Students' Experiences of Change in a PBL Curriculum

Dahl, Bettina; Holgaard, Jette Egelund; Hüttel, Hans; Kolmos, Anette

Published in:
International Journal of Engineering Education

Publication date:
2016

Document Version
Version created as part of publication process; publisher's layout; not normally made publicly available

International Journal of Engineering Education Vol. 32, No. 1(B), pp. 1–12, 2016
Printed in Great Britain

0949-149X/91 $3.00+0.00

Students' Experiences of Change in a PBL Curriculum*

BETTINA DAHL[1]
Department of Development and Planning, Vestre Havnepromenade 5, Aalborg University, 9000 Aalborg, Denmark.
E-mail: bdahls@plan.aau.dk

JETTE EGELUND HOLGAARD
Department of Development and Planning, Vestre Havnepromenade 5, Aalborg University, 9000 Aalborg, Denmark.
E-mail: jeh@plan.aau.dk

HANS HÜTTEL
Department of Computer Science, Selma Lagerlöfs Vej 300, Aalborg University, 9220 Aalborg Ø, Denmark.
E-mail: hans@cs.aau.dk

ANETTE KOLMOS
Department of Development and Planning, Vestre Havnepromenade 5, Aalborg University, 9000 Aalborg, Denmark.
E-mail: ak@plan.aau.dk

Very few institutions have a problem based learning (PBL) curriculum at an institutional level and there is therefore limited experience with change in systemic PBL models. Aalborg University (AAU) practices an institutional PBL model, and in 2010 a rather comprehensive curriculum restructuring took place at the Faculty of Engineering and Science. The original PBL model assessed some of the courses and projects together, whereas since the reform there is separate assessment of each course and of the project. This article reports the findings from a study of how students have experienced this curriculum change. An explorative mixed method study was used that included qualitative focus group interviews with 10th (final) semester students about their experience of the change. Based on the qualitative study, a questionnaire was sent to all 10th semester students from computer science, software engineering, and architecture and design. The findings indicate that the students always prioritize the projects but with the reforms they experienced a significantly lower degree of integration and coherence of the various elements in a semester. Furthermore, the alignment between project supervision and project exam has increased in the new curriculum as the exams of courses and projects are separated.

Keywords: curriculum development; PBL models; alignment; projects

1. Introduction

Problem based and project based learning (PBL) is implemented at different levels in various institutions. Most commonly, the literature refers to the implementation of PBL at a course level where students work with minor cases or projects within the disciplinary boundaries. This can be a very helpful way to generate experience and trust with new teaching and learning systems, but very often this approach is uncoordinated at the system level or is even outside of the curriculum as a co-curricular activity [1, 2].

At the more systemic level there are, of course, the reform universities such as McMaster University, Canada (established in 1969), followed by Maastricht University in the Netherlands (established in 1974, both of which started out with problem based learning as part of their curriculum where groups of students learned the content knowledge by studying cases [3, 4]. In Sweden, Linkoping University was established in 1975 and adapted problem based learning in medicine in 1986 [5, 6]. During the same period, Roskilde University (established in 1972) and Aalborg University (established in 1974) were founded in Denmark with a slightly different model called problem-oriented and project organized learning. For both Danish universities, this was an institutional approach across all faculties and students worked on socially relevant problems as a starting point for projects [7, 8]. The reform universities more or less broke new ground by building up a new curriculum and having the freedom to rethink the role of a university and its pedagogy. The reform universities have served as living laboratories and proof of alternative educational practice. Since the 1990s, many institutions have implemented PBL at a system level but this has always been a much more difficult process as it involves changing existing practice.

The reform universities have undergone several changes. Neville and Norman describe phases of major curriculum change at McMaster University [9]. The change in the medical school illustrates the dilemma between a more conceptual and disciplinary focus and a more contextual focus. This is a discussion that most PBL programs and universities

[1] The authors are listed in alphabetical order according to surname.

* Accepted 11 August 2015.

recognize as it is a core element of the difference between a traditional academic curriculum and a PBL curriculum.

Within engineering education, the CDIO community (Conceive, Design, Implement and Operate) represents a systemic approach to curriculum development by including the mapping of learning outcomes in a curriculum, integration of competences into existing disciplines, faculty training, quality assurance, and the establishment of professional courses in the curriculum that are just some of the standards which engineering institutions, certified as CDIO institutions, should address [10]. Although there is no claim of utilizing PBL learning principles, there are clear synergies in the teaching and learning approaches between PBL and CDIO [11].

This paper will present a literature review on PBL curriculum development and show the context for the changes that happened at Aalborg University as well as the justification for the proposed changes and how some students responded to the changes.

2. PBL curriculum

A project and problem based learning (PBL) curriculum is a student-centered teaching and learning approach to the learning of knowledge, skills and competences [12]. There are three dimensions in PBL: (1) the cognitive dimension resting on experienced based learning theory, (2) the collaborative dimension involving student centered learning and based on social psychology and learning theories, and (3) the content dimension involving interdisciplinarity and exemplarity in choice of methods, theories and real world problems [13]. Within a contextual or/and disciplinary framework, which states the overall learning outcomes, students identify problems that they want to analyze and solve. The problems determine what kinds of theories are applied and usually result in project reports. The problems do not always need to lead to a solution, but might also be based on exploring something unknown.

The definition of curriculum can be slightly confusing as there are several definitions and the most common one is that a curriculum refers to all the courses that are offered in a program, which is basically a bottom-up perspective. Bernstein interprets the curriculum through four different aspects: the intended curriculum, the delivered curriculum, the understood curriculum and, finally, the hidden or tacit curriculum [14]. In creating a curriculum, it is not enough to simply focus on all the explicit elements but, indeed, to also consider the unintended education. These four aspects of a curriculum illustrate that even if we have formulated explicit learning outcomes and have explicitly organized student-centered learning processes; the understood curriculum or the tacit curriculum might be very different from both the intended and the hidden curriculum.

Today's debates on curriculum try to take a holistic approach that includes at least three dimensions: the "what" question which addresses the content of the curriculum and what the students have to learn; the "how" question as the organization of the learning process, the pedagogy including teaching and learning; and the assessment. There can be more elements—but the point is that there is interaction among the elements, and the elements in the process will impact each other. There involves coherent considerations of what Biggs and Tang would call "alignment" among all the elements [15]. The assessment system plays a particularly important role in the curriculum, and Gibbs argues that this is the most important element in any curriculum as it will control students' behavior [16]. The alignment of assessment in the various models is less developed than other elements and most PBL and assessment literature is concerned with peer assessment and self-assessment methods [17–19].

Barnett and Coates address the objectives of the curriculum and define the curriculum as knowing, acting and being [20]. This emphasizes the nature of a curriculum as a space for learning processes and that the curriculum should not only address the knowing and acting processes but, indeed, also the being process as identity growth. In a PBL curriculum, the knowledge (knowing), skills (acting) and competences (being) are all central elements and research indicates that students achieve a high level of competences and skills [21–24]. The PBL curriculum at a system level should meet the requirements of knowledge, skills and competences—and the assessment system will be a core component of the curriculum.

Barrows has developed curricular taxonomies in an attempt to categorize different types of case-based and problem-based learning models ranging from lecture-based cases to more open problem-based learning models [25, 26]. Kolmos and Graaff have developed a more concrete PBL curriculum model which identifies the core elements and their interactions, such as: objectives, types of problems and projects, relationship between lectures and projects, progression, organization of students' learning, academic staff and facilitation, assessment, and more organizational aspects such as learning space and organizational support [27]. This model can be used for both analysis of the curriculum as well as a framework for designing the curriculum. Savin-Baden is one of the other researchers who has developed theories for understanding the PBL curricula and models in terms of

how PBL can be implemented in the entire curriculum [28]. There are many models of how PBL can be implemented in a curriculum; however, the models illustrate how PBL can be weaved into the curriculum during a whole program or at one semester. A curriculum will always be a social construction, and there are no right or wrong answers, but the models serve as possible comprehensive curriculum frameworks. In a later article, Savin-Baden presents a series of new constellations of PBL in the curriculum that links to the purpose of learning. The concrete model/constellation should be aligned with the focus of knowledge, ranging from a narrow disciplinary focus to a broader interdisciplinary and uncertain knowledge construction [29].

As indicated above, there is theoretical work on curriculum development, and, more specifically, PBL curriculum development. When building up a new educational practice, the conceptual development is important, together with research on the impact and efficiency of PBL. However, there is less research on how the various elements influence each other and on the students' learning outcomes. Assessment is a significant component in the curriculum but how different assessment systems influence PBL students' learning processes and students' learning outcomes is yet to be studied. We also know very little about the relationship between lecturing and students' active projects or case work. In most PBL systems lecturing still exists as a significant teaching and learning method, however, we do not know what impact a change in the amount or the content of lecturing will have on students' learning. We have no research findings that can shed light on these and many other questions.

3. Context for this study: change in the Aalborg PBL model

As stated above, there are many PBL curriculum models and there is a need to study the interaction among the different curriculum elements. An opportunity to do this occurred when the Aalborg PBL model, which had formed the basis for the structure of the PBL curricula for more than 30 years in the Faculty of Engineering and Science, was redesigned into a "new", reconstructed Aalborg PBL model, implemented in spring 2010.

The original and redesigned models share important characteristics: during the semester a group of students (usually between five and eight) will formulate an initial problem within the framework of a predefined project unit theme. The students in the group then carry out an analysis of the problem setting and, based on this, they formulate a more defined problem that falls within the boundaries of their discipline. The students then attempt to solve the problem using a chosen methodological framework. Finally, the students assess their proposed solution and, in so doing, they take the results of the problem analysis into consideration. The problem analysis, the solution, and the assessment of the solution are all reported in the form of a written project report.

The differences between the two models are two important curricular aspects: assessment and the relationship between the courses dominated by lectures and the students' projects.

In the original Aalborg model, illustrated in Fig. 1 [7], the so-called "project unit" covered approximately 75% of the semester and consisted of a project covering 50% of the semester and project unit courses amounting to 25% of the semester. All project activities were carried out under a semester theme. In particular, the project unit courses considered topics that were intended to be used and evaluated together with the project. For each group of students working on a project, the final deliverable of the project unit would be a project report jointly authored by the students in the group. The remaining 25% of the semester, not covered by the project unit, consisted of general study courses.

In the project unit courses, the students were given lectures and worked with assignments which were related to the semester theme and the learning objectives and, due to the intended close relationship with the project, these courses were assessed through a project assessment. This was distinct from the general study courses that were targeted towards more generic skills and competences to be developed over several semesters and not necessarily to be used in the semester's project unit. Courses in the fields of mathematics and physics were typical examples of such general courses. The general study courses were assessed separately, usually by either an oral or an individual written exam.

In the case of rather narrow semester themes, the project learning outcomes could be directly related to one or more project unit courses. Here the role of the project was to develop the skills that students were supposed to obtain from the project unit

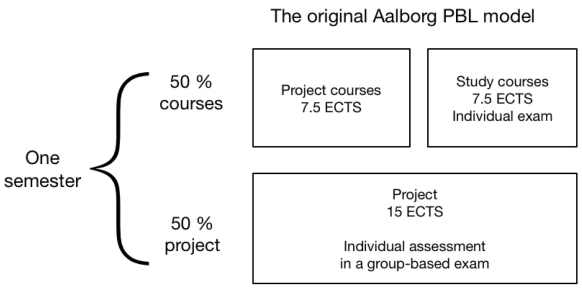

Fig. 1. The original PBL model at the Faculty of Engineering and Science for one semester.

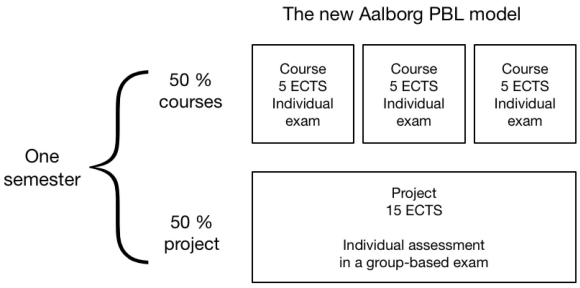

Fig. 2. The new PBL model at the Faculty of Engineering and Science.

courses into deeper competences through addressing real life problems. In cases where the project themes were more openly defined, the project unit courses were developed in a more ad-hoc manner in order to address the challenges students were facing in their actual projects. To prepare project unit courses that could capture the diversity of the projects, a high number of small project-unit courses of 1–2 ECTS were developed [30].

In the new PBL model, the principle of a project unit is abolished and project unit courses no longer exist. The distinction is now between *course modules* and *project modules* and there is a clear separation between these, and the theme is now related to the project. In each semester there are three course modules of 5 ECTS with their own assessment and a project of 15 ECTS (see Fig. 2). The course modules do not necessarily complement the projects and there is substantial variation in the various programs how projects and courses are interlinked. In some semesters there is a close interaction between the learning outcomes for the courses and the learning outcomes for the projects—in other semesters, the learning outcomes for projects and courses point in different directions.

3.1 Study of the reasons for change

There were several reasons for the changes. Externally, Danish accreditation bodies had pointed to problems with the transfer of credits from Aalborg University to other universities as the learning outcomes and credit points were distributed between courses and projects. The Bologna process had required a new grading scale and the assessment of the project unit courses became problematic when the Danish government imposed a ban on group-based assessments in 2007. This meant that it was no longer possible to assess students' learning by using a group-based oral examination; the discussion of the project was broken up into short individual sessions with each student in the group examined separately [31, 32].

Both the internal and external demands resulted in a thorough revision of the study regulations and the structure of the curricula. The Danish universities were also required to adapt to the Bologna process and the change of grade-scale, but they did not, at the same time, have to change their whole educational structure. Even so, the grade-scale change in itself required the imposition of considerable change [33].

One of the first studies of this change focused on curriculum management and concluded that there were too many smaller courses and it was difficult to credit other types of courses earned outside of the enrolled program. Furthermore, there was a desire to develop the teaching and learning in the courses in the direction of more active learning [34, 35].

Kolmos and Holgaard reported that one of the biggest challenges to the implementation process was the redesign of the project unit courses, as well as general courses, to fit the standard of having three courses of 5 ECTS each semester and, at the same time, reselecting the content of the courses to ensure that every course complied with the demand that it should be a multiple of 5 ECTS [35]. Different reselection strategies have been used—merging different subjects, excluding specialized subject areas or moving areas of application to be considered in the projects—leaving the theoretical abstractions for the course modules, which was not the internal intention of the reform. Kolmos and Holgaard state that the managers found that the largest challenge in the new model was the relationship between the course modules and the project. The original model also had many challenges, for instance that of adapting the project unit courses to the projects and that of dealing with the general observation that students would attach less priority to courses that were not subject to a separate examination (the project unit courses) [35]. Despite these challenges, the managers found that the original model also had a number of strengths, in particular, having semesters with clearly integrated learning goals and content.

3.2 Research question and hypotheses

This study focuses on the students' experiences with the new PBL curriculum model. The overall research question for this paper is: What is the impact of the change in the PBL model on student perception and experiences in relation to the courses, projects, and the assessment?

This research question has led us to study the following three hypotheses: that after the restructuring of the curriculum, students now (1) experience the courses as being less relevant to the projects, (2) experience a better alignment between teaching, supervision and project assessment, (3) attach higher priority to courses than previously, as

demonstrated in relation to the priority that they attach to the projects.

4. Methodology

The student target group consisted of 10th semester students who matriculated in 2008. The students in the target group had experienced the original model during their three years of undergraduate study and the new model during the following two years at master's level. Typically, the students would work on their master's thesis during the spring of 2013 and would, therefore, have an overview of the entire education process. For this study we have chosen to focus on students from architecture and design (AD), computer science (CS), and software engineering (SE) as previous studies have identified substantial differences in the responses from these three programs.

An explorative mixed methods study has been conducted [36, 37] starting out with focus group interviews followed by a more quantitative oriented questionnaire. We performed qualitative focus group interviews with four students from AD and four students from CS during the winter of 2013. Students from SE were at this point not included in this part since Computer Science and Software Engineering programs are quite similar (the first two years of the B.Sc. and second year of the Master are identical and more than half the courses in the other semesters coincide).

4.1 The focus group interviews

Based on the conclusions from the studies of Kolmos and Holgaard, a focus group interview was conducted to identify core variables for the questionnaire to be administered to all students. This would also allow us to triangulate the data and the conclusions [37]. The students were volunteers who responded positively to emails sent out to all 10th semester students. Focus group interviews were held with the CS and the AD students separately as the programs are quite different. Each interview took about one hour. The students in each focus group knew each other and this cannot be avoided when they have participated in the same study program for almost five years. However, this is also an advantage since we via the focus group aimed to some extent to re-create the context in order to understand it better. The participants might also feel more comfortable being interviewed amongst equals [38]. None of the interviewers had a background within these programs but, according to Schulz, a stranger is able to recognize the particularity of a situation with clarity [39]. Furthermore, in a focus group the participants ask questions of each other and comment on each other's remarks, which helps the interviewer to find out new things [38]. A critique of focus group interviews states that they can create conformity [40]. To avoid this the students were informed of the objectives of the interview as an explorative phase for identifying variables and describing the diversity of their experiences and perceptions. The interview style was qualitative and semi-structured as we had specific questions that we wanted them to respond to [41]. Such questions included: "What is the relationship between theory and application now and before?", "Did you study equally hard at all types of courses?" and "Is, or was there, a connection between courses and projects?" The students received these questions in advance. We used the focus group interviews to formulate relevant questions to the questionnaire. The interviews were audiotaped but not transcribed. They were reheard several times in order to formulate the students' self-understandings and experiences within the focus areas of the study [41].

4.2 The questionnaire

The interviews were followed by a questionnaire study for all students from AD, CS, and SE during the spring/summer of 2013. Since we wanted to study the self-reported student experiences of both versions of the AAU PBL model, we divided the questionnaire into two parts: before and after the changes. We asked almost the same questions in each part with a few questions that only addressed one of the AAU PBL models. Even though the majority of the questions were similar, we did not ask them in exactly the same way, only approximately, for the following reasons:

- There will always be a difference in breadth/depth when going from a bachelor program to a master program.
- The students mature naturally during their five years of study and this may change their perception and behavior as students.
- The curricula for the master program were completely new, hence new programs always need to be adjusted.

The questionnaire was developed in SurveyXact and distributed to 115 students. We received answers from 29 students (7 from CS, 11 from AD, and 11 from SE). The response rate is, therefore, 25%. Krosnick states that surveys that students fill out in class have a tendency to lead to more neutral answers owing to the phenomenon called 'satisficing', where respondents choose the middle option for fear of judgment, interruptions, or time constraints [42]. Nulty writes that online surveys generally have a lower response rate than questionnaires distributed on paper and if one accepts a

confidence interval of 80%, then a response rate for course evaluations of 12-15% is satisfactory for class sizes between 150 and 200 students [43]. Our study is not a course evaluation but a program evaluation, which is not the same but, nevertheless, related. Our response rate is, therefore, reasonable but could be better.

The design and communication of the questionnaire builds on the advice of Oppenheim in order to secure validity and to give as high a response rate as possible [44]. The advice includes telling the participants why they are important for the study, who is behind the study, and that their anonymity is secured. Furthermore, a questionnaire should not be too long and its layout should appear pleasant and conservative, and it is important to send out reminders. Questions should be short, only contain one question, and double negatives should be avoided. It is also important to strive for everday language, avoid leading questions or value-laden words. We used a 5-step Likert scale with a neutral option, so our data are ordinal. We could also have chosen to omit the neutral option, however Garland writes that bias might occur both with and without the neutral option and we did not want to force our participants to have a specific opinion, thus it was essential to keep the neutral option [45]. The questionnaire aimed at investigating students' views in respect of the three hypotheses, and the questions were coded as primarily associated with one of these three.

For the analyses, an initial examination of the significant differences in how the students from AD and CS and SE answered the single questions was carried out. Since Computer Science and Software Engineering programs are quite similar (as explained above), the students from these two programs were treated as one group when compared with AD. A chi-square test that combined the categories "completely agree" and "agree", as well as "completely disagree" and "disagree" was used. The only significant (alpha = 5%) difference appears for a question about the original project unit courses: "I had to read ahead in the project unit courses since what we needed for the project came later in the course" ($c^2(1, N = 14) = 10.08$; $p = 0.01$). CS and SE students significantly agreed with this question more often than the AD students. For all the other questions, all answers were treated as one group. When comparing all the students' attitudes to a before and after situation, the answers are not independent and we do not know the distribution of the population. The non-parametric Wilcoxon Matched Pairs Rank test (2-tailed) was used to compare the ordinal data in dependent samples in the before and after situation.

5. Results

The students' responses in terms of the three hypotheses are presented and discussed below. The presented data analysis is mainly statistical findings from the survey, but supplemented with the analysis from the focus group interviews. The relatively low response rate puts a limitation to how sure we can be that the answers represent all students. Furthermore the low number of answers also means that the risk of type 2 errors is high, *ergo* that we may not always be able to observe a difference in how students perceive the two PBL models, even when in fact there is a difference.

5.1 Relevance of the courses for the project

One of the questions aimed at exploring to what extent the project unit courses in the original AAU PBL model were, indeed, useful for the project

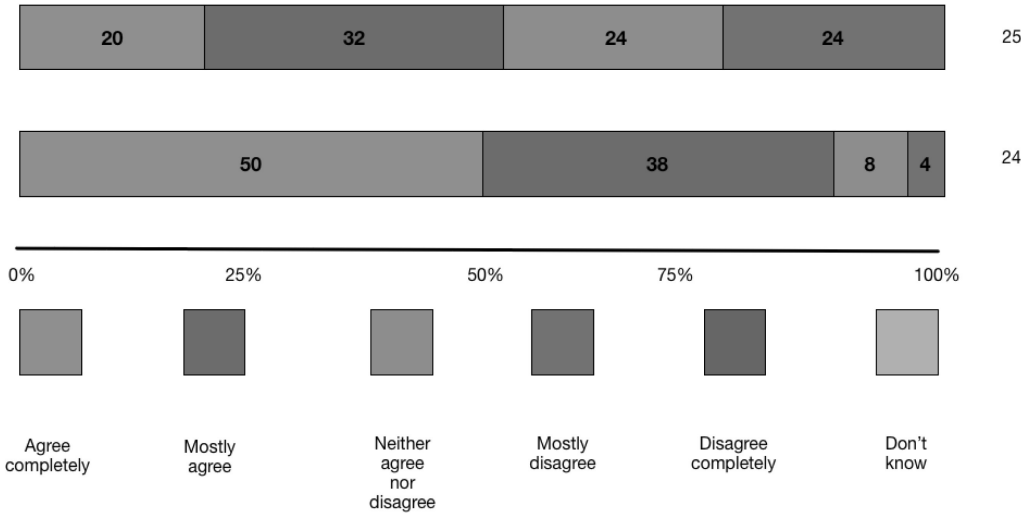

Fig. 3. Question: Some (project unit) courses were not used in the projects? Before (top), now (below).

(which was the intention of the courses). We asked a similar question about the courses in the new AAU PBL model (see Fig. 3).

There is a significant difference between then and now ($z = -2.49$; $p = 0.013$). For the original AAU PBL model, 52% agreed that some project unit courses were not used in the projects, whilst 88% agreed that this was true of the new AAU PBL model. On the one hand, this result shows that the change of models affected the extent to which the courses were used in the projects, which was also the intention of the new model. However, the question equally illustrates that in the original AAU PBL, the intention behind the project unit courses also sometimes failed since more than half of the students had experience of a project unit course that had not been used in their project.

One reason for this might be that, as stated above, some projects have a narrow theme and a close natural relationship to the courses and projects whilst other projects were broad innovation projects with a more openly defined project theme, hence the focus of the project could depart from the originally planned project unit courses. During the focus group interviews, the students explained that sometimes the lecturers changed the order of topics within the project unit course in order to accommodate the projects. Therefore, a question about this was added to the questionnaire. We saw an almost significant difference ($z = 1.78$; $p = 0.075$); 44% confirmed that this happened in the original AAU PBL model, whilst only 17% confirmed that something like this happened in the new AAU PBL model. This means that almost half of the students confirmed that the idea behind the project unit course, as something that helped with the project, was fulfilled. It might be remarkable that this also happens to a rather large extent in the new AAU PBL model where the idea of a "project unit" is abolished, hence there is no explicit principle of a relationship between courses and projects.

To further explore the relationship between the courses and the projects, we also asked if the (single subject) courses were relevant for projects in the same semester and in later semesters. In relation to whether the (single subject) courses were relevant for the project in the same semester, the answers were mainly positive (52% before; 46% now; $z = 1.3$; $p = 0.211$), whilst around a third chose the neutral option (32% before; 29% now). Hence, the difference between the original and new model is not significant. The same pattern is seen in the answers to the question of whether the (single subject) courses are relevant to projects in later semesters. Again the answers were mainly positive (60% before, 46% now; $z = 1.2$; $p = 0.230$), whilst around a third chose the neutral option (36% before, 29% now). The differences were not significant. Hence, looking at the study programs overall, both the original and new AAU PBL models ensured that courses and projects were well connected and even the single subject courses in the original model appeared to have been useful to the projects. Finally, some students told us in the focus group interviews that the teaching assistants or lecturers sometimes helped the students with the projects during the exercise time allocated for the (single subject) courses. We wanted to investigate if this occurred regularly since one could argue that this would ensure even more well-connected semesters. Here we saw a significant difference in the students' answers (60% positive before; 29% positive now; $z = 2.9$; $p = 0.004$). What might be remarkable is that even though the difference between the original and the new PBL model is significant, almost one-third of the students experience in the new PBL model that they received help to their projects during exercise time in the single subject courses (the course modules).

The importance of the connection between courses and projects was a further variable. The students were overwhelmingly positive in their answers to both models: 84% positive for the original model and 79% now, with 16% and 13%, respectively, choosing the neutral option. Hence, there are hardly any students for whom it is not important to experience semesters with a connection between courses and project. During the interviews, the students explained that they actually found the semesters in the new AAU PBL model well-connected and well-integrated. The students also explained that it was generally more difficult to gain overlap between project and courses in the later semesters since these semesters are more specialized. They found the idea of project unit courses more suitable for the bachelor part of the programs, not the master level.

5.2 Alignment between supervision, teaching, and project exam

Teaching is aligned when the learning outcomes are formulated as operative competencies, the examination measures precisely those competencies, and the teaching matches these competencies. Furthermore, the assessment system has a large influence on the students' motivation and learning. Therefore, the students were asked if the project supervision had emphasized the same things that were emphasized during the project exam. The majority answered positively both for the original and new AAU PBL models (respectively 52% and 92%; see Fig. 4). It appears that the alignment between supervision and exam is now even more aligned than in the original AAU PBL model.

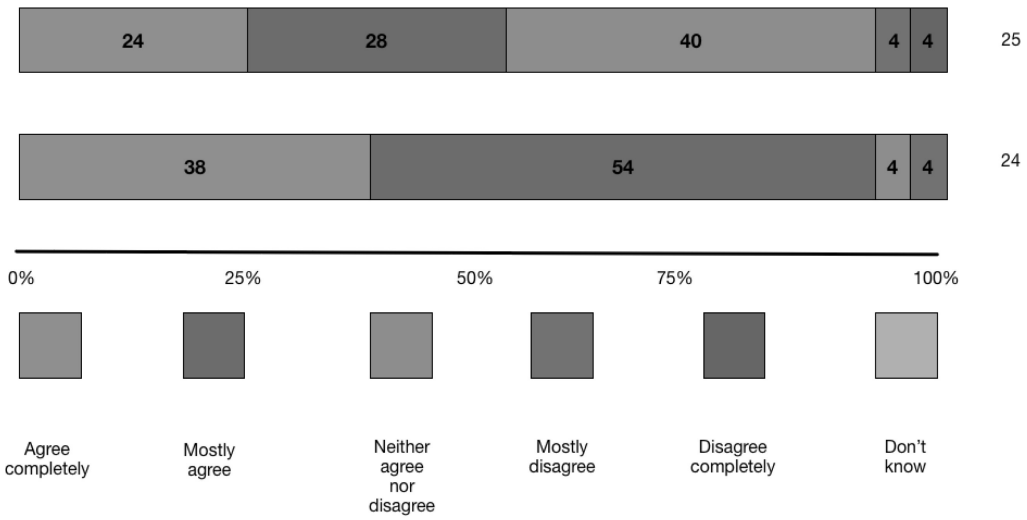

Fig. 4. Question: In the project exam, were the same areas emphasized as had been emphasized during supervision? Before (top), now (below).

On a question related to whether the project unit courses in the original AAU PBL model were only assessed to the extent they had been used in the projects, 76% answered positively. It might appear that the project unit courses were only rarely evaluated during the project exams. However, this also depends on how much of a project unit course was actually used in a project. An exam never assesses everything in a course, only a selection. If a project made use of 75% of a project unit course, the fact that 25% was not assessed during the project exam cannot lead us to conclude that the project unit course was not, as such, assessed. To dig deeper into this issue, the students were asked if they did not read up on topics from the project unit courses that had not been used in the project. Here, 72% agreed. Again, if the project had used 75% of a project unit course, it does not mean that the course, as such, was not assessed, but it confirms that this might reflect a complex relationship between the exam of the project unit courses in a project exam.

During the interviews the students confirmed that it was usually only the elements that had been used in the project that were assessed in the project exam. The students found that this partly made it easier to prepare for the exam, but they also believed that this meant that the examiner had higher expectations of them. It, therefore, appears that the students' behavior and experience fits with what the managers expressed in Kolmos and Holgaard [34, 35]. The students were also asked if they paid attention in the project unit courses since they did not always know what elements of the course they would use in the project; 56% agreed whilst 12% disagreed. It appears that the students still paid attention in the course, not because there was an exam but because they wanted to ensure that they took in everything that might be useful for the project. This may be an example of a situation where a missing alignment between the exam and the teaching does not affect the learning.

5.3 Priority of course exams in relation to the project exam

Prioritizing projects or courses during a semester before and after the reform was an important issue. In the original AAU PBL model, the project had a significantly higher priority than the courses ($z = 4.19$; $p < 0.0001$), the same is the case in the new AAU PBL model ($z = 2.85$; $p = 0.002$). Also, since the students were in their 10th semester, we assumed that they would be able to assess to what extent the courses and/or the projects were important for their education. Regarding the courses in the original and new AAU PBL models, 80% and 75%, respectively ($z = 0.17$; $p = 0.865$), found the courses important for their education. In terms of the project, the number who agreed was even higher; 92% and 96% respectively. Comparing the courses and projects in each of the two AAU PBL models shows that the projects were judged to be significantly more important than the courses in both models (before: $z = -2.61$; $p = 0.009$; now: $z = -2.47$; $p = 0.014$).

Similarly, change in students' behavior when the examination was approaching was a question. With regard to whether the project exam received the highest priority towards the end of the semester, the answers for the two PBL models were almost identical (before: 63% agree and 17% disagree; now: 58% agree and 21% disagree). On the other hand, in response to the question of whether the (single subject) course exams received the highest priority towards the end of the semester (see Fig. 6), we see

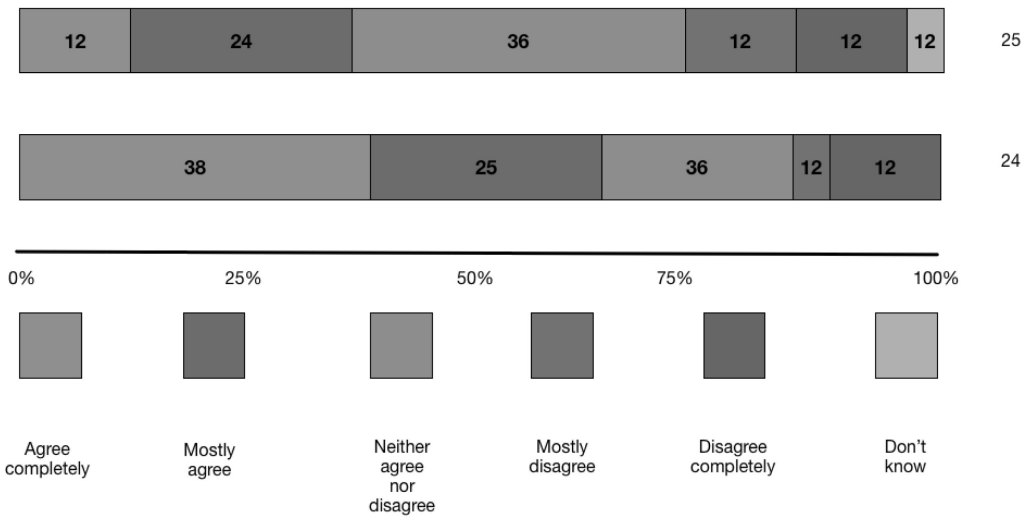

Fig. 5. Question: Do (single subject) course exams receive highest priority towards the end of the semester? Before (top), now (below).

an almost significant ($z = -1.85$; $p = 0.064$) change of answers (before 36% agree and 24% disagree; now: 63% agree and 17% disagree). The (single subject) course exams, therefore, receive higher priority now than in the previous model.

Thus, 58% agreed that after the reform the project exam received the highest priority towards the end of the semester, whilst 63% said the same about the course exams. One might note that the total percentage is higher than 100% but the reason may be that for some students all exams receive highest priority, which makes sense in everyday language. The difference is, furthermore, almost significant ($z = 1.83$; $p = 0.067$).

6. Discussion and conclusion

6.1 Conclusions

Three hypotheses were formulated for this study: that after the restructuring of the PBL curriculum at AAU, students would (1) experience the courses as less relevant to the projects, (2) experience a better alignment between teaching, supervision and project exam, (3) attach higher priority to courses than before, as seen in relation to the priority that they attach to the projects. Although the number of respondents is small and although these may conflate experiences from their bachelor program with experiences from their master's program, the results still raise some important issues for the construction of PBL curricula.

In relation to the first hypothesis, the findings indicate that some project unit courses were not used in the projects in the original model, and even fewer in the new AAU PBL model. This illustrates that the change of models affected the extent to which the courses were useful to the projects. Even though the project unit no longer exists, it is not uncommon that projects draw from material taught in the courses in the same semester, or previous semesters. It is also important to the students that a semester is connected and well-integrated but they have experienced less integration now compared with before. One might argue that this result is a given since one major change in the AAU PBL model was the abolishment of the project unit, hence it would be unlikely that the students would experience a more integrated semester in the new model than in the old. However, what is interesting here is the rather large extent to which the semesters are still integrated in the new model. This supports the earlier study with the managers, namely that this integration was secured through individual lecturers being willing to swap the order of subjects during a course. The study also shows, and confirms the statement from the managers, that in the original model, the project unit courses might not always have fulfilled their objectives.

In relation to the second hypothesis, there appears to be a larger alignment between supervision and exams today than previously. This might be due to the grade-scale stipulating the requirement for such a connection or it may be that the new project module has a more straightforward objective when it only covers the projects. According to the exam in the original AAU PBL model, the project unit courses were not assessed beyond what had been used in the projects. An interesting result here is that it appears that the students still paid attention to the courses, not because of an exam, but because the courses contain useful disciplinary knowledge for their projects. This might provide an example of a situation where a missing alignment between an exam and the teaching does

not affect the learning and where, if the students are engaged in the learning process, the exam does not determine their learning in a PBL system.

In terms of the third hypothesis, the survey shows that students always attach a high priority to the projects and it is clear that the students emphasize the project work to a large degree. It is interesting that the students now place more emphasis on the course exams than on the project exam. This might be a consequence of a more fragmented semester but it may also be the case that because more ECTS are now taken up by courses (and each course is larger in extent), a change to exam priorities might have been expected.

6.2 Discussion

The findings from the change to this PBL model might be quite interesting as educational researchers to a large degree refer to the constructive alignment hypothesis as a "basic rule" in higher education [13]. The results appear to demonstrate the accuracy of this hypothesis for the PBL curriculum as the students do react to more course exams and have to focus more on the courses in order to pass the exams. On the other hand, the findings also indicate that in a PBL system, exams might play a minor role if the students are engaged in the learning process. This is actually the case when implementing PBL in countries where national tests exist and academic staff have no possibility of influencing the exam system. By stating this, it is not claimed that constructive alignment does not apply as a theoretical frame for PBL curriculum, but only that there might be other factors influencing an outcome of a curriculum, such as engagement and motivation.

There may never be an ideal curriculum—there will always be advantages and disadvantages. However, the combination of the various curriculum components do have an effect on students' learning and no matter which PBL curriculum construction is developed, it is important to analyze the potential pitfalls for less engagement and learning.

A further, more general, question that can be raised from this study is concerned with whether everything should be assessed in a curriculum? In a PBL curriculum, there will be a larger differentiation between the learning outcomes at a knowledge and understanding level, which might be found in the courses, and the deep learning outcomes at an analytical level, which are associated with the projects. There is a basic belief that students only learn what is attached to an exam—and the results from this study actually indicate that this is not the case. The students in a PBL system might be more focused on the relevance of knowledge for the analysis and solution to the problems posed by their projects. However, in a PBL system there is a risk of educating learners who are too instrumental and only focused on the application and relevance of knowledge for their projects instead of the more general discipline education. One could say that this might have been one of the drivers for the change. Emphasizing the importance of disciplinary knowledge and the balance between disciplines and social context is a constant variable in the development of a PBL curriculum.

References

1. V. Shinde, Design of Course Level Project Based Learning Models for an Indian Engineering Institute—An assessment of students' learning experiences and learning outcomes. PhD thesis, Aalborg University, Aalborg, 2014.
2. A. Kolmos, R. G. Hadgraft and J. E. Holgaard, Response strategies for curriculum change in engineering, *International Journal of Technology and Design Education*, 2015, pp. 1–21.
3. E. de Graaff and P. A. Bouhuijs, *Implementation of problem-based learning in higher education*, Thesis Publishers, Amsterdam, 1993.
4. H. S. Barrows and R. M. Tamblyn, *Problem-Based Learning: An Approach to Medical Education*, Springer Series in Medical Education vol. 1, Springer Publishing Company, New York, 1980.
5. H. Hanberger, A.-C. Persson and B. Bergdahl, Web scenarios-building on reality and supporting the problem-based learning structure of an undergraduate medical programme, In *Proceedings of the 2008 European LAMS Conference: Practical Benefits of Learning Design*.
6. M. A. Dahlgren, *Portraits of PBL : a cross-faculty comparison of students' experiences of problem-based learning*, Linköpings universitet, Department of Behavioural Sciences, Linköping, 2002.
7. A. Kolmos, L. Krogh and F. K. Fink, *The Aalborg PBL model : progress, diversity and challenges*, 3 Printing, Aalborg University Press, Aalborg, 2004.
8. P. Bitsch Olsen and K. Å. Pedersen, *Problem-oriented project work: a workbook*, 1st edition, Roskilde University Press, Roskilde, 2005.
9. A. J. Neville and G. R. Norman, PBL in the undergraduate MD program at McMaster University: three iterations in three decades, *Academic Medicine*, **82**(4), 2007, pp. 370–374.
10. E .F. Crawley, et al., The CDIO Approach, in *Rethinking Engineering Education*, 2014, Springer US. pp. 11–45.
11. K. Edström and A. Kolmos, PBL and CDIO: complementary models for engineering education development, *European Journal of Engineering Education*, **38**(5), 2014, pp. 539–555.
12. D. Boud and G. I. Feletti, *The challenge of problem-based learning*, 2nd ed. Kogan Page, London, 1998.
13. A. Kolmos and E. D. Graaff, Problem-Based and Project-Based Learning in Engineering Education: Merging Models. In *Cambridge Handbook of Engineering Education Research.*, B. M. Olds and A. Johri, Editors. 2014, New York, NY, USA: Cambridge University Press. pp. 141–161.
14. B. Bernstein, *Class, codes and control*, Primary socialization, language and education, Routledge & Kegan Paul, London, 1974.
15. J. Biggs and C. Tang, *Teaching for Quality Learning at University*, 4 edition, Open University Press, Maidenhead, 2011.
16. G. Gibbs, Using Assessment Strategically to Change the Way Students Learn, in *Assessment matters in higher education: choosing and using diverse approaches*, S. A. Brown and A. Glasner, Editors. McGraw-Hill International, New York, 1999.
17. F. J. R. C. Dochy and M. Birenbaum, Alternatives in assessment of achievements, learning processes and prior knowledge. In *Evaluation in education and human services*, Kluwer Academic, Boston, 1996.

18. D. Boud and N. Falchikov, *Rethinking assessment in higher education: learning for the longer term*, Routledge, London, 2007.
19. M. Segers, F. J. R. C. Dochy and E. Cascallar, *Optimising new modes of assessments : in search of qualities and standards*, Innovation and change in professional education, Kluwer Academic Publishers, Dordrecht, 2003.
20. R. Barnett and K. Coate, *Engaging the Curriculum in Higher Education*, 1st edition, Open University Press; Maidenhead, 2004.
21. F. Dochy et al., Effects of problem-based learning: A meta-analysis, *Learning and instruction*, **13**(5), 2003, pp. 533–568.
22. S. Bell, Project-based learning for the 21st century: Skills for the future, *The Clearing House*, **83**(2), 2010, pp. 39–43.
23. C. Hmelo-Silver, Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, **16**(3), 2004, pp. 235–266.
24. K. J. Chua W.M. Yang and H. L. Leo, Enhanced and conventional project-based learning in an engineering design module, *International Journal of Technology and Design Education*, 2013, pp. 1–22.
25. H. S. Barrows, *How to design a problem-based curriculum for the preclinical years*, Springer Series on Medical Education. Springer, New York, 1985.
26. H. S. Barrows, A taxonomy of problem-based learning methods. *Med. Educ.*, **20**(6), 1986, pp. 481–486.
27. A. Kolmos and E. D. Graaff, Problem-Based and Project-Based Learning in Engineering Education. In *Cambridge Handbook of Engineering Education Research*, B.M. Olds and A. Johri, Editors, Cambridge University Press, pp. 141–161, Cambridge, UK, 2014.
28. M. Savin-Baden and C. H. Major, *Foundations of problem-based learning*, Open University Press, Maidenhead, 2004.
29. M. Savin-Baden, Using Problem-Based Learning: New Constellations for the 21st Century, *Journal on Excellence in College Teaching*, **25**, Oxford, Ohio, USA, 2014.
30. A. Kolmos, Reflections on Project Work and Problem-based Learning, *European Journal of Engineering Education*, **21**(2), 1996, pp. 141–148.
31. A. Kolmos and J. E. Holgaard, Responses to Problem Based and Project Organised Learning from Industry, *International Journal of Engineering Education*, **26**(3), 2010, pp. 573–583.
32. J. E. Holgaard and A. Kolmos, Group or Individual Assessment in Engineering, Science and Health Education, in *Research on PBL Practice in Engineering Education*, A. Kolmos and A. Kolmos, Editors. Sense Publishers, Rotterdam, 2009, pp. 57–69.
33. C. Brabrand and B. Dahl, Using the SOLO taxonomy to analyze competence progression of university science curricula, *Higher Education*, **58**(4), 2009, pp. 531–549.
34. A. Kolmos et al., Reconstructing the Aalborg Model for PBL. In *PBL Across Cultures*, F. A. Phang, Editor. Aalborg Universitetsforlag, Aalborg, 2013, pp. 289–296.
35. A. Kolmos and J. E. Holgaard, *Evaluering af ændringerne i PBL modellen pÅ TEKNAT AAU*. UCPBL UNESCO Chair in Problem Based Learning, Aalborg, 2012.
36. J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 4th Edition*, SAGE Publications, London, 2013.
37. M. Hammersley, *Reading ethnographic research: A critical guide*, Longman, London, 1990.
38. D. L. Morgan, *The focus group guidebook*, Focus group kit, Sage Publications, London, 1998.
39. A. Schutz, The stranger: an essay in social psychology. In *Studies on Social Theory* A. Brodersen, Editor. 1964, Martinus Nijhoff: The Hague. pp. 91–105.
40. M. A. Carey, The group effect in focus groups: planning, implementing, and interpreting focus group research, *Critical issues in qualitative research methods*, 1994: pp. 225–241.
41. S. Kvale, *Interviews : an introduction to qualitative research interviewing*, 3rd printing. ed., Sage Publications, London, 1996.
42. J. A. Krosnick, Response strategies for coping with the cognitive demands of attitude measures in surveys, *Applied cognitive psychology*, **5**(3), 1991, pp. 213–236.
43. D. D. Nulty, The adequacy of response rates to online and paper surveys: what can be done? *Assessment & Evaluation in Higher Education*, **33**(3), 2008, pp. 301–314.
44. A. N. Oppenheim, *Questionnaire design, interviewing and attitude measurement*, Bloomsbury Publishing, London, 1992.
45. R. Garland, The mid-point on a rating scale: Is it desirable. *Marketing Bulletin*, **2**(1), 1991, pp. 66–70.

Bettina Dahl (Søndergaard) is an Associate Professor within the field of mathematics and engineering education in the Department of Planning at Aalborg University. She has a Danish Candidate degree (M.Sc + B.Sc.). in Mathematics from Aalborg University, a M.Sc. in Educational Research Methodology from University of Oxford (UK) and her Ph.D. is in Mathematics Education from Roskilde University (DK). Dr. Dahl Søndergaard is now affiliated to the Aalborg Centre for Problem based Learning (PBL) in Engineering Science and Sustainability under the auspices of UNESCO (UCPBL). Previously she was Associate Professor of Aarhus University (DK) working with e.g. educational development at higher education within the fields of science and mathematics. Before that she was Assistant Professor at Virginia Tech (USA) working with mathematics teacher training for middle schools and high schools and before that she was Advisor at the Norwegian Centre for Mathematics Education at the Norwegian University of Science and Technology where she e.g. worked on developing the first national tests in mathematics for the Norwegian compulsory education. Her recent special responsibility at UCPBL is research on assessment, educational development at the Faculty of Engineering and Science and PBL introduction to students at the faculty. She has published more than 100 publications related to this field.

Jette Egelund Holgaard is an Associate Professor within the field of Sustainability, Technology and Organizational learning at the Department of Planning; Aalborg University. She has a M.Sc. in Environmental Planning and a Ph.D. in Environmental Communication. Both degrees are from Aalborg University. Dr. Holgaard is now affiliated to the Aalborg Centre for Problem based Learning (PBL) in Engineering Science and Sustainability under the auspices of UNESCO, where she has the special responsibility of making use of a PBL framework to enhance engineering education and innovation for sustainability. She has published more than 80 publications related to this field.

Hans Hüttel is an Associate Professor in the Department of Computer Science at Aalborg University. He is a member of the Board of Studies for Computer Science at Aalborg University and was head of the committee that revised the degree programs in computer science and software technology in 2009-2010. From 2011 he was involved in drafting the guidelines for re-introducing group-based project exams at Aalborg University. His research interests are in the mathematical foundations of computer science including structural operational semantics of programming languages, process calculi, type systems – and in computer science education. Hans Hüttel received the Teacher of the Year award at Aalborg University in 2014 and is a member of DUN (Danish University Teachers' Network).

Anette Kolmos is a Full Professor in the Department of Planning at Aalborg University and the Director of the Aalborg Centre for Problem-Based Learning in Engineering Science and Sustainability. Her other portfolios include those of Guest Professor at KTH Royal Institute of Technology, Guest Professor at UTM University Technology Malaysia, Associate Editor for the European Journal of Engineering Education and formerly those of Associated Editor for Journal of Engineering Education (ASEE) and President of the European Society for Engineering Education. She was awarded the IFEES Global Award for Excellence in Engineering Education in 2013. Over the last 20 years, Professor Kolmos has carried out research on the development and evaluation of project based and problem based curriculum, change from traditional to project organized and problem based curriculum, development of transferable skills in PBL and project work, and methods for staff development. She has supervised 13 PhD projects and published over 200 journal articles.