The effects of the CDIO curriculum on engineering students' experiences of their study environment

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ABSTRACT: The focus of this article is on engineering students' experiences of their 2nd, 3rd and 4th years of their programme. In 1999, the implementation of the *Conceive – Design – Implement – Operate* (CDIO) curriculum started with the first project-based course, which was compliant with the CDIO philosophy, introduced in 2002 during the 1st and 3rd study years. The results are based on responses from three questionnaires given to all registered students in all four cohorts at the start of their 3rd, 4th and 5th years. In total, 664 responses were received. In this study, the focus is on the following areas: satisfaction with study results; estimated work and perceived workload; aspects of study related health; and influence and cooperation with teachers and peer students. Comparisons have been made within cohorts over time and between cohorts with regard to students' self reported experiences in these areas. The results indicated that there were significant differences in some of the areas between cohorts who had not studied in a project-based approach and those who had done so. As the 1998 and 1999 cohorts had not followed the CDIO curriculum, whereas the 2000 and 2002 cohorts did, differences between the cohorts in various areas can be related to the implementation of the CDIO curriculum.

INTRODUCTION

In this article, the author draws on data from a relatively large, ongoing, longitudinal cohort study, which was initiated in 1998 with the overall purpose of comparing the expectations and experiences of four cohorts of students in applied physics and electrical engineering [1]. The focus is on the self-reported aspects of several areas, such as working hours and perceived workload, influence on the study situation and cooperation with teachers and students, study related health, etc. Changes have been made in the curriculum throughout the years of this study.

In 2002, a new approach to education was introduced. From the start, students would work in project groups, involving more scheduled time working together with other students in small groups; this differs quite a lot from the previously more traditional form of education that is based very much on individual achievement and large lectures. The results are based on a total of 664 response to three questionnaires from four cohorts that started the programme in 1998, 1999, 2000 and 2002. The first questionnaire concerns students' experiences of year two, while the second and third questionnaires concern year three and year four in the programme, respectively. The response rate was the highest for the first questionnaire, but then dropped (see Table 1).

Table 1: Response rates for questionnaires concerning year 2, year 3 and year 4 (the total number of students and the questionnaire responses expressed as a percentages are noted within parentheses).

	Year 2	Year 3	Year 4
Cohort 1998	77 (135, 57%)	76 (117, 64%)	62 (120, 52%)
Cohort 1999	75 (150, 50%)	65 (139, 47%)	43 (131, 33%)
Cohort 2000	82 (129, 64%)	47 (117, 40%)	39 (114, 34%)
Cohort 2002	56 (123, 46%)	42 (104, 40%)	-
Total	290 (537, 54%)	230 (479, 48%)	144 (365, 40%)

The results are divided into the following parts: satisfaction with the study results; average working hours and perceived workload; health; and influence and cooperation. The collection of the first questionnaire was undertaken by researchers who visited a popular lecture during the autumn of year 3 of the programme. Students answered the questionnaires, which were immediately collected by the researchers. The second and third questionnaires were distributed to the homes of the students via mail with stamped envelopes, since there were no compulsory lectures, including all students of cohorts in the third and fourth years. The response frequency is based on all answered questionnaires in relation to the registered students. It should be noted that some students drop out after their first year od studies in the programme. In one report, this reduction in students numbers was calculated to be 20% [1].

As can be seen in Table 1, it is clear that the response frequencies reduced for the second and third questionnaires. One reason for the decreased response rate could be that students who had the questionnaires distributed to their homes were not as inclined to return completed questionnaires compared to students asked to complete the questionnaire in class. Therefore, there is a risk that the reduction of responses is systematic and may result in a bias in the results [2]. One hypothesis is that those students who answered the questionnaires differ from those students who chose not to respond. The heterogeneity among the cohorts will, therefore, decrease over time and those students who answered the questionnaires will be more homogenous over time; as such, the results will, to a great extent, refer to *successful* students. No questionnaire was coded and students were anonymous. Thus, it is only possible to discuss changes over the years at the cohort level. All questionnaires were, to a great extent, identical and contained the same fields of questions. The only main difference was that the questionnaires covered different years in the programme. Most of the questions are of Likert-scale type.

Changes in the Programme

The changes that have been introduced in the programme between 1998 and 2002 resulted in the 2002 cohort being the first to have a project course that was compliant to the *Conceive – Design – Implement – Operate* (CDIO) philosophy already in their first year. For a discussion of the CDIO Syllabus, see ref. [3]. The 1998 and 1999 cohorts did not undertake any such course and the 2000 cohort carried out its first one in the third year. The project courses compliant with the CDIO philosophy have two main purposes. Firstly, students shall learn a project management model called the Lightly Interactive Project Management (LIPS) model, which has been developed at Linköping University in Linköping, Sweden. It indicates how a project should be structured and managed. The model specifies that the phases of the project contain a number of *tollgates* and *milestones* that the project group must pass as the project is carried out. Secondly, students have to reach the learning outcomes specified in the CDIO Syllabus, eg be part of, and learn how to cooperate in, a project group during a limited amount of time [3]. Project-based learning generally means that students and the supervisor, within certain frames, choose how they manage the project and take positions on various issues in the project, such as content, process and organisation [4]. Students are supposed to actively manage their own education and work according to the LIPS project model. Furthermore, the project group has a social dimension that could have a decisive influence on students' decisions to continue in the programme [4]. Research has shown that, if correctly organised, project-based learning increases students' motivation to study [5]. It also increase student engagement in investigating authentic problems, and facilitates a high degree of teamwork [4][6].

When the results are interpreted, the following hypotheses will be the starting point. First, there has been a process of self-selection over time, which means that those students who stay in the programme and choose to answer the questionnaires become more homogenous as a group, resulting in decreased differences between cohorts over time. Second, the CDIO curriculum, as well as the project and team-based learning approach, which are compliant to the CDIO philosophy, increase students' opportunities to cooperate with teachers and students' peers.

RESULTS AND DISCUSSIONS

In this section, results from the areas of satisfaction, average working hours and perceived workload, health, and influence and cooperation are presented and discussed.

Students' Satisfaction with Their Studies

Students were asked in the questionnaires if they were satisfied with their study results. Table 2 presents the percentage of students who reported that they were very satisfied, as well as very dissatisfied, with their study results.

Table 2: Percentage of students who stated that they were very satisfied and very dissatisfied with their studies after year 2 (Y2), year 3 (Y3) and year 4 (Y4).

Cohort	Very Satisfied (%)			Very Dissatisfied (%)		
	Y2	Y3	Y4	Y2	Y3	Y4
1998	62	71	71	6	9	10
1999	61	58	81	9	15	5
2000	52	53	68	13	9	8
2002	64	66	-	11	6	-

Over time, more students were satisfied with their studies. One explanation could be that students in their second semester of Year 3 chose a study profile that contained a number of *profile courses*, which, to a large extent, they study in their fourth year. It is possible that these courses were perceived as more relevant and interesting, thus making them more satisfied. The hypothesis that there was a level of self selection among students who replied to the questionnaires is also a possible explanation, ie if one is successful, then one is more satisfied. Other differences are difficult to interpret as there is no obvious pattern regarding students' satisfaction with their studies.

Working Hours and Workload

Students' estimated their personal average working hours per week, as listed in Table 3.

Table 3: Students' estimations of their real, average working hours per week.

Cohort	< 40 hours (%)			> 40 hours (%)		
	Year 2	Year 3	Year 4	Year 2	Year 3	Year 4
Cohort 1998	11	9	28	47	66	39
Cohort 1999	14	19	26	45	67	19
Cohort 2000	20	20	45	39	51	24
Cohort 2002	11	13	-	36	45	-

It was found that more students from the 1998 and 1999 cohorts studied more than 40 hours per week during their second and third years, while for the fourth year, the largest percentage was for the 1998 cohort. Interestingly, the 2002 cohort, who spent the most time studying out of all the cohorts during the autumn semester of their first year, were those who spent the least time on their studies during the second and third year [1]. The percentage of students who studied less than 40 hours per week was, at the same time, higher than for the other cohorts. It is obvious that it is in their third year when most students estimated that they worked studied over 40 hours per week, and that the percentage was higher for the 1998 and 1999 cohorts than for the 2000 and 2002 cohorts. One possible explanation for this is that the latter cohorts each did a project course compliant with the CDIO philosophy during that year, which may have had an effect. Furthermore, the percentage of students in the 2000 cohort who studied more than 40 hours per week was higher than for the 2002 cohort. The explanation for this difference may be that it was the first time that the 2000 cohort undertook a project course that was compliant with the CDIO philosophy course, while the 2002 cohort, who carried out their second project course, were more used to this type of course and learning.

Students were also asked about their subjective perception of their workload. Students indicated how they perceived their workload on a 5-grade Likert scale, from small to overwhelming. Table 4 details the percentage of students who answered that they had experienced a very heavy or overwhelming workload.

Table 4: Percentage of students who perceived their workload to be very large and overwhelming.

Cohort	Year 2 (%)	Year 3 (%)	Year 4 (%)
Cohort 1998	20	46	11
Cohort 1999	17	63*	2
Cohort 2000	12	47	11
Cohort 2002	22	18*	-

* Significant difference at the 0.005 level.

In the third year, the largest percentage of students who perceived the workload as being very high or overwhelming were found in the 1998, 1999 and 2000 cohorts. For the 2002 cohort, a different pattern developed where a smaller percentage of students perceived the workload in year three as being very high or overwhelming compared to year two. Significant differences were detected for year three. Significantly more students from the 1999 cohort and significantly fewer students from the 2002 cohort perceived the workload as being very high or overwhelming (χ^2 (6, N = 228) = 22.14, p < 0.005). Both the 2000 and 2002 cohorts had project courses that were compliant with the CDIO philosophy in that year, but they differed regarding perception of their workload. It was found that 47% of students from the 2000 cohort experienced a very high or overwhelming workload, but only 18% in the 2002 cohort experienced the same. One explanation for this may be that students in the 2000 cohort had their first project that was compliant with the CDIO philosophy and, therefore, they were not used to dealing with deadlines, cooperation, etc, which may have led to extra strain. On the other hand, the 2002 cohort were used to studying in projects as they already had experiences from a project and team-based learning approach during their first year, which may explain why the percentage of students who perceived the workload as overwhelming was much smaller. It is possible that students in the 2002 cohort, through their first project, learned how to treat the frames and learned the LIPS project model.

Health Aspects

Highly demanding studies can affect students' psychological and physical health. Ill health can be a subjective experience, such as feelings of inadequacy, but it can also be related to physical complaints like infections. The questionnaires incorporated general questions about health and ill health, as well as more specific questions about complaints that may be related to the study situation. For the general questions of health, a factor analysis resulted in a bipolar scale (explaining 39% of the variance), which covered the following poles: *My health is good*; *I enjoy the place of study* and *The studies have affected my health in a negative way*; *I have felt that I do not really fit in the programme*; *I have experienced feelings of social isolation*. This factor can be called *health* and *ill health*. The scale can assume values between 1 and 5, where 1 means good health and 5 means ill health. The mean values are below the centre for all cohorts, meaning that students experienced more health than ill health, but slightly poorer health than during their first year [1]. No significant differences between the cohorts were found.

Feelings of social isolation may be related to both the situation (eg a student may have many relations outside the university and have problems feeling at home in the academic world) and relations (eg a student may find it difficult to establish contact with other students). In both cases, a dominant feeling could be not really fitting in. Research indicates that social integration, which involves the structural aspects of social relations, is more important for most students than academic integration [7]. Further, a lack of experienced or actual social support and a social support network is a significant reason for students dropping out [8]. The latest report showed that the 1998 to 2000 cohorts experienced social isolation to a greater extent during their first semester, whereas the 2002 cohort experienced a higher degree of social isolation during their second semester [1]. One hypothesis presented in that report was that the 2002 cohort, which was the first cohort to have

been divided into project groups in the first semester, *may* have been allotted belongingness, but that this belongingness did not last when the groups were dissolved in their second semester. Table 5 presents the percentage of students who have experienced social isolation to some extent during their second, third and fourth years. The percentage of students in the 2002 cohort who have had such feelings decreased slightly from 37% (see ref. [1]) to 33%, and then remained at that level. For the other cohorts, the results were different, where the percentage instead increased from similar or higher levels to a level much higher in their third year.

Table 5: Percentage of students who experienced feelings of social isolation.

Cohort	Year 2 (%)	Year 3 (%)	Year 4 (%)
Cohort 1998	34	59	56
Cohort 1999	35	42	37
Cohort 2000	48	53	39
Cohort 2002	33	33	-

It is also apparent that students in the 1998 cohort experienced social isolation to a greater extent than all other cohorts during their third- and fourth year. A χ^2-test showed a significant difference in the third year, when cohort 1998 experienced more social isolation and cohort 2002 experienced less social isolation than could be expected (χ^2 (3, N = 227) = 9.0, p > 0.05). One hypothesis is that the board's intentions to break the negative experiences that cohort 1998 and to a certain extent cohort 1999 initially manifested, has proved effective to a greater extent for cohort 2002, for whom most interventions were introduced. Notable is that the feelings of social isolation of cohort 2002 was significantly lower than for cohort 2000 even though the interventions had been introduced for both these cohorts and both had project based courses during their third year.

Cooperation

Research indicates that teacher support, friendliness and fairness are important components for study motivation [9]. Furthermore, support from teachers is necessary in order to increase students' possibilities for social integration in their courses [8]. Using a factor analysis, the questionnaire statements of influence and cooperation were reduced to two factors that can be called *influence and contacts with teachers* and *cooperation with other students*. These two factors explain 30% and 54% of the variance, respectively. The following items impacted on the factor, *influence and contacts with teachers*: *I have had good opportunities to influence my study results*; *I have had satisfying and inspiring contacts with lecturers*; *I have had satisfying and inspiring contacts with course assistants* and *I have had satisfying and inspiring contacts with laboratory assistants*. The following items impacted the factor, *cooperation with other students*: *I think the cooperation with other students has been rewarding* and *In class, we have had a satisfying and inspiring exchange in our spare time*. Regarding students' experienced possibilities to influence and cooperate with teachers, these possibilities were relatively high, ranging between 2.9 and 3.3. No significant differences were found between cohorts or years in the programme. The mean values for the factor, *cooperation with other students*, are presented in Table 6.

The results indicate that students in the 2000 and 2002 cohorts experienced possibilities to cooperate with other students as

being better than for students from the other cohorts. One hypothesis is that the project and team-based learning approach had a positive effect on students' possibilities to cooperate with each other. An analysis of variance of the cooperation showed a significant difference. Over all three years, the 2002 cohort encountered possibilities to cooperate with other students as being significantly better than the 1999 cohort (F=3.821, $p < 0.05$). This can be interpreted that the two project courses undertaken by the 2002 cohort may have increased their experiences of possibilities to cooperate.

Table 6: Students' experiences of their possibilities to cooperate with other students (the spread was between 0.73 and 0.93 for all mean values).

Cohort	Year 2 (%)	Year 3 (%)	Year 4 (%)
Cohort 1998	3.8	3.5	3.7
Cohort 1999	3.6	3.5	3.7
Cohort 2000	3.9	3.9	3.9
Cohort 2002	4.0	3.8	-

CONCLUSIONS

In this article, questionnaire results from a larger ongoing longitudinal cohort-study of four cohorts of students in applied physics and electrical engineering are presented and discussed. Differences between the cohorts regarding students' level of satisfaction with their studies, average working hours and perceived workload, health, and influence and cooperation with teachers and peers are presented.

The results showed that, over time, more students were satisfied with their studies. One reason for this may be that those students who answered the questionnaire were those who had been successful and, as a result, were more satisfied with their studies. Another reason could be that students chose their courses in the third and fourth years of the programme, which made them more satisfied. The results also showed that the cohorts' average working hours and perceived workload peaked during the third year.

Regarding differences between the cohorts, one conclusion is that the project courses, which are compliant with the CDIO philosophy, plus other interventions in the programme, seemed to positively affect students, especially the 2002 cohort. For example, there was a clear difference between the 1998 and 1999 cohorts, who more often studied more than 40 hours per week and perceived the workload as being very heavy or overwhelming, and the 2000 and 2002 cohorts, in which significantly fewer students studied more than 40 hours per week or perceived the workload as being very heavy or overwhelming. The results also indicated that students in the cohorts 2000 and 2002 experienced more opportunities to cooperate with other students compared to the 1998 and 1999 cohorts.

According to the author's hypotheses, this is one effect of the CDIO curriculum. For example, the project courses may have positive affected study hours per week, perceived workload and opportunities for students to cooperate with each other. Another difference was that more students in the 2000 cohort estimated that they studied more than 40 hours per week and perceived the workload as being very heavy or overwhelming than students in the 2002 cohort, despite the fact that both cohorts studied the project courses. Finally, on average, the 2002 cohort experienced better possibilities to cooperate with other students.

Regarding the health-related findings detailed in this article, all cohorts generally reported relatively good health, but a rather large proportion of students experienced problems like social isolation. Even here, the 2002 cohort distinguished themselves from the other cohorts with a significantly smaller percentage of students who experienced social isolation (χ^2 (3, $N = 227$) = 9.0, $p > 0.05$). The explanation of the results suggested here are that the study board's intentions to break the negative experiences of the 1998 cohort and, to a certain extent, the 1999 cohort initially manifested, has proved effective to a greater extent for the 2002 cohort, for whom most interventions were introduced.

One question that remains is whether the improvements the 2002 cohort generally experienced will continue or not. It is probable that the percentage of students who experience the workload as being very heavy or overwhelming remain lower and that the experience of possibilities to cooperate with other students will remain higher for students who study project-based courses. However, more research must be carried out in order to be sure if these improvements will continue or not.

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