INDUCTIVE TEACHING BY INTERACTING WITH CDIO-PROJECTS

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ABSTRACT

The paper describes experience with the use of CDIO-project results in a traditional course, taught for both those students who will attend the relevant CDIO-project and those who will not. The classic course in concrete structures interact with the CDIO-project, both by using project results as a inductive starting point for the traditional teaching and by creating a basis for a CDIO-project, which runs parallel to the last part of the course. The use of such results as a starting point for the teaching allows the teacher to start with simple observations from tests and to build the general understanding of the assumptions and formulas on such observations, thus linking objective, simple observations to the classic theories. The use of the results improves both the students understanding and motivation and illustrates the clear link between the reality and the theories and formulas. This has also the added benefit that it proves to the students that their project results are valuable and useful, which again increases motivation in the course and in the projects.

KEYWORDS

Inductive teaching, experiments, videos, students own contributions.

INTRODUCTION

Teaching engineering students involves a number of activities: We have to teach them both the basic technical design rules and theories and teach them to think as engineers and scientists. This is quite a challenge and we constantly try to update, improve and adjust our teaching to reach these goals as well and as efficient as possible.

An investigation [1] of the candidate's competences was recently carried out by questionnaire; send to over 300 of the newly graduated candidates (1-5 years experience) from the Department of Civil Engineering (BYG) at the Technical University of Denmark (DTU) and over 300 of their employers. This investigation did also ask which competences should have the highest priority and revealed that both the students and their employers report that the

1. Engineering thinking;
2. Basic engineering knowledge;
3. Personal skills;
4. Communication skills;

are the most important competences for an engineer. This fits quite well with the points identified by MIT [2] in connection with the development of the CDIO concept.

DTU provides a very good basis for the basic knowledge and the specializations as DTU offers a large number of courses and more or less predefined projects (totalling 1175 [3]) in addition to the bachelor and master projects. These courses are divided into basic BEng-courses (225 courses, all in Danish), basic BSc-courses (125 courses, all in Danish) and advanced courses for the MSc and PhD-students (775 courses, all in English) in order to provide both basic and advanced courses and projects.

A large part of these courses are, however, traditional deductive courses and may not train the engineering thinking as efficient as possible. The introduction or strengthening of CDIO-activities combined with a more inductive approach should have a very good chance of improving the student's ability to think as engineers.

A problem observed [4] is that the students find it difficult to have an overview of how the content of a specific course relates to the rest of their study and their later work as engineers. The students reach the overview towards the end of their bachelor study, but it would be an improvement if the student could get such an overview earlier and easier.

Students and teachers agree that the student's motivation and understanding increases significantly, when the use and relevance of the session and the course is easily realised by the students. BYG aims therefore at linking the classic theories in the sessions and courses to real structures, observations or experiments, in order to facilitate the overview, to encourage the students to use their logical sense and (of course) to improve the students motivation.

The use of CDIO projects and use of inductive teaching are main parts of this strategy, as this paper will illustrate with the inductive use of CDIO-project results in teaching of classic courses in basic concrete structures.

THE STUDENTS AND THE TEACHERS

BYG offers a total of 140 courses annually, taught either once or twice a year, in order to support our 9 different building engineering educations. It is therefore necessary to describe the bachelor student population and also the teacher team for the teaching of concrete structures.

Our many different students

BYG is responsible for the teaching 5 building engineer educations on the bachelor level and 4 educations at the master level (www.dtu.dk). The bachelor educations include:

1. BEng-students in the field of Building Engineering, starting in the spring;
2. BEng-students in the field of Building Engineering, starting in the autumn;
3. BEng-students in Arctic Engineering, starting in the autumn;
4. BEng-students in Architectural Engineering, starting in the autumn;
5. BSc-students in Civil Engineering, starting in the autumn.

The BEng-students have fixed combinations of courses during their first four semesters, after which they have a mandatory semester in a company. The Building Engineering students will often work on constructions sites, either as contractors or consultants, whereas the Architectural Engineering students tend to work for the design companies, architects or consultants. The students have then two additional semesters at DTU to finalize their education.

The Arctic Engineer students follow courses on Greenland for the first four semesters, where teachers from BYG in Lyngby are flown in to teach for shorter, intense periods in cooperation

with BYG's permanent staff at Greenland. These students have an additional four semesters at DTU in Lyngby with a mandatory semester in a company and graduates as Building Engineers with the additional skills and focuses, required for the Arctic Engineering.

The BSc-students in Civil Engineering follows a more flexible list of courses and are required to study six semesters in order to reach the bachelor degree.

All these educations require a total of 180 ECTS-point and will differ from each other, both in the list of courses and in their focus.

However, certain technical areas are tough to all at approximately the same stage in their education and this means that all are taught basic concrete structures in the courses 11311 (BSc), 11746 (BEng-Building and Arctic) and 11941 (BEng-AE) [3] in the spring semester, normally corresponding to their fourth semester, but in some cases in their third semester – but always prior to the BEng students mandatory fifth semester in a company.

Our concrete structures teaching team

The teaching of the three basic concrete structures has jointly been carried out by a group of teachers, who have also been involved in the CDIO-projects to some extend:

A. An older, very experienced professor, (over 30 years at DTU).
B. A newer professor, educated in Germany and USA, (over 5 years at DTU).
C. A newer professor (the author), educated in Denmark, (over 5 years at DTU).

The number of different educations makes it a challenge to teach the students efficiently, but it provides a very good opportunity to test new teaching approaches on different groups of students. The teachers A and B have used the traditional, deductive approach, whereas teacher C (the author) has moved towards a more inductive based teaching approach, using contributions from the student CDIO-projects or other student projects.

INDUCTIVE TEACHING OF STUDENTS

The author has introduced systematic use of samples, test specimens, photographs and videos in the teaching of concrete structures. The intention was to illustrate the use and the relevance of the topics taught to the future work as an engineer and to strengthen the link between the theories being taught and reality (as observed in tests or even better in collapses of actual structures) and to increase the student motivation, as an increased motivation leads to better learning.

This has later been improved so lectures are initiated by a small demonstration, by tests or by videos showing e.g. the failure mode, dealt with in the lecture, as this has been found to provide a good basis for the understanding of assumptions and estimations. The material used was at first been supplied by the industry, but has more recently been obtained from student's or past student's lab exercises, CDIO-projects and later bachelor or master projects.

The use of the material in the inductive teaching can best be illustrates through the steps in Kolb's classic learning circle [5], as this will be a simple way of illustrate the thinking and the students involvement.

Kolb's learning circle

The results from the CDIO-project 11702 Beam Testing, where the students cast and test concrete beams are used for the session on deflections and cracking and also for the

session on bending moment capacity. The use of this follows Kolb's well-known learning circle [5] of why, what, how and what-if through the lecture and the exercises.

Figure 1. Test set-up for the concrete beam with student marking the cracks (traditional)

Step 1: Why

Teaching engineering students usually includes teaching the students to evaluate and estimate the structures performance, as e.g. deflections and load-carrying capacities. In the field of concrete structures, we do of course have design rules and theories and formulas for estimations and these have always been verified by substantial amounts of testing, (just as student projects often carry out testing as documentation in their projects).

Figure 2. Extract from video available at YouTube [6], showing beam behaviour at failure.

The students tested beams and produced a video recording of the test. The video has been stored at YouTube [6] and allows the actual bending failure to be observed, just as frames may be extracted from the original video and shown in Figure 2. Several of the tested beams are also kept available for inspections and discussions in the auditorium.

The video shows that such a failure mechanism needs to be considered (just as other videos show why those other failures need to be considered as well).

Step 2: What

The video shows clearly what is happening in the failure mechanism. It illustrates the plastic behaviour of the reinforcement (yielding is required to create the large cracks); just as it shows the plastic failure of the concrete in the compression zone and in which areas and directions you may utilize the strengths of the concrete and the reinforcement.

The video and the beams illustrate in a very simple manner a number of the assumptions for the classic theories and encourage the students to form an opinion, based on their own observations (and it is the author's impression that this approach makes the theory a lot simpler to understand, than the classic deductive approach).

Step 3: How

Based on the video, the test beams present in the auditorium and the screen capture in Figure 2, it is possible to make a simple engineering estimate of the capacity by analyzing the failure mode as shown in Figure 3. The formulas derived in this manner are identical to those used for normal concrete, although modifications are required for more special concrete types.

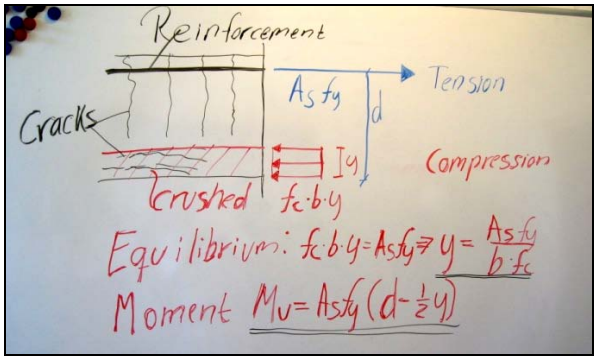

Figure 3. Analysis of failure mechanism.

Additional test data available may be used for estimating the capacity of this beam and provides a good opportunity to stress the fact, that there are variations in geometry, material strengths and beam capacities – even for identical concrete mixes and identical beam geometries (with so many students doing CDIO-tests, you will have variations – just as you have it on the construction site).

Step 4: What if ?

The session on bending moment capacity has until this point dealt with the observation and analysis of the observed failure in that actual beam (autopsy style). We proceed after this to establish the limitations to the model based on theory already known by the students and our autopsy of the beam.

We work at this stage already on the what-if angle: What if we change the strengths, the geometries etc. and we generalize the simple estimations to the theories required to cover all the bending designs.

It needs also to be said that the lecture is followed by theoretical exercises in the same four hour session, where the students estimate beam capacities, check conditions etc. The courses are normally followed by project work outside these courses, which either run in parallel with the courses or in the following semester.

Student response

All courses and involved teachers at DTU are evaluated in questionnaires by the students towards the end of the course, just as the students may comment on the course, the teaching and the teacher. The evaluation of the teacher includes three important statements:

1. I think that the teaching gives me a good grasp of the content of the course;
2. I think the teacher is good at communicating the subject;
3. I think the teacher motivates us to actively follow the class;

to which the students can choose one of five answers: 1) Agree totally; 2) Agree; 3) Neutral; 4) Disagree; or 5) Disagree totally.

We can compare the classic deductive approach to the inductive approach through the standard evaluation [7] of the teachers (Deductive = teacher 1+2, Inductive = teacher 3), in order to evaluate the differences in student's motivation, the students understanding of the topics and their motivation.

Table 1
Student response to statement: "I think that the teaching gives me a good grasp of the content of the course"

Group	BSc-CE		BEng-B		BEng-AE		All	
Approach	I	D	I	D	I	D	I	D
Agree totally	34%	11%	56%	25%	45%	10%	47%	18%
Agree	44%	39%	35%	38%	45%	30%	39%	38%
Neutral	17%	34%	7%	22%	5%	20%	11%	26%
Disagree	3%	13%	1%	5%	0%	35%	2%	11%
Disagree strongly	2%	3%	0%	9%	5%	5%	1%	6%

Table 2
Student response to statement: "I think the teacher is good at communicating the subject"

Group	BSc-CE		BEng-B		BEng-AE		All	
Approach	I	D	I	D	I	D	I	D
Agree totally	46%	11%	67%	25%	75%	5%	60%	18%
Agree	37%	33%	23%	41%	20%	14%	28%	35%
Neutral	14%	34%	9%	16%	0%	43%	10%	26%
Disagree	2%	17%	1%	7%	0%	19%	1%	12%
Disagree strongly	2%	5%	0%	11%	5%	19%	1%	10%

Table 3
Student response to statement: "I think the teacher motivates us to actively follow the class"

Group	BSc-CE		BEng-B		BEng-AE		All	
Approach	I	D	I	D	I	D	I	D
Agree totally	42%	9%	64%	20%	55%	10%	55%	15%
Agree	41%	23%	24%	41%	40%	14%	32%	31%
Neutral	14%	50%	10%	20%	0%	38%	10%	33%
Disagree	3%	14%	2%	11%	0%	33%	2%	15%
Disagree strongly	0%	3%	0%	9%	5%	5%	1%	6%

The Tables 1 to 3 presents the answers from app. 200 students from the three main groups of students (BEng Arctic listed under BEng-B), just as the Figures 4 to 6 present the average of all the students' responses.

It is clear from this that the students appreciates the more inductive approach, that it gives them a better grasp of the course content, makes it easier to understand the teacher and that this approach motivates the students to active follow the class.

One of the most interesting observations here is probably that the inductive approach with a combination of observations and theory is a success with all the different types of students: This indicates that it should be implemented in a larger number of courses.

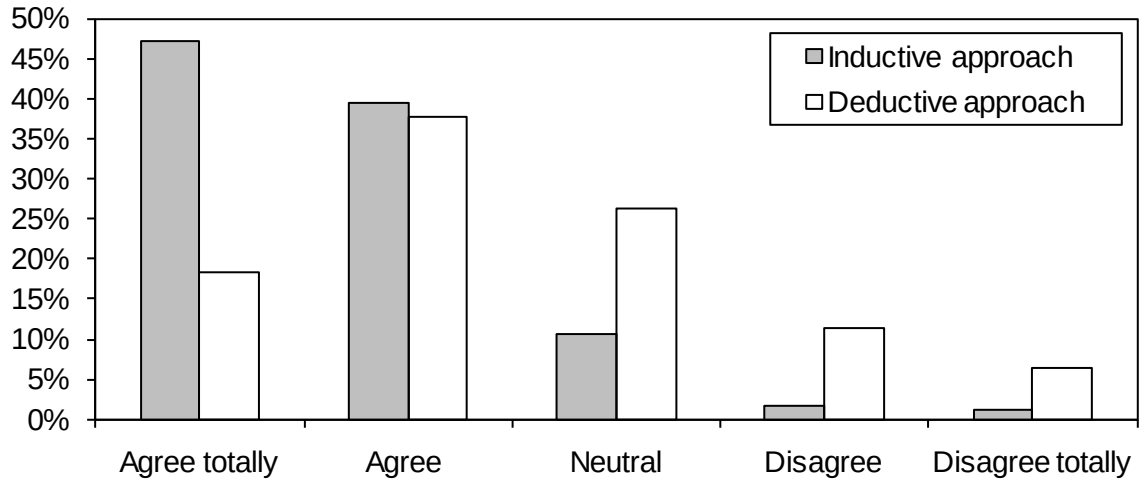

Figure 4. Student response to statement: “I think that the teaching gives me a good grasp of the content of the course” – all groups

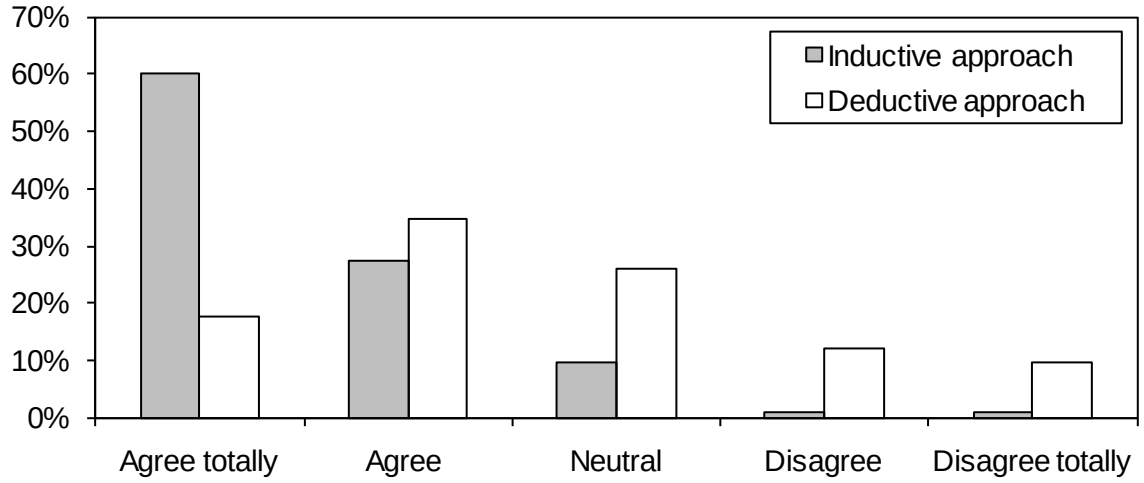

Figure 5. Student response to statement: “I think the teacher is good at communicating the subject”– all groups

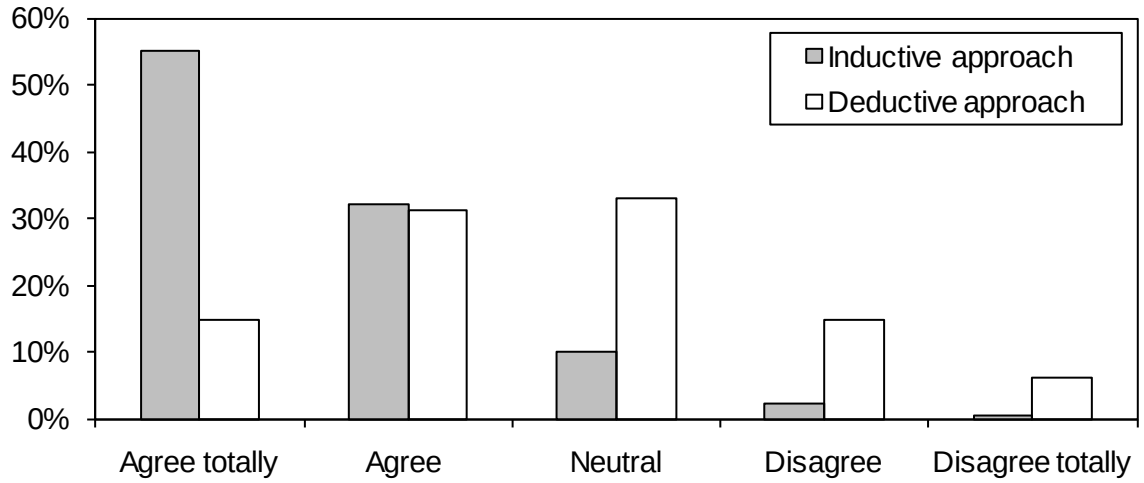

Figure 6. Student response to statement: “I think the teacher motivates us to actively follow the class – all groups

INTERACTION BETWEEN COURSES AND CDIO-PROJECTS

The semesters at DTU are divided into 13 weeks of teaching in a number of courses, followed by examinations over a few weeks and followed by a 3 week period, where the students work with one project or one course full time.

The basic concrete courses are taught in the 13 week period in the spring and will be combined with the CDIO-projects in different ways for the different student groups

1. BEng-students in Building Engineering, starting in the spring: This group will have a CDIO-project 11702 dealing with casting, testing and analyzing concrete beams during the last half part of the 13 weeks period at their semester. The concrete course teaches beam theory and design during the first half part of the same 13 week period. The students will follow 11742 in the following semester and have their semester in practice in the fifth semester.
2. BEng-students in Building Engineering, starting in the autumn: This group has a large CDIO-project 11742 Design of Structures in the 13 week period, parallel to the concrete structures course (but it may be changes so that project runs over both the 13 weeks and the 3 weeks period, as this would enable a better project). These students will have their semester in practice in the following semester.
3. BEng-students in Arctic Engineering, starting in the autumn: These students are few up to now and attend the teaching at DTU (courses and projects) as a part of either group 1 or 2 above.
4. BEng-students in Architectural Engineering, starting in the autumn: These students have a CDIO-project 11945 on Sustainable Design during the 13 week and 3 week period in which they to some extend use the results of the concrete structures course, but with a strong focus on energy. DTU is, however, strengthening the focus on sustainability in all courses, including the concrete structures courses and an improved interaction is expected.
5. BSc-student in Civil Engineering, starting in the autumn: These students have a CDIO-like project 11691 on Integrated Design, including an initial design of the concrete structures. This project runs during the 13 week and 3 week period.

It need to be stressed, that on top of all the CDIO-projects, all students at the BYG are offered a material technology course with testing of materials, including traditional testing of reinforcement bars and concrete cylinders, just as bachelor students are offered experimental work each semester.

These interactions are not always easy to arrange, however, cooperation between the many CDIO-projects and the classic courses is a benefit to all. The reported experiences show that both types of teaching can be improved by cooperation, where the courses support the CDIO-projects and these projects in return use the content taught in the courses as well as produce additional teaching material for the courses.

CONCLUSIONS

It can be concluded that the introduction of inductive elements in the classic courses in concrete structures is a clear success, both in aspects of student motivations and in the actual understanding of the topics.

It is also the author's impression that use of the students – or other students – own results, samples, videos etc. is much more convincing and motivating than use of more professional videos and tests, produced by professors and professional photographers. This type of teaching material obtained from students seems actually to appear more genuine and

convincing and it proves to the students, that their work is appreciated and used, which again improves the students motivation.

Using results from CDIO-projects in the supporting courses is also an efficient way of creating cooperation between the CDIO-project and the traditional courses: cooperation is after all a situation, where both parties benefit. This will both create a better cooperation among teachers and enable the traditional courses renewal through a steady flow of additional teaching material, created as one of the results of the CDIO-project.

REFERENCES

[1] Christensen, B.L. and Hoffmeyer, B.: "Ingeniørkompetencer i det første job (Engineering competences in their first job)", LearningLab at Technical University of Denmark, September 2009.

[2] Crawley, E.F.: "The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education", CDIO, 2001 at http://www.cdio.org/files/CDIO_Syllabus_Report.pdf

[3] DTU course database at DTU's webpage at http://www.kurser.dtu.dk/search.aspx

[4] LearningLab: "Evaluering af bacheloruddannelsen Byggeteknologi (Evaluation of bachelor education Building Technology)", LearningLab at Technical University of Denmark, January 2009.

[5] Kolb, D.A.: "Experiential learning: experience as the source of learning and development", Englewood Cliffs, New Jersey: Prentice Hall, 1984.

[6] Video library page for ConStruct2800Lyngby available at YouTube at http://www.youtube.com/user/ConStruct2800Lyngby#p/a

[7] DTU Course evaluations F2009-F2010 for 11311, 11746 and 11945, available from DTU CampusNet

Bibliographical Information

Per Goltermann is a professor at the Department of Civil Engineering at the Technical University of Denmark. He has an MSc.C.E. degree and a PhD degree from the university and has worked for more than 20 years as a consulting engineer in the Ramboll-group, dealing with design, reconstruction, supervision, material optimization and deterioration as well as litigations in the fields of concrete structures. He has been project leader of a number of R&D projects in cooperation with the industry and international experts. He has worked as a professor at the university for more than 5 years and is study leader, study board chairman at the department as well as chairman of the national code committee on lightweight concrete structures, of national code coordination committee, of a CEN-standardisation working group as well as chairman of the Danish Concrete Society's committee for educational seminars and excursions for the society's members and chairman of the Nordic Concrete Associations network for educators in the field of concrete structures.

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