and just-in-time teaching applied has resulted in more motivated and hard working students. They attend classes and practical sessions, and they put much energy in the writing of their final projects. It has also introduced personal, professional and interpersonal competences in a natural way. As teachers we receive far better and more interesting reports to read, due to the fact that several tools are combined to provide a better understanding of a certain problem.

The transition from traditional theoretical and topical courses to interdisciplinary and practically oriented courses pose special demands on teachers and instructors/tutors, among these are more complex (and very important) coordination among different course elements as well as adaption of the curriculum.

We have presented student evaluation data available from a CEQ-like test as well as qualitative statements from the standard DTU course evaluations and individual student feedback to support our findings and conclusions. The feedback confirms that the new composite course form is an efficient and challenging way to teach engineering with good learning outcome over the broad spectrum of the CDIO syllabus.

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BIOGRAPHICAL INFORMATION

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APPENDIX 1

Learning objectives for course 11821 Site Investigations:

A student who has met the objectives of the course will be able to:

- Plan, carry out, process and evaluate GPS-measurements in connection with site investigations.
- Work with datum, map projections and control points in Greenland, and be able to transform coordinates between the systems.
- Use GIS to collect data from field measurements, maps and orthophotos and to organize presentation of data.
- Describe relevant geological processes and deposits and develop engineering geological models as a framework for site investigations.
- Complete engineering geological classification of soils and rocks, as well as measure and describe the strength characteristics.
- Conduct simple geophysical investigations and apply the results in relation to geology, geotechnics and permafrost.
- Conduct a simple environmental investigation in an arctic area.
- Recognize signs of prehistoric remains.
- Describe forms of cooperation, draw up a group contract and write a basic technical report that complies with formal demands.

APPENDIX 2

Results from official DTU course evaluation 2010 (section 1, scale from 1 to 5):

22 students have answered the evaluation form (out of 22 attending the course)

1.1	I think I am learning a lot on this course	4.4
1.2	I think the teaching method encourages my active participation	4.2
1.3	I think the teaching material is good	4.1
1.4	I think that throughout the course, the teacher/s have clearly communicated to me where I stand academically	3.8
1.5	I think the teacher/s create/s good continuity between the different teaching activities	3.9
1.6	5 points is equivalent to 9 hrs./week (45 hrs./week in the three-week period). I think my performance during the course is (5 more – 1 less)	3.6
1.7	I think the course description’s prerequisites are (5 too low – 1 too high) [There are no prerequisites]	2.9
1.8	In general, I think this is a good course	4.3

APPENDIX 3

Questions asked in the modified Course Experience Questionnaire, and abbreviation of the appropriate scale to which the result is assigned:

1.	This course was intellectually stimulating	MS
2.	The aims and learning objectives of this course were NOT made clear	*CTS
3.	The teacher normally gave me helpful feedback on my progress	GTS
4.	It seems to me that the syllabus in this course tried to cover too many topics	*AWS
5.	The teacher showed no real interest in what the students had to say in this course	*GTS
6.	I have usually had a clear idea of where I was going and what was expected of me in this course	CTS
7.	I have found the course motivating	MS
8.	It was often hard to discover, what was expected of me in this course	*CTS
9.	This course helped me sharpen my analytical skills	GSS
10.	This course made me feel more confident about tackling new and unfamiliar problems	GSS
11.	This course has stimulated my enthusiasm for further learning	MS
12.	In this course it was always easy to know the standard of work expected from me	CTS
13.	The course helped me to develop the ability to plan my own work	GSS
14.	Where it was used, Information Technology has helped me to learn	ITS
15.	I was generally given enough time to understand the things I had to learn in this course	AWS
16.	The teacher made a real effort to understand any problems and difficulties I had in this course	GTS
17.	This course has stimulated my interest in the field of study	MS
18.	This course developed my problem-solving skills	GSS
19.	The teacher has put a lot of time into comments (orally and/or in writing) on my work	GTS
20.	In this course it was made clear right from the start what was expected from me	CTS
21.	The teacher worked hard to make the subject of this course interesting	GTS
22.	The volume of work necessary to complete this course means that it cannot all be thoroughly comprehended	*AWS

Abbreviations:

GTS	Good Teaching Scale
CGS	Clear Goals Scale
AWS	Appropriate Workload Scale
GSS	Generic Skills Scale
MS	Motivation Scale
ITS	Good use of IT scale
*	Indicates that the result is reversed before it is added to the appropriate scale.