

## Development of Evaluation Procedure for Effective Implementation of Cdio

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# **DEVELOPMENT OF EVALUATION PROCEDURE FOR EFFECTIVE IMPLEMENTATION OF CDIO**

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## **ABSTRACT**

One of the challenges in modern engineering education is the demand for teaching of high quality where the subject is presented in an interesting and engaging way. By integrating and involving the students in the teaching process, the learning can be increased. At the Technical University of Denmark (DTU), the CDIO approach was started in the autumn of 2008 in the process of reforming the engineering education in order to educate the students to become more effective engineers. One of the goals is to effectively implement CDIO practices and reduce time for implementation. One of the ways to do this is to evaluate the students' view on the CDIO learning environment.

In order to get a high response rate from the students, it was decided to make the first student evaluation of the CDIO learning environment as a two page inquiry form with 16 questions on the front page and possibilities for individual comments on the reverse side of the page. In addition to the paper inquiry form there was the traditional electronic inquiry at the CampusNet. The two forms show significant difference in response rate since the paper inquiry form gave a response rate of 84% (=100% of all students attending the presentation day) compared to only 45% at the electronic inquiry at the CampusNet – giving the paper inquiry form a far more representative value.

Altogether, this material has given the CDIO staff very good material for the evaluation of the CDIO Design Build course and input for improvement and effective practices. In general the results show a very high satisfaction with the Design Build course and the students like the practical approach in the CDIO concept. The students are very committed and the course motivates them for added interest in studying constructional engineering.

## **KEYWORDS**

Design Build course, evaluation, inquiry form, paper inquiry form, effective implementation

## INTRODUCTION

Earlier the traditional standard format for lectures was a 45-minute teacher monologue. Research showed that this kind of teaching had a number of weaknesses, and there was a need for supplementing the lecture in the form of student activities [1] [2] [3]. Human beings are not able to keep the attention for more than around 15 minutes before concentration falls dramatically [1]. For this reason, it is necessary to vary the lecture activities. In the 21<sup>st</sup> century there has been an increasing recognition that teaching needs to have a higher priority, and it is necessary to put a lot of effort in the process of increasingly improving the quality of the teaching [4]. The result of this is that teaching in modern engineering education demands teaching of high quality, and the theory has to be presented in an interesting and engaging way. One way is to integrate and activate the students in the teaching process, and in this way the students can learn more.

The semester at DTU consists of a 13-week period prescribed for 5 ECTS courses, a two-week exam period and a three-week period prescribed for 1 ECTS course, usually as a more practical course, where parts of the theory from the 13 week period is used. At the Technical University of Denmark (DTU), the CDIO approach [5] [6] was started in the autumn of 2008 in the process of reforming the engineering education in order to educate the students to become more effective engineers. This paper deals with evaluation of the first CDIO course in the autumn 2008 in the first semester at the Department of Civil Engineering. CDIO is introduced as a Design Build course.

## DESIGN BUILD COURSE

In the “Design Build course” the students had to build a model house. The demands concerning the house were that it had to be built in scale 1:20 as a model of a realistic house and had to be tight. In addition, it had to include a measurement unit, which could be connected to an outside measuring instrument. All the houses were placed on a plate of polystyrene in order to make the heat loss negligible.

Each group of students as part of the CDIO process had to design a house and from this implement the best solution chosen from a free focus area. This could, for example, be the best insulation, the most untraditional shape, alternative building materials or the most original house. After the model house had been constructed, the student had to operate it by measuring the heat loss for one month and compare these results to theoretical calculations of heat loss of the model house based on methods they had learned in a parallel course. The total calculated heat loss was calculated per Kelvin temperature difference in order to be able to compare theoretical results with measurements.



Figure 1. Students working on the model house – left. The final model of a house – right

## QUESTIONNAIRE

For the last 12 years, the students at DTU have evaluated the courses they have attended. For the last 7 years this has been done electronically as an integrated part of the CampusNet computing and course administration system. The electronic evaluation system at DTU has been described in a former paper at the 1<sup>st</sup> CDIO conference [7].

One of the important reasons for creating an evaluation system of the engineering education system is to get an idea of how well the defined goals and objectives are met. By doing this kind of evaluations year after year, it is possible to get a relative quality measure for the teaching systems over the years. This evaluation can take place on several different levels, where one of them will be on course level. By introducing the electronic evaluation system on our CampusNet, there has been opened up for a more detailed number of evaluation data, which makes it possible to extract important information. However the negative side effect is that the students get tired of all these evaluation questions of all the courses – six courses each semester making it up to 12 evaluation questionnaires a year. The response rate varies a lot from course to course, and in many cases the response rate is rather low, which means it will not be representative. One way to get around this would be to make it obligatory for the students in order to pass their exams that they have evaluated their courses. The risk of this would be that the response is unserious.

In this investigation of the Design Build course there has been a focus on a high response rate as close as possible to 100% for the students attending a special teaching day where the students presented their work. The students were informed in advance that they had to attend at this specific day. The inquiry forms were handed out to the students, and they were asked to fill it out right away and after having done so the forms were collected. The result from this was a 100% response rate of the students that were attending this obligatory presentation. The missing students were not included in the evaluation. It was discussed whether they should be contacted to fill out the enquiry form, however, in order to secure their anonymity, it was decided not to include them, since the answers could be affected by the fact that they could be recognised. If one looks at the response rate of the total number of students, only 16% were not included because they did not show up for this obligatory presentation. Since 100% of the students attending the presentation day answered the enquiry form, the results are very representative.

In addition to the paper inquiry form, there was also the traditional electronic inquiry at the CampusNet. The two forms showed a significant difference in response rate since the paper inquiry form gave a response rate of 84% (100% of all students attending the presentation day) compared to only 45% at the electronic inquiry at the CampusNet – giving the paper inquiry form a far more representative value.

The paper questionnaire was made as a two-page inquiry form with 16 questions on the front page and possibilities for individual comments on the reverse side of the page. The answers are ranked from very good (positive) (5) to very bad (negative) (1) in order to simplify the students' answers and be able to quantify the answers. As a consequence of other questionnaires, with too many questions, resulting in lack of answers or unserious responses, it has been considered important to simplify the inquiry form. In addition to the inquiry form, students will be selected for personal interviews in order to give more detailed information about the CDIO evaluation. Similarly, an inquiry form for the evaluation of the teaching staffs' views on the implementation of CDIO has been developed.

**Evalueringsskema – BYG-Diplom: Design-Build-Projekt  
Efterår 2008**

Følgende spørgsmål vurderes på skala fra 1 til 5, hvor 5 er bedst – og 1 er dårligst

		5	4	3	2	1	
1.	Hvor høj grad har kunsten bevidstgjort dig om processen fra udvikling af ide til udførelse?	Meget godt					Lidt
2.	Har du har fået tilstrækkelige værktøjer til projektarbejdet?	Tilstrækkelig					Ikke til
3.	Engagerer undervisningen projektet dig?	Ja i høj grad					Nej slet ikke
4.	Har undervisningsformen i dette kursus motiveret dig til yderligere interesse for at studere til bygningsingeniør?	Ja i høj grad					Nej slet ikke
5.	Hvad synes du generelt om projektets indhold?	Meget godt					Meget dårligt
6.	Hvordan er dit samlede faglige udbytte af projektet?	Meget godt					Meget dårligt
7.	Hvor meget har projektarbejdet udviklet dine samarbejdsevner?	Meget godt					Lidt
8.	Integrerer projektdokumentation de øvrige fag på semestret?	Meget godt					Meget dårligt
9.	Hvordan har samarbejdet været i din gruppe?	Meget godt					Meget dårligt
10.	Oplever du at kurset giver en bred introduktion til ingeniørarbejde og bygningsingeniør studier?	Meget godt					Meget dårligt
11.	Hvad er dit udbytte med hensyn til egen problemløsningskompetence for projektet?	Meget godt					Meget dårligt
12.	Hvad er dit udbytte med hensyn til design af løsninger til projektet?	Meget godt					Meget dårligt
13.	Hvad er dit udbytte med hensyn til udførelse af projektet fysisk?	Meget godt					Meget dårligt
14.	Hvad er dit udbytte med hensyn til målning og drift af projektet?	Meget godt					Meget dårligt
			Andel	M	K		
15.	Hvor mange har deltaget i din gruppe?						
16.	Hvor mange timer har du arbejdet med projektet foruden de + skemaets projekttimer per uge?	0-10 time	10-15 time	15-20 time	20-25 time	25-30 time	>30 time

Nedenfor opfordres du til at komme med mindst én mening om hvert af de følgende 3 punkter:

- Jeg værdsætter:

- Jeg kritiserer:

- Jeg foreslår:

Nedenfor kan du komme med supplerende oplysninger til de enkelte spørgsmål hvis du ønsker det. Vær venlig at skrive spørgsmålsnummer foran, hvis du vil udbylle et enkelt punkt.

Figure 2. The two-page questionnaire in Danish as it was distributed to the students. Front page to the left and reverse side to the right.

The two-page questionnaire is shown in figure 2. The front page of the questionnaire contains the questions specially designed for this course. The questions will be gone through later in this paper. A mistake was made by not putting in a “turn the page” note. 17% of the students never got to the reverse side of the questionnaire.

The reverse side of the questionnaire contains, first of all, the possibility for the students to make personal comments – see figure 2 to the right. The following is the text of the reverse side of the two-page questionnaire in Danish – translated into English:

Below you are requested to write at least one opinion of each of the following 3 items:

- I appreciate:
- I criticize:
- I recommend:

If you want to, below you can add further information to the specific questions. Please note number of question if you wish to clarify something.

The simplified form of the questionnaire makes it easy and fast for the students to answer the evaluation questions.

The inspiration and development of the questionnaire is based on personal interviews with students during the course in order to select the right questions and how to perform the questionnaire in order to get the highest number of answers from the students.

## ANALYSIS OF THE QUESTIONNAIRE

Below is a going through of some of the questions of the questionnaire – in figure 5 you can find all the specific percentages for each of the questions of the questionnaire.

Unfortunately the electronic inquiry at the CampusNet was not coordinated with the paper inquiry form. The consequences of this were a missing opportunity to make a good comparison between the two inquiries, especially looking into the fact that the paper inquiry form included 84% of the students compared to the only 45% at the electronic inquiry at the CampusNet. This would definitely have been of great interest to do.

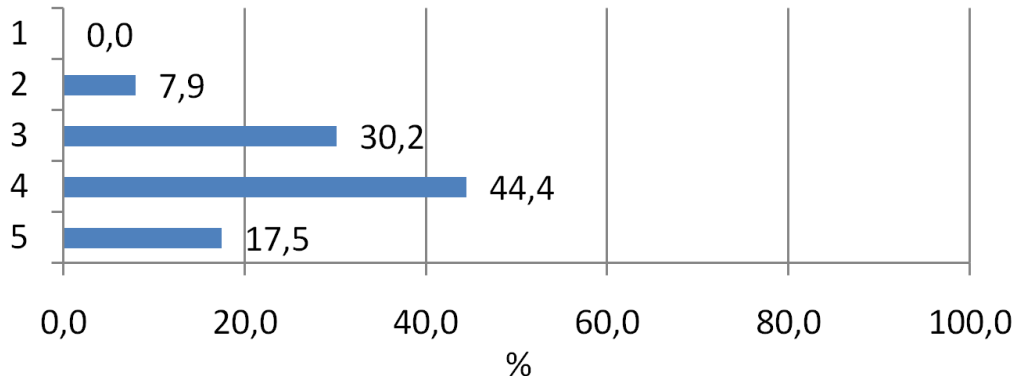


Figure 3. Results from question 1 – To what extent did this course make you conscious of the process from conceiving an idea to the implementation? The scores are ranked from very good (positive) (5) to very bad (negative)(1)

1. To what extent did this course make you conscious of the process from conceiving an idea to the implementation? – See results in figure 3. The philosophy behind the concept of CDIO is to make the C, D, I and O visible and form part of the teaching frame progress. The teaching has to show a picture and authentic elements have to be brought into the teaching in the CDIO Design Build course. In the first question, where the students have been asked: to what extent did this course make you conscious of the process from conceiving an idea to the implementation? – 62% gave the score 4 or 5, 30% average 3. Only 8% gave the low score 2 and 0% the lowest score very bad – 1. The results from this question show that the course seen from a CDIO point of view has been a great success since 92% gave from medium to the highest score.

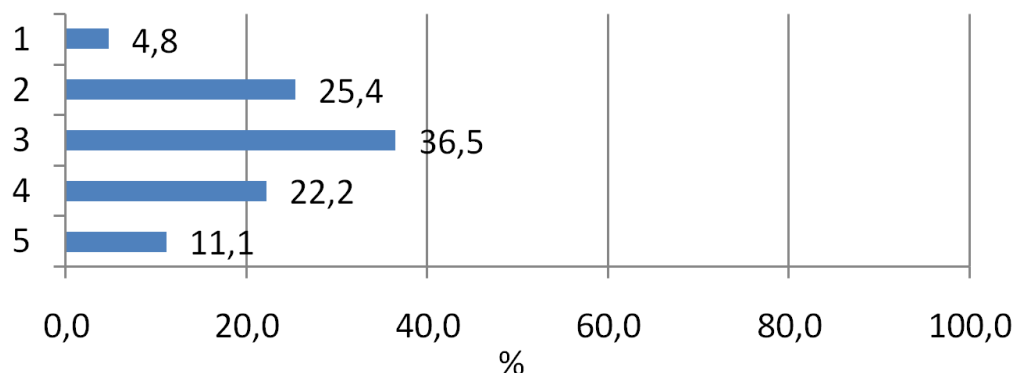


Figure 4. Results from question 2 – Did you get adequate instruments/tools for working with this project? The scores are ranked from very good (positive) (5) to very bad (negative) (1)

2. Did you get adequate instruments/tools for working with this project? – See results in figure 4. The results of this question follow a normal distribution with 37% at average 3 and approximately 24% at the scores 2 and 4 each. The conclusion from this is that the instruments for working with this project have been insufficient – however the formulation of

the question is rather unclear since it can be misinterpreted. The word “værktøjer” in Danish can be understood as a tool like a hammer the students need to build the model of the house – however, the word “værktøjer” can also be understood as an instrument, for instance describing how to write a report. The inspiration for this question came from a personal interview with two of the students in order to get ideas about how to build up the questionnaire. The students complained that they were working on the project on a practical level, but they lacked instructions how to build up the report since they were only told to take notes. Based on this inspiration from the students the question was proposed. As seen from the above, the question has been formulated unclearly and can be understood as two different questions: 1 – tool like a hammer and 2 – instrument like instructions.

This is an example of how difficult it actually is to make a good questionnaire – it is most important to make sure that the students will not misinterpret a question. The result from this question cannot really be used for anything since the students from personal interviews indicate that they have been satisfied with the practical physical objects and have been dissatisfied about the information of how write a report. See also question 7.

3. Did the lessons/project make you commit yourself? – 75% gave the score 4 or 5, 20% the average score 3. Only 5% gave the low score 2, and 0 % the lowest score very bad – 1. From this it can be seen that 95% of the students find themselves committed to the project by giving the score from medium to high. This shows that the CDIO concept commits the students in the engineering education but also that the students who are maybe not so book-learned but rather prefers practical education can use the CDIO concept.

4. Did the teaching method of this course motivate you for added interest in studying constructional engineering? The concept of CDIO is to integrate and involve the students in the teaching process and make them more interested in the study. The scores show that the CDIO concept used in the course has been a success in respect to making the students interested in studying to be an engineer, since 74% of the students gave the score 4 or 5, 20% average 3 and only 5% gave the low score 2 and 0 % the lowest score very bad.

5. Overall what do you think of the contents of the project? – 27% gave score 3, 51% – score 4 and 10% the highest score 5. The results show a high satisfaction with the project since 88% gave a score from 3 to 5 with the maximum at score 4.

6. How is your total professional, technical benefit of the project? – Average positive score: 48% gave score 3, 37% – score 4 and 3% – score 5. It looks as if the students' total technical benefit from the project could be better, and there might be a need for working on that.

7. How much did working with this project develop your interpersonal skills? – Average positive score: 38% gave score 3, 40% – score 4, adding up to 78%. 14% gave the poor score 2, which, compared to the other answers, are relative high. Incorporating tools for the students to develop better interpersonal skills could be a good idea, especially since this is the student's first course at our university. This is an obvious subject to include in a course like this, since the corporation here and as an engineer is so important. See also question 2 and 9.

8. Did the project process integrate with the other subjects of the term? – The project was planned to integrate the theory from the other courses in order to support the design build project. The results show a reasonable success rate: 35% gave score 3, 43% – score 4 and 14% – score 5.

9. How was the teamwork in your group? – The teamwork in the groups seems to have worked very well since 32% gave the score 4 and 40% the highest score 5. Compared to the results in answer 7 (development of your interpersonal skills), the result seems to give

approximately 1 point higher score. This can be a result of the Scandinavian tradition, where the students work very much in groups in the gymnasium before they start at the technical university, and as a consequence of this, the students had already a good skill for teamwork in groups.

10. Do you experience that the course gives you a wide introduction to engineering and studies of constructional engineering? – 29% gave score 3, 44% – score 4 and 14% the highest score 5. Altogether adding up to 87% giving a score from 3 to 5 shows a high satisfaction. This can be an important issue for the students' decision concerning whether to continue their study to be engineer or change study. The answer also indicates that the CDIO course is a good alternative to the traditional teaching.

11. What is your benefit with regard to your own problem delimitation for the project? This is the only question where both score 1 and 5 gave 0%. 64% gave the medium score 3 and 32% score 4 – giving a total of 96%, showing that the students delimitation seems to have worked satisfactorily.

12. What is your benefit in regarding the design of solutions for the project? – 41% each for score 3 and 4. – and 8% for score 5. This is a total of 90% – this is very good. In the design phase the students have their focus on creating a good design for the building, which includes drawings, plans and calculations that all together describe what will be implemented.

13. What is your benefit in regarding the physical implementation of the project? – 37% score 3 and 44% score 4 and 11% score 5. This is a total of 92% – The results show a good satisfaction by the students concerning the implementation stage in which the students transform the design into the small model on which they are measuring in the last operating stage.

14. What is your benefit in regarding the measuring and the operation(s) of the project? 38% gave score 3 and 45% score 4 and 6% score 5. This is a total of 89% – In the final stage, the students have been operating the model of the house, got measuring results and extracting the data from the model, and transformed them to their laptop. The responses from the students indicate satisfaction with this operation stage.

15. How many students were in your group? The groups have consisted of 3 or 4 members, with a majority of 4. The average has been 3.7 members.

16. How many hours a week did you work with the project in addition to the four scheduled project lessons? 0 - ½ h; 1-2 h; 2-3 h; 3-5 h; >5 h

A 5 ECTS course is prescribed for 9 hours per week, which means that an average answer to fulfil this should be additional 5 hours. Less than 13% answer that they work 3-5 hours more per week and only 1.6% (1 person) indicate more than 5 hours, indicating that only 14% work more than 7 hours per week compared to the prescribed 9 hours per week. This can to some extent be compared to the electronic inquiry at the CampusNet, where 64% answer that they work 9 or more hours per week. This is a very significant difference in answers between the two inquiry forms:

	> 7 h/week	9 h/week	> 9 h/week	≥ 9 h/week
Paper form	14%			
Electronic form		49%	15%	64%

86% work less than 7 hours per week according to the paper inquiry form compared to 36% less than 9 hours in the electronic inquiry form. It is very clear that the responses in the two inquiry forms are very different. One of the reasons deals with how the question is raised.



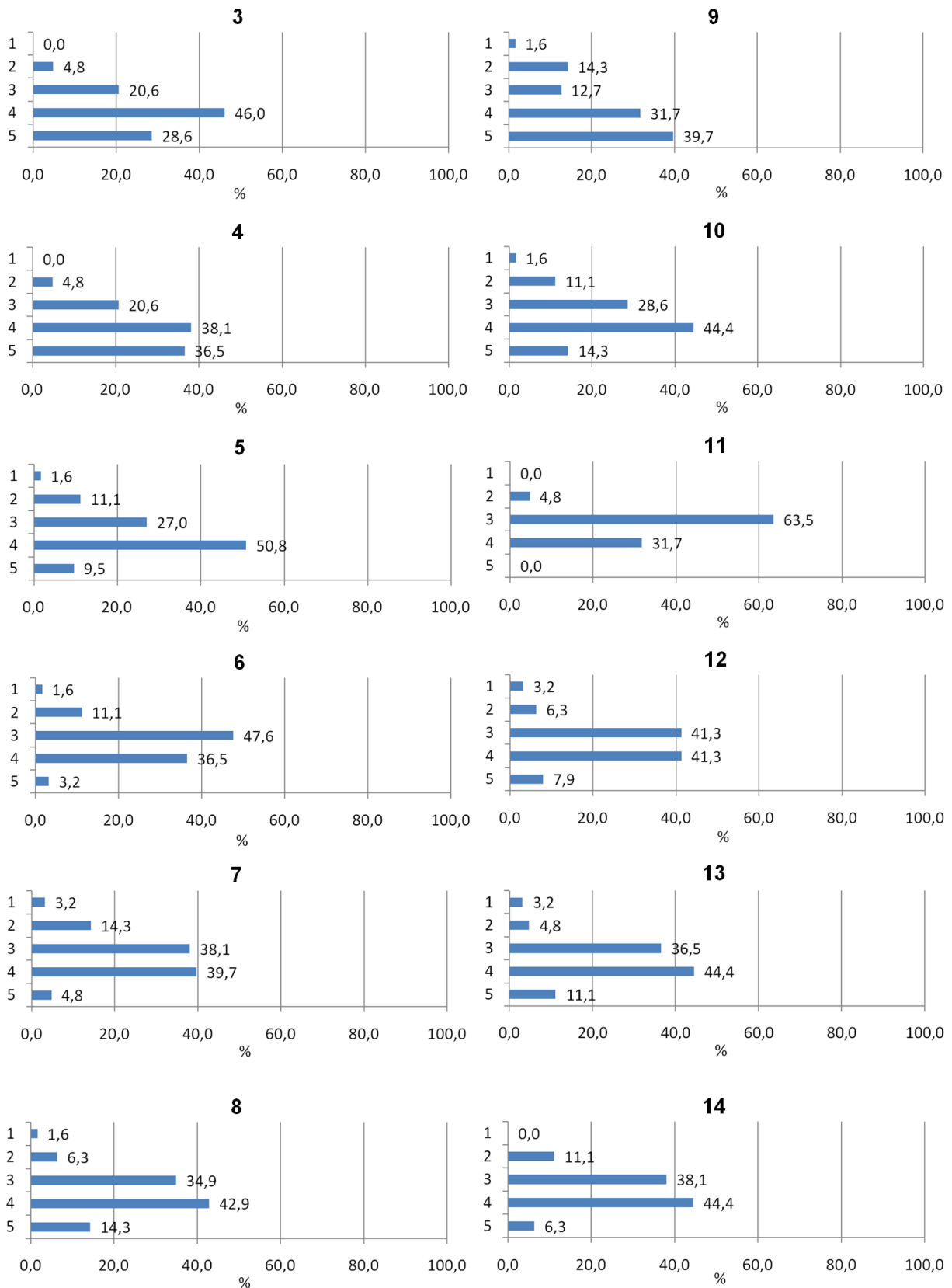


Figure 5. Results from questionnaire – The scores are ranked from very good (positive) (5) to very bad (negative) (1).

The question in the paper form: *“How many hours a week did you work with the project in addition to the four scheduled project lessons?”* In this case the student reflected directly about how many hours he/she was working, outside the university.

In the electronic form the question is: *“A 5 ECTS course is prescribed for 9 hours per week. I mean that my working load in the course is (I have put score on below):*

<i>Much less</i>	score 1	
	score 2	
	score 3	(9 hours per week)
	score 4	
<i>Much more</i>	score 5”	

As it can be seen from the question it is more diffuse in the performance of the question. 49% write approximately 9 hours per week. This looks like that the students tend to answer that they work the average number of hours per week even when they do not, according to the paper inquiry form. In personal interviews with some students, they told that they mostly work on the project when they are at the university. This indicates that the direct question of how many hours they work more gives the best answer.

This example shows how difficult it can be to raise the right question, and also how much the answer can differ. In addition, 84% have answered the paper form and only 45% the electronic form, which means that not the same relative percentages have answered the question.

## **CONCLUSION**

The implementation of CDIO is a year long process according to experiences from other universities. In order to speed up the process at Department of Civil Engineering (Byg), Technical University of Denmark, a process for evaluation of the first CDIO course, which has taken part as a Building Design course, has been started. The evaluation has been done using a paper inquiry form in addition to the traditional electronic inquiry form at the CampusNet. The response rate from the two forms show significant difference since the paper inquiry form gave a response rate of 84% (=100% of all students attending the presentation day) compared to only 45% at the electronic inquiry at the CampusNet. This gives the paper inquiry form a far more representative value. Unfortunately the two inquiry forms were not coordinated properly in order to compare the results, and by this way get an idea about the extra benefit of making a manual collation of data from the paper form. However one of the questions concerning the students' working hours on the course per week could be compared and showed remarkable difference. In the paper form only 14% answer that they work more than 7 hours per week compared to the electronic inquiry form, where 64% answer that they work 9 or more hours per week. This is an extreme difference. If these results are compared with personal interviews, where students have earlier expressed that they only worked very few hours outside the scheduled 4 hour course time, this indicates that the result from the paper inquiry form is far more reliable than the answer at the CampusNet. In addition to this, the two results differ so much, that it is difficult to understand that both inquiries deals with the same course.

Altogether, this material has given the CDIO staff very good material for the evaluation of the CDIO Design Build course and input for improvement and effective practices. In general the results show a very high satisfaction with the Design Build course, and the students like the practical approach in the CDIO concept. The students are very committed and the course motivates them for added interest in studying constructional engineering. In addition the course is a good alternative to the traditional technical courses.

The students complained that they wanted better material in the early stage for writing a report since they were only told to take notes. There was also a lack of working space for the students when all were in the workshop and wanted a workbench. It seems that the students did not work the requested 9 hours per week and more work could be done in order to activate them outside the scheduled 4 hours weekly workshop. This could for example be information of how to write a report, co-operation, teamwork, communication, etc. This seems to be an important improvement since some of the negative comments from staff personal about CDIO are that they learn too little, and the general technical knowledge will suffer from the introduction of CDIO and the more project oriented teaching approach. Another improvement suggested by the author is in the beginning of the CDIO course on the first semester to introduce an introduction communication workshop for the new students [8].

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### **Biographical Information**

Jørgen Erik Christensen received his M.Sc. and Ph.D. degrees from the Technical University of Denmark in Copenhagen in 1981 and 1987 respectively. From 1988 to 1991, he worked at the Danish Building Research Institute, Denmark and was in 1990 appointed to senior researcher. From 1992, he worked as Professor of Integrated Building Technology at Narvik University College, Norway. From 2003 to 2007 he has been an Associate Professor at Faculty of Engineering, Oslo University College and since 2007 until present he has worked as an Associate Professor with the Department of Civil Engineering, Technical University of Denmark.. He has been involved in national and international research in the field of energy and environment and a co-developer of an international used thermal analysis program – tsbi3.

Carsten Rode received his M.Sc. and Ph.D. degrees from the Technical University of Denmark in Copenhagen in 1987 and 1990 respectively. From 1990 to 1992, he worked as a PostDoc researcher with the Thermal Insulation Laboratory, Technical University of Denmark. From 1992 to 1996 he worked as a Senior Researcher with the Danish Building Research Institute, and since 1996 until present he has worked as an Associate Professor with the

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Egil Borchersen received his M.Sc. and Ph.D. degrees from the Technical University of Denmark in Copenhagen in 1968 and 1972 respectively. From 1972 assistant professor later associate professor at the Technical University of Denmark. 2001-2006 program leader for B Eng in Arctic Technology in Greenland, 2007- program leader for B Eng in Civil Engineering at DTU. Main topic has been design and structural analysis of houses. For several years involved in educational activities and committees at DTU.

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