Int. J. Engng Ed. Vol. 26, No. 3, pp. 573–583, 2010
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Responses to Problem Based and Project Organised Learning from Industry*

ANETTE KOLMOS and JETTE EGELUND HOLGAARD
Aalborg University, Fibigerstraede 13, DK-9229 Aalborg, Denmark. Email: ak@plan.aau.dk

In this article problem based and project organised learning (PBL) is studied as an educational model to enhance student centred learning in alignment with the prevailing innovation practice. From a theoretical point of view, theories of experiential learning and innovation are combined, and empirically the Danish case is taken as an example investigating how employers respond to PBL models in Engineering and Science Education in general and team-based assessment in particular. The conclusion is that in general Danish employers highly value PBL in engineering, which speaks for PBL as a good example of combining student centred learning in an educational context with innovation practice in an industrial context. In particularly, employers seem to be ready to defend a coherent PBL system with team-based assessment as core educational elements. However, employers also stress a need for increased integration of business models into future engineering education, which poses new challenges to the development of PBL models.

Keywords: PBL, problem and project based learning, innovation.

1. INTRODUCTION

ENGINEERING IS A profession with traditionally close links between engineering education and the work place. Therefore, employers are important stakeholders for engineering education and their response should be taken into account for its enhancement. In Denmark, many engineering institutions practice a problem based and project based (PBL) curriculum, and in recent studies on team-based assessment, company responses turned out to defend these teaching and learning methods in engineering education. The fact that Danish industry is characterised by small and medium-size enterprises (SMEs) with limited resources to research and development (R&D) has created good conditions for collaboration between engineering education institutions and industry. The political framework has supported this development, but in 2007 it was decided to ban team-based assessments causing disturbance to the established triple helix harmony related to engineering education. In this article we will first develop a theoretical framework combining theories on innovation and experimental learning, identifying PBL as a good example of this approach. Next we will present studies on employer responses to PBL in engineering education in general and team-based assessment in particular.

2. THEORETICAL FRAMEWORK

As noted by Henriksen [1], engineers are not, and should not be, unconscious upholders of systems they do not understand. They should be creative architects of technological systems. However, the processes by which technological systems emerge are complex in terms of emergence and diffusion of knowledge and production processes reflect the complexity by complicated feedback mechanisms and interactive relations [2]. In an era of globalisation, driven by swift advances in communication, information technology and transportation, organisational patterns of companies have become more flexible; partnering arrangements with other firms have become commonplace, and participation in worldwide distribution networks has become essential for doing business [3]. In the late 1980s and the 1990s, innovation researchers conceptualised a network approach [4] or a system of innovation approach [2] to characterise these complex innovation processes.

The network approach stressed that innovation should not be seen as a product of only one actor but as a result of the interplay between two or more actors [4]. This does not mean that the individual contributions to the innovation process are not important. Rather the individual contributions can be seen as pieces of a puzzle—each contribution is crucial, but by themselves they are insufficient to fill in the whole picture when confronting the challenge of innovation. This is underlined in the system of innovation approach, which was already introduced as a conceptual understanding in 1988 by Lundvall [2]. The system of innovation approach can be further described in the following way:

> The innovation process is characterised by complicated feedback-mechanisms and interactive relations involving science, technology, learning, policy and

* Accepted 17 January 2010.

> demand. Innovation processes occur over time and are influenced by many factors. Because of this complexity, firms almost never innovate isolated. In the pursuit of innovation they interact with other organisations to gain, develop and exchange various kinds of knowledge, information and resources [2].

Etzkowitz and Leydesdorff have criticised the system of innovation approach for assigning the leading role of innovation to the companies, and they argue instead for a Triple Helix model of University–Industry–Government relations emphasising the importance of the tri-lateral network relations [5]. The triple helix serves as a theoretical framework for establishing what in practice can be described as one of the major challenges universities are facing in the 21st century—to change the institutional framework in order to step out of the ivory tower and become entrepreneurs, as Etzowitz et al. puts it [6], and at the same time obtain integrity and independency.

A complementary development, from an individual to a more collaborative perspective, can be found in educational research in the experiential learning tradition based on the influential work of Dewey [7] and Negt [8]. In the mid 1980s, Kolb [9] contributed significantly to experiential learning by modeling it, which later authors like Dixon [10] have drawn on and developed a theory of organisational learning. According to this perspective knowledge of the individual has to be seen in relation to the knowledge of other individuals; knowledge is collected, diffused, integrated, negotiated, developed and brought into action though mutual interplay with the surrounding environment [10]. At the same time, Wenger [11] introduced his theory on communities of practice, characterising communities by mutual engagement instead of organisational structures, leaving more room for what the organisational theorist Scott [12] has termed the open system approach.

More recently, researchers with an interest in both innovation and learning processes utilized these complementary developments to stress the need for alignment of lifelong learning and innovation in a globalised economy.

Nonaka and Takeuchi [13] conceptualised organisational knowledge creation as a process that: 'organisationally amplifies the knowledge created by individuals and crystallises it as a part of the knowledge network of the organisation'. This process takes place within an 'expanding community of interaction which cross intra and inter organisational levels and boundaries' [13:59]. Furthermore, Nonaka & Taukeuchi [13] have stressed the importance of acknowledging tacit knowledge in the innovation process.

Hakkarainen et al. [14, 15] propose a knowledge-creation metaphor emphasising learning as a collaborative effort to enhance expertise in some subject matters, which fundamentally relies on the interaction between individual and communal processes. In this way, learning is not only knowledge acquisition or participation in a social community; it is also about knowledge creation. This notion provides a way of thinking about the genesis of new knowledge as well as providing an approach for examining learning in terms of social structures and collaborative processes that support knowledge advancement and innovation.

Saywer [16, 17], working in the field of collaborative learning, states very clearly that collaborative learning is fundamental for innovation as:

> No single actor comes up with the big picture, the whole plot. The play emerges bit by bit. Each actor, in each line of dialogue contributes a small idea. In theatre, we can see this process on stage; but with an innovative team, outsiders never see the long chain of small incremental ideas that lead to the final innovation. Without scientific analysis, the collaboration remains invisible. Successful innovations happen when organisations combine just the right ideas in just the right structure [16: 14].

To create this appropriate web of ideas, Saywer argues that every idea is perceived as an extension of another, and individual creative actions take on meaning only after they are woven into other ideas. The social interaction in teamwork thereby becomes crucial for the innovation process. If the individuals of the team cannot situate their knowledge and express it in meaningful ways, or if they are not capable of understanding and elaborating on other team members' knowledge, the collective knowledge base for innovation is not activated.

Inspired by Wenger [11] and Saywer [16], we define teamwork as the process of activating and developing a collective knowledge base following a shared engagement, and a team as the group of individuals sharing this engagement. From that definition teamwork skills can be defined as the individual's ability to express their knowledge, internalise impressions from others and elaborate on other team members' knowledge (extend ideas) to bring cognitive schemas together and create what Dixon has termed collective meaning structures [10]. These meaning structures are materialised in the product or process innovation by the process of reification, a process described by Wenger [11] with reference to Berger and Luckman [18].

Like any other skills, teamwork skills have to be facilitated through learning processes. Studies show that teams have a performance curve that ranges from a working-group level which is a group of individuals, and goes through several steps before becoming a real and high-performance team with complementary skills and members who are equally committed to common goals and working approaches [19].

To sum up, the attention toward teamwork skills in order to foster innovation has developed parallel to the technological development and the globalisation of economy. In educational research, the same attention towards collaborative learning has developed based on a constructivist and experience-based learning perspective. One of the philosophies and methodological frameworks derived from that theoretical framework is Problem Based Learning.

Therefore, we will now address PBL as an educational strategy for innovation and its value to employability within the engineering profession.

3. PBL AS A STRATEGY FOR INNOVATION AND EMPLOYABILITY

Over the last 40 years, PBL has been implemented all over the world. Research has shown that PBL has turned out to be an efficient method for students to achieve new types of process skills (such as collaboration, project management, creativity and communication), increase students' motivation for learning, entrepreneurship, and collaboration with society and enhance regional development [20–24].

However, PBL is not just one model—nor is PBL just one type of educational practice. Since the start of PBL universities in the late 1960s and early 1970s, research on the PBL practice has shown that the PBL models have developed incredibly since the traditional Danish PBL models and McMaster and Maastricht models in medicine were established, as discussed by Kolmos, Graaff and Du [25].

A second wave of mixed models have also been developed that take into account cultural diversity and been applied in diverse subject areas such as health, science, engineering, social science and humanities. Graaff and Kolmos [20, 21] have formulated a set of learning principles common across the Maastricht PBL model and the Danish PBL models. Based on an analysis of problem based and project based practices and the underlying learning principles, they have formulated PBL principles that can be captured in three approaches: learning, contents and social. The **learning approach** is characterised by the *learning organised around problems* and *carried out through the use of projects.* The **contents approach** is characterised by problems becoming more complex, *interdisciplinary* knowledge crossing traditional subject-related boundaries and needing to use new methods. The **social approach** centres on team-learning. *Team-learning* underpins the learning process as a social activity; learning takes place through dialogue and communication. The social approach also covers the concept of *participant-directed learning,* which indicates a collective ownership of the learning process and, especially, the formulation of the problem.

The changing conditions due to the increasing globalisation create new challenges and possibilities for PBL as an educational model within engineering and science. First of all, increased interaction in global networks makes room for communities of practice engaged in applying PBL to the context of emerging economies. Secondly, the technological development of information technology provides different opportunities in educational design. Third, as pointed out by Giddens [3], globalisation is not restricted to large, global systems. It might also be reflected in closer regional public-private partnerships which see the collaboration with local educational institutions as a mean to strengthen the competiveness on the global market. Fourth, the easy access to information and international collaboration might also result in other project types, as the so-called megaprojects. There are already examples of such megaprojects consisting of several student teams working together to combine elements in order to develop real complex technological systems [26].

Depending on the PBL practice, the employer perspective can be integrated into the students' PBL process in many different ways e.g. the identification of problems, project organisation, team aspects, solving practical problems, solving company problems, focusing on innovation processes and developing prototypes or real systems.

However, as there are different types of PBL not all problem-oriented projects lead to all of the above mentioned competencies. There is a basic distinction between study projects/discipline projects and innovation projects/problem projects. Study projects are projects within a discipline with clear subject objectives in order to acquire certain knowledge. Study projects can still be based on a problem; however, there is a limited frame for choosing one. Innovation projects are real problem based projects, where the students have to identity an unsolved problem, choose a methodology for analysing and solving the problem and create new solutions. Innovation projects represent new knowledge creation. The study projects fulfill some of the employers' requirements, however, not all of them. Innovation projects are more like what employers call real-life projects [20, 21].

A very important element in the curriculum is the assessment system. Gibbs [27] has indicated that assessments are the main drivers for students' learning and if the assessment system is not in alignment with the overall objectives, there is a disturbance and unintended learning approach. Therefore PBL will only address innovation and complexity if the assessment system supports these objectives.

4. RESEARCH QUESTION AND METHODS

Drawing from a theoretical framework combining theories of experimental learning and innovation we have argued for experimental learning in general and PBL models in specific in order to train engineers and scientist for innovation. To obtain empirical support for this argument, we have studied how employers respond to PBL in engineering education, taking the Danish case as an example. The Danish case is extraordinary of several reasons. The Danish Innovation system is characterised by many small and medium-sized enterprises and low-tech but relatively innovative firms regarding ongoing and local incremental change in products and processes; often combined with a high level of competence in industrial design and advanced organisational techniques and marketing methods [28]. As SMEs has relatively few resources for R&D per unit, there are clear incentives for collaboration with the state financed HE institutions. Even with a majority of SMEs and a private R&D spending below EU-average, the percentage of companies collaborating with higher education in Denmark is about average [28]. However, as the innovations activity in the Danish SMEs are often practical and experience based [28], it becomes crucial for higher education institutions to balance and mediate the synergic relationship between theory and practice. Students do not move from university labs to business labs—they move from university labs to experience based practice. This calls in specific for collaborative as well as contextual skills for the partners involved and a need for an educational model supporting the training of such skills to get students successfully involved in HE-industry collaboration.

Secondly, the Danish case makes room for investigating employers' response to PBL, as there has been a PBL practice for many years and employers have become used to engineering graduates who have been trained within a PBL environment. Over the last ten years in Denmark, there has been a change in the landscape of engineering institutions. It went from two engineering universities that offered both bachelor and master levels programmes and eight university colleges that provided only bachelor level programmes, to having four universities offering engineering educations at master level and three university colleges providing only bachelor level degrees. Despite the institutional merging, most Danish engineering institutions still incorporate elements of PBL into the engineering curriculum ranging from a small-scale approach to a large-scale approach. The types of PBL models that have been implemented have been very much influenced by the concrete model that Aalborg University practices; meaning that the type of projects, problem formulation, students expectations, resources and assessment are all found within the same type of PBL framework, see [29] for further elaboration on the Aalborg PBL model.

Third, the Danish case also shows potential for comparing employer's responses to PBL compared to more traditional education models. Most Danish engineering institutions have gone through a process of change and begun integrating some type of PBL approach—ranging from small-scale models to large-scale models. However, at the post graduate level, there are two institutions, Aalborg University and the Technical University of Denmark, which represent two opposite educational models: a PBL model and a traditional model.

Fourth, there have been particular studies on team assessment initiated by employer organisations due to the abandonment of this assessment method by the Danish government. Team assessment is a very important component of the Danish PBL model, and it is quite impressive that employer organisations have invested resources in studying this phenomena.

These considerations left us with the following research question for the empirical research:

How do Danish employers respond to PBL in engineering education in general and team assessment in particular?

Through this empirical material the following specific research questions will be addressed:

- How do companies assess PBL institutions compared to institutions that have a more traditional educational model?
- How do employers assess higher education's ability to align engineering education with companies' needs?
- How do employers react to changes in the PBL-model towards a more traditional model of education—following on the political intervention to prohibit team-based examination in Denmark?

In the next three sections these questions will be addressed one-by-one. We will draw on four studies, where it has been possible to access basic data, of companies' approaches to higher education. Data has been provided by the Danish Magazine Ingenioeren published by the Danish Society of Engineers, Danish Industry, Danish Association of Consulting Engineers, the Danish Chairs of External Examiners for Engineering Studies and Aalborg University.

5. DANISH EMPLOYERS' RATING OF INSTITUTIONS IN ENGINEERING EDUCATION

The weekly magazine Ingenioen from the Danish Society of Engineers has asked several times for industrial employers' opinions of engineering graduates' skills and knowledge. In earlier surveys, the magazine found that after considering a long list of skills and technical knowledge, Aalborg University seemed to be rated higher than the Danish Technical University [30].

In a recent study from Ingenioeren [31], companies are asked which engineering institution is the best in developing engineering education according to the needs of society and companies, see Fig. 1.

Figure 1 shows that Aalborg University is ranked as the university that answers best to the needs of the companies. This may not only be due to the PBL model, but also that the PBL model is combined with an extensive regional and national collaboration with companies. Not all of the students' projects include so called company

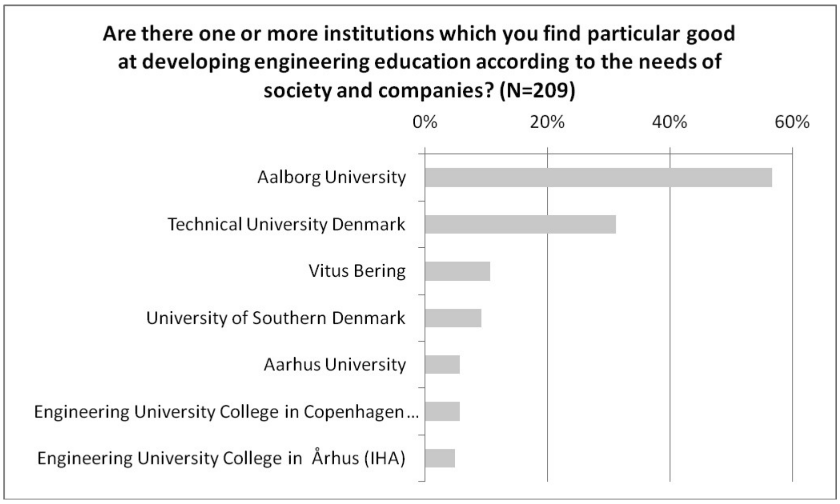

Fig. 1. Companies' ranking of engineering institutions according to innovation.

projects—but a substantial amount of the projects are either company projects or other types of community projects.

6. ALIGNMENT OF ENGINEERING EDUCATION AND COMPANY NEEDS

Danish Industry has conducted several studies among their members on employer perceptions of university alumni. One of the studies carried out in 2008 [32] represents 67 companies (response rate of 17%) by which only half the companies employ engineers. The alumni represent all types of educational programmes and universities and do not particularly address PBL-institutions. The overall aim of this study was to contribute to the political discussion concerning the development of higher education and formulate the industry's voice.

As can be seen in Table 1, Danish Industry has asked two comparable questions: In which areas do the graduates possess the strongest competencies and which of the competencies is aligned with companies' needs and the possibility for growth? Comparing these two types of data, there are two concerns: the ability to work in a solution oriented environment and the ability to communicate. In both aspects, PBL may be a solution for solving these types of requirements. Especially the transfer aspect, where students have to use a variety of theories for analyzing problems, should address such needs. However, project work does not necessary address practice at a business model level.

The recent study from Ingenioren [31] also addressed several questions concerning employers' responses to engineering education. Figure 2 shows that more than half of the employers want graduates to have more business models, project management and communication in the engineering curriculum.

Comparing the results from these two studies indicates that there is a desire from many of the companies that graduates achieve an understanding of business models and skills to work in a

Table 1. Comparison of strongest competency with needed competencies. Multiple choice

Competencies	In which areas do the new graduates possess the strongest competencies? N = 67 Possibility for multiple answers (149)	Which of these competencies is required by companies if the new graduates are going to contribute to the needs of the company and the possibility for growth? N = 67 Possibility for multiple answers (182)
To work project oriented	49%	27%
Ability to work analytically and systematically	30%	48%
Ability to participate in equal interdisciplinary collaboration	28%	18%
Strong professional knowledge	25%	33%
Ability to work solution oriented and transfer theory to practice (business models)	21%	54%
Creativity and innovation in solving professional tasks	19%	39%
Language	16%	9%
Understanding of cultures in relation to global market	9%	3%
Project management and ability to motivate others	3%	9%
Ability to communicate specifically and concisely—orally and written	1%	30%

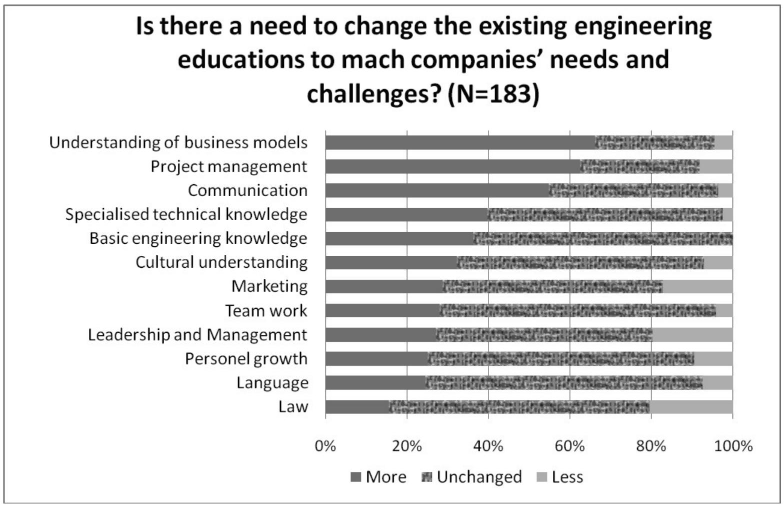

Fig. 2. Need for change in engineering education.

solution-oriented environment and communicate more effectively. The 2008 study from Ingenioeren [31] also stresses the importance of project management competencies. However, it seems that the studies from Ingenioren to a higher degree stress the need for the competency of working on projects when compared to the study from Danish Industry. This may be caused by the fact that the Danish Industry study includes all educational programmes, whereas the Ingenioeren study only considers engineers.

7. DANISH POLICY ON TEAM ASSESSMENT AND EMPLOYER RESPONSES

Assessment is a very important component of the PBL curriculum and there should be alignment between the intended learning outcomes, learning methods and assessment systems. There are many different ways of assessing problem based projects; however, in Denmark the traditional way has been to run oral team-based assessment session after submitting a final report. This practice has been more or less the same for all engineering institutions practicing PBL curricula and the oral team assessment has been rather comprehensive normally consisting of three types of elements:

- Students' presentation and reflection on the project and the final report
- General discussion of the chosen problem, design and methodology
- More technical questions addressed to individuals in the team

A team assessment session typically took five hours for a team of six students. The assessors, in accordance with Danish law, are the supervisor/facilitator of the project and in many of the exams an external examiner from another university or company. The role of the external examiner is to ask questions together with the supervisor/facilitator and to ensure fairness. All grades were based on the individual performance in the assessment session.

A purely individual system requires an assessment of the individual without the presence of team members after the submission of a team's common report. Students now have to defend the entire project at an individual assessment session without any of the peers from the team. The oral defence is between 35–45 minutes. As in the team assessment system the grade is individual.

However, since the Danish liberal government banned the assessment of students in a team setting, all assessments have to be carried out individually without any other students in the room (Governmental proclamation LBEK 280 of 21/03/2006). This has created strong reactions from the academic staff, external examiners and students regarding project exams. There has been heavy debate in newspapers, online discussion forums and on television. If you write in the two words, 'forbud' and 'gruppeeksamen' in Google (the Danish words for prohibition and team-based exam), you will get almost 7000 hits. Responses from both students and faculty staff showed a considerable resistance towards the new assessment system [33]. Because many of the external examiners are from companies, there were also strong negative reactions from Danish companies. In this article we present three studies on project assessment—two done by company associations and one by Aalborg University—focusing on the employer responses to the new inability to carry out team based project exams.

7.1 Danish Association of Consulting Engineers

The first study is carried out by the engineering organisation FRI (Danish Association of Consulting Engineers). FRI sent out surveys to members asking for their attitudes on the abolition of team assessments [34]. Fourteen (the equivalent of about 75% of the members when counted in total number of employers) of the largest engineering consulting

Table 2. External examiners' perception of old and new assessment systems.

	Old team assessment system N = 1092		**New individual system N = 1092**	
Did you differentiate the grades?	Yes 79%	No 21%	Yes 64%	No 36%
Was it difficult to differentiate the grades?	Yes 16%	No 84%		

firms answered the question: should the government reintroduce team assessments?

All 14 organisations answered that they felt it was a mistake to abolish team assessment in higher education and that they would recommend reintroducing this assessment method. They believe it is essential to be able to work in a team in real working life and to be able to collaborate with others. Only with team assessment is it possible to assess collaboration skills, and many of the additional comments argued that the consulting line is especially dependent on engineers' ability to collaborate. However, many of the respondents also indicated that the assessment of individual knowledge should be an integrated part of the team assessment.

7.2 External examiners

The second study was carried out by the chairs of the external examiners for engineering studies [35]. These are national groups acting as external examiners to all the engineering institutions in Denmark. The survey was sent out to 2081 external examiners and had a response rate of 53%. Of the respondents, only 29% are university professors and 71% represent companies. This study has a special focus on the individual assessment and individual grading.

The conclusion is that 70% of the external examiners do not regard the new individual assessment system to be an improvement and find that they do not have time to go into more depth with scientific questions. This conclusion corresponds to the results of a study on the different assessment systems' ability to capture a variety of engineering skills. Here it is pointed out that the individual assessment has reduced the project assessment to a control function, testing what is memorized, and neglecting the analytical, methodological and communicative skills that is used to solve technological problems [33].

Furthermore, the study shows that differentiating the grades is not easier with the individual system which was one of the key arguments in banning team-based exams. On the contrary, it seems that the majority of the external examiners found it was easier to differentiate the grades in the old system, probably because they were able to compare the students to each other, than in the new system where grades have to be given at the end of each individual assessment session, Table 2.

7.3 Aalborg University study

This study was designed by the use of questionnaires and has been documented in six Danish reports [36–41]. Questionnaires were distributed to students, external examiners and faculty academic staff at AAU (Aalborg University) and to academic staff at several technical university colleges. The questionnaire was distributed by email to all faculties at AAU in 2006 and 2008, whereas the 2007 investigation only included the faculties of Engineering, Science and Medicine. Although the survey was constructed to provide quantitative data, the respondents were asked to comment on their answers to obtain some qualitative data as well.

In general, when comparing external examiners' responses with responses from both academic staff and students, the external examiners were more positive towards the new individual-assessment system. However, if the group of external private examiners is compared to the external examiners from other universities, the private employers are significantly more positive towards team assessment than the public employers, see Fig. 3.

The immensely positive response from the external examiners for the team assessment may be grounded in the alignment of the philosophy in team-based assessment and the increasing focus on collaborative and team-based learning in industry. A qualitative semi-structured analysis of the comments from privately employed external examiners shows that the largest part of the comments are in favour of team assessment. There are four types of arguments stated:

First of all, it is argued that differentiating between grades is not made easier by the new system, as one of the respondents stated:

- 'The assessment is more random as you do not get a homogeneous overview of the individual qualifications, and you do not get an overview of the skills and creativity at all.'

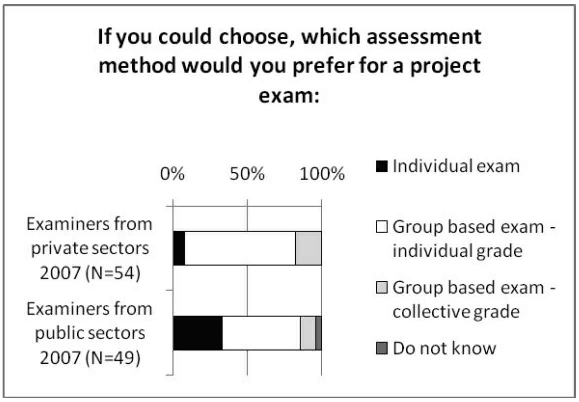

Fig. 3. The significant differences in preferences towards assessment methods between privately and publicly employed external examiners (Sig: 0,026).

- 'Compared with the team-based exam, the individual exam is, from my point of view, a poor alternative. The students have spent four months preparing a project, which has professional and maybe also contextual depth. It is almost rude to arrange a 30 minutes exam on that foundation. At a team-based exam the questions develop from the simple, reaching-out kind of questions to deeper specific questions. In a team setting, it is easier to assess whether a student is broadly founded in the whole project, than it is individually in the considerable shorter period of time. Directly opposite of the intentions, it is harder to differentiate the grades at an individual exam than in a team-based exam.'
- Individual assessment might give the best possibilities to judge each individual whereas the team assessment reflects reality in working life. The risk with a team assessment is that one judges the common product (reference to the project report and potential material product prepared by the team) and then how the individual performance differs from this instead of judging each individual on his/her own. Despite this risk, I think that if you have made a project together then you have to be assessed in that type of knowledge construction and be judged in relation to each other.

Secondly, it is stressed that the organisation of work in PBL is similar to the work organisation in companies, as the following quotes exemplify:

- In the real world we need candidates who can collaborate in the process of solving problems. In relation to this, the team assessment practice is a nearly perfect basis for judgement. Memorising knowledge is useless and should not be addressed at all at a university.
- I prefer team-based exams with an oral project presentation, and team examination and discussion followed by individual grading. The reason is that the students will later be part of real life where the ability to collaborate and enter into a creative dialogue is essential. This means that it is important to focus on the ability to express oneself individually as a part of a team.

Third, comments show a concern for the lack of discussion of the project and feedback to students. As one examiner states:

- There is only the minor possibility of giving general feedback on the project report since the individual examination focuses on the specific parts.

In relation to the lack of discussion and feedback, it is furthermore stated that in the individual assessment mostly control questions are asked, leaving very limited room for more innovative questions. This can be illustrated with the following quotes from the external examiners point of view:

- 'I am disturbed about this new assessment method as it makes the examination less smooth and makes it into a questioning process and not a learning process. As a person I get less professional gain by being an external examiner, as the discussion and the learning process of it—which very often was present with the previous assessment method—is now definitely out of the picture. It is also my guess that this goes for students and faculty examiners as well. After all, the students have put many hours into their project, and they have a lot of stuff they would like to communicate and try out at the exam.'
- As an external examiner I get the biggest challenge from challenging the entire team and not only one individual with all my questions, comments and ideas. Control questions are less challenging.

The results from both the open and the closed questions from our survey show that without a doubt, the majority of external examiners find the individual assessment method inappropriate for project exams. This is in line with the opinion from students and academic staff.

8. CONCLUSIONS AND PERSPECTIVES

The purpose of this article was to study employers' reactions towards PBL in engineering education. The Danish case was chosen first of all as PBL is dominating engineering education and at the same time different educational models within engineering education co-exist, but also because elements of PBL have been challenged and even banned in recent years. Furthermore, the authors have access to the raw data material from several surveys that address the reactions of employers to Danish engineering education.

The conclusion that can be drawn from these surveys is that competencies stressed as important for graduates if they are to contribute to company needs are: (1) The ability to work in a solution-orientated context and transfer theory to practice (understanding of business models), (2) the ability to work analytically and systematically, (3) the need for creativity and innovation in solving professional tasks. The fact that Alborg University is ranked as the top university in developing engineering education according to the needs of labour market together with its extensive PBL environment, it can be concluded that the PBL model is quite successful in aligning engineering education with companies' needs. PBL is regarded as a learning methodology that leads to some of the competencies that companies ask for and the fact that employers ask for more competencies such as communication and project management also points to PBL as a methodology for the future. Another challenge for the development of PBL is to relate PBL models to establish business models, since employers stress the need to change the existing engineering education to enhance graduates understanding of business models.

Also concerning the team assessment, employers stand up to defend the PBL philosophy as the government's prohibition of the team-based assessment system has been strongly criticised by business. Danish Industry, The Danish Chamber of Commerce, The Danish Association of Consulting Engineers and a long list of companies and external examiners have argued against the prohibition in the press, arguing that since the engineering profession is practised in teams, collaborative team skills should also be tested. The Aalborg study also shows that among the external examiners, the ones employed in the private sector are the strongest proponents of the team assessment. Again they argue for coherence between the team assessment and the working situation in industry.

The conclusion in this article to the overall question of considering how companies react to the PBL systems is that, in general, companies are positive to the graduates from PBL curricula and their competencies are highly valued. Furthermore, in the example of the government's prohibition of team-based exams, industry has shown to be some of the most vocal advocates for a PBL environment.

The innovation activity in the Danish SMEs are often practical and experience based, and this corresponds to the Aalborg PBL model, whereas the project work might take its point of departure in a practical problem; analysing the nature and context of the problem and bringing in theories when needed proposing suitable solutions. Furthermore, the social and learning approach embracing collaborative, contextual and methodological skills in the PBL model corresponds to the organisational flexibility and triple helix collaborations which is one of the key factors behind the competiveness of Danish SMEs.

For larger companies the interest for collaboration with university partners, and the incentive for supporting PBL may differ. However, to obtain the needed flexibility in organisational arrangements in the globalised economy the collaboration between partners and the management of stakeholder relations becomes even more complex; and the process skills provided in a PBL environment seems even more relevant. Collaboration with R&D environment in HE furthermore brings possibilities for long term strategic research with high economic risks.

Furthermore, for companies with extensive R&D activities, the universities are not only collaborative partners, but also suppliers of human resources. This implies competence to manage innovation projects in a globalised and intercultural environment which poses more challenges to the social and learning approach of PBL.

In this article we have focused on the synergic relation between innovation and PBL supported by a theoretical framework and empirical investigations of industry's response to PBL HE institutions. However, it is important to stress the need to go beyond the bilateral relation between academia and industry. As indicated by the triple helix Model of University-Industry-State relations, there are more to the P in PBL than defined by industry interests. The challenge of PBL models in the future is to strengthen the link to industry even further and at the same time uphold and provide students with academic integrity and contextual knowledge reflecting the complex interplay of science, technology and society.

REFERENCES

1. Henriksen, Lars Bo, *Engineers and Bildung*. P. 43-60 in: Engineering science, Skills, and Bildung. Edited by. Jens Christensen; Lars Bo Henriksen; Anette Kolmos. Aalborg University Press, 2006.
2. C. Edquist, *Systems of innovation approaches—their emergence and characteristics* pp. 3–15 in the book 'Systems of innovations—Technologies, Institutions and Organisations' edited by Charles Edquist, 1996.
3. A. Giddens, *Sociology*, 4th Edition, Blackwell Publishing Ltd, Cambridge UK, 2001.
4. Håkansson, Håkan: Introduction, pp. 3–26 in: *Industrial Technological Development—A network approach*, Håkan Håkansson (edit), Routledge, 1987.
5. H. Etzkowitz and L. Leydesdorff, The Dynamics of innovation: from National Systems and 'Mode 2' to a Triple Helix of university-industry-government relations, *Research Policy*, **29**, 2000, pp. 109–123, Elsevier Science B.V., 2000.
6. H. Etzkowitz, A. Webster, C. Gebhardt and B. R. C. Terra, The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm, *Research Policy*, **29**, 2000, pp. 313–330, Elsevier Science B.V., 2000.
7. J. Dewey, *Experience and Education*, Kappa Delta Pi, New York, 1938.
8. O. Negt, Soziologische Phantasie und exemplarisches Lernen. *Zur Theorie der Arbeiterbildung.* (Sociological Fantasy And Exemplary Learning. On the Theory of Workers' Education), Europäische Verlagsanstalt, Frankfurt A.M. 1968.
9. D. A. Kolb, *Experimental Learning—Experience as the source of learning and development*, Prentice-Hall, 1984.
10. N. M. Dixon, *The organisational learning cycle—How can we learn collectively*, Gower, 1999.
11. E. Wenger, *Communities of Practice—Learning, Meaning, and Identity*, Cambridge University Press, 1998.
12. W. R. Scott, *Organisations—rational, natural and open systems*, Prentice Hall, 1992.
13. I. Nonaka and H. Takeuchi, *The knowledge creating company*. Oxford University Press, Inc. New York, 1995.

14. K. Hakkarainen, T. Palonen, S. Paavola and E. Lehtinen, *Communities of Net-worked Expertise: Professional and Educational Perspectives*. Amsterdam: Elsevier, 2004.
15. K. Hakkarainen and M. Sintonen, Interrogative Model of Inquiry and Computer-supported Collaborative Learning. *Science & Education,* **11**(1), 2002, pp. 25–43.
16. K. Sawyer (ed.), *The Cambridge Handbook of The Learning Sciences*, Cambridge University Press, 2006.
17. K. Sawyer, *Group Genius—The Creative Power of Collaboration*, Basic Books, New York, 2007.
18. P. L. Berger and T. Luckmann, *The Social construction of Reality. A Treatise in the Sociology of Knowledge*, Doubleday, Garden City, N.Y., 1966.
19. J. R. Katzenbach and D. K. Smith, *The Wisdom of Teams*, The McGRAW-Hills, 1993.
20. E. de Graaff and A. Kolmos (eds), *Management of Change*. SENSE Publisher, Rotterdam, 2007.
21. E. de Graaff and A. Kolmos, Characteristics of Problem Based Learning. *International Journal of Engineering Education*, Vol. 19, No. 5, pp. 657–662, 2003.
22. M. Savin-Baden, *Facilitation Problem-Based Learning*, Society for Research into Higher Education and Open University Press, 2003.
23. B. Faland and M. Frenay (eds) (2006): *Problem and Project Based Learning in High Education: Impact, Issues, and Challenges*, Louvain-la-Neuve: Presses Universitaires de Louvain.
24. D. Evensen and C. Hmelo (eds), *Problem-based Learning—a Research Perspective on Learning Interactions*, Lawrence Erlbaum Associates Publications, London, 2000, pp. 227–250.
25. A. Kolmos, E. de Graaff and X. Du, *Diversity of PBL: PBL Learning Principles and Models*. pp. 9–21 in: Research on PBL Practice in Engineering Education. Xiangyan Du; Peter de Graaff; Anette Kolmos (ed.). Sense Publishers, Rotterdam, 2009.
26. J. D. Nielsen, X. Du and A. Kolmos. *A Knowledge Building approach for learning engineering: a case study of GENSO (student satelite) project*, in: Fink. F. ed. Quality Assessment Employability and Innovation, SEFI 2008, 36th Annual Conference, nr. 36, Aalborg, Sense Publishers, 2008.
27. G. Gibbs, *Using Assessment strategically to Change the Way Students Learn*, in Brown, S., and Glasner, A., Assessment Matters in Higher Education, The Society for Research into Higher Education and Open University Press, 1999.
28. J. L. Christensen, B. Gregersen, J. Johnson, B. Å. Lundvall and M. Tomlinson, *The Danish Innovation System*, Working paper, Department of Business Studies, Aalborg University, 2005.
29. A. Kolmos, F. Fink and L. Krogh (ed.), *The Aalborg PBL Model: progress, diversity and challenges*. In: (ed.), Kolmos. Anette; Fink, Flemming (ed.); Krogh, Lone (ed.). Aalborg: Aalborg Universitetsforlag, 2004.
30. Ingenioren: *Aalborg Ingenøren får top-karakterer af industrien* (Aalborg Engineers are top rated by Industry, By Henning Mølsted and Trine Reitz Bjerregaard. Published, Friday the 26th of March, Number 13, 2004.
31. Ingenioren: *Danske virksomheder peger op Aalborg Universitet som den bedste ingenøruddannelse i landet* (Danish companies point at Aalborg University as the best engineering education institution in Denmark) By Bjørn Kock Sørensen. Published, Friday the 30th of May, Number 22, 2008.
32. Dansk Industri: Medarbejdere i rådgivningsfirmaer (Danish Industry), Employers in consulting firms, carried out by Megafon, October 2008.
33. J. E. Holgaard and A. Kolmos, Group or Individual Assessment in Engineering, Science and Health Education: Strengths and Weaknesses, pp. 57–69 in: *Research on PBL Practice in Engineering Education*. Edited by Xiangyun Du; Erik de Graaff; Anette Kolmos. Rotterdam: Sense Publishers, 2009.
34. FRI (2007) Danish Association of Consulting Engineers, *data excerpt* of a study conducted by FRI among business representatives acting as external examiners. Main results published by Ingenoeren and Politikken 03. Sept. 2007.
35. Ingenioercensorformandskaberne (Chairs for external examiners within engineering): *Evaluering af eksamen baseret på baggrund af et gruppefremstillet produkt* (evaluation of assessement based on a team based project) Undersøgelse fortaget blandt samtlige beskikkede censorer inden for ingeniørcensorkorpsene. December 2008, Dec. 2008.
36. A. Kolmos and J. E. Holgaard, *Delrapport 1: Sammenligning af gruppebaseret og individuel eksamen sommer 2006 ved Fakultet for Ingeniør-, Natur- og Sundhedsvidenskab*. Dansk center for ingeniøruddannelse, 2007a.
37. A. Kolmos and J. E. Holgaard, *Delrapport 2: Individuel og gruppebaseret projekteksamen sommer 2006 og 2007 ved Fakultet for Ingeniør-, Natur- og Sundhedsvidenskab*. Dansk center for ingeniøruddannelse, 2007b.
38. J. E. Holgaard, A. Kolmos and S. H. Clemmesen, *ProjektGruppeEksamen: delrapport 3: Projekteksaminer ved Ingeniørhøjskolen Odense Teknikum, Ingeniørhøjskolen i København og Vitus Bering.* Dansk Center for Ingeniøruddannelse, 2008.a.
39. J. E. Holgaard, S. H. Clemmesen and A. Kolmos, *ProjektGruppeEksamen: delrapport 4: Individuel og gruppebaseret projekteksamen ved Humanistisk Fakultet, Aalborg Universitet. En sammenligning imellem gruppebaserede projekteksaminer 2006 og individuelle projekteksaminer 2008.* Dansk Center for Ingeniøruddannelse, 2008.b.
40. A. Kolmos, J. E. Holgaard and S. H. Clemmesen, *ProjektGruppeEksamen: delrapport 5: Individuel og gruppebaseret projekteksamen ved de Ingeniør- Natur- og Sundhedsvidenskabelige fakulteter (INS), Aalborg Universitet*. En sammenligning imellem gruppebaserede projekteksaminer 2006 og individuelle projekteksaminer 2008. Dansk Center for Ingeniøruddannelse, 2008.
41. S. H. Clemmensen, J. E. Holgaard and A. Kolmos, *ProjektGruppeEksamen: delrapport 6: Individuel og gruppebaseret projekteksamen ved Det Samfundsvidenskabelige Fakultet*, Aalborg Universitet. En sammenligning imellem gruppebaserede projekteksaminer 2006 og individuelle projekteksaminer 2008. Dansk Center for Ingeniøruddannelse, 2008.

Anette Kolmos Ph.D., Professor in Engineering Education and PBL and Chairholder for UNESCO Chair in Problem Based Learning in Engineering Education, Aalborg University. President of SEFI 2009-2011. Dr. Kolmos has a PhD in 'Gender, Technology and Education' (1989). During the last 20 years, she has conducted research in the following areas,: Change to PBL curriculum, development of transferable skills and faculty development. She is actively involved in developing profile of Engineering Education Research in Europe as well as internationally. She was first chair of the SEFI working group on Engineering Education Research. Dr. Kolmos is associate editor for European Journal of Engineering Education, SEFI and served as associate editor for Journal of Engineering Education. She is coordinator for the EU-project, Socrates project, PBL-Engineering which has developed the master programme: Problem Based Learning in Engineering and Science.

Jette Egelund Holgaard Ph.D., Associate professor at the Department of Development and Planning, Aalborg University, Denmark. She is a Civil Engineer within the field of environmental planning, and holds a PhD in Environmental communication. Her current research, in relation to engineering education, is focused on communication, organizational learning, and PBL & sustainability. She has been the head of study board for the basic education and is director for the Centre for PBL and sustainability.