

Using Problem Based Learning Methods from Engineering Education in company based development

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Abstract: This paper discusses how Problem-Based Learning (PBL) methods were used to support a Danish company in its efforts to become more of a 'learning organisation', characterized by sharing of knowledge and experiences. One of the central barriers to organisational learning in this company involved a lack of understanding for the work processes from one shift to another, and across departments. Through facilitated workshops focusing on problem-analysis and development of solutions, members of the organisation gained a greater understanding of the need for learning, as well as an increased motivation for sharing of experiences across organisational boundaries. The case also emphasises the importance of management involvement and support when attempting to develop a learning environment.

Introduction

It has become more of a norm than an exception in today's workforce to focus on learning and development, but often establishing practices that support organisational learning and development can be a challenge. In this paper, a case study is presented from a company wishing to establish 'a learning organisation' and to support the employees in changing their culture from just doing what to be told to acting independently. The overall aim of the company was for the employees to perceive themselves as an organisation of teams that not only functioned internally, but across team boundaries, so that they would be able to use and share knowledge and experiences across the whole organisation. An essential part of this creating this perception involved a process of breaking down barriers between departments and enabling channels for problem analysis and problem solving between teams. Rather than viewing these cross-functional activities as a one-time project, the company wished to initiate creation of a learning culture throughout the organisation.

Half of the employees in the case company worked in production on a three-shift basis. The shifts had been very engaged in teambuilding activities for some time and were driven by a desire to be recognized as the best shift within their respective departments. The way in which the shift members developed knowledge, shared experiences within their respective teams, and had a strong team identity is representative of what Wenger (2002) refers to as communities of practice. According to Wenger (ibid), a community of practice exists when individuals with regular interaction share a desire for learning, and purposefully direct their behaviour so as to support group learning. Further, legitimate peripheral participation (Lave & Wenger, 1984), or the process by which newcomers are brought into the community of practice, was accomplished through on-the-job training of new shift members.

On the other hand, there was a strong tendency for the teams to compete against each other, and each shift claimed to be the best. Due to both the competition to be recognized as the best shift within a department and/or in the production facility, there was no sharing of knowledge or experiences between shifts. For this reason, the individual shifts had become extremely isolated and they felt that it was difficult if not impossible to obtain support from the other shifts or departments in the company. Furthermore, it was very difficult for the shifts to cross the border to other departments when they had

to ask questions to get information or to solve problems which included a common understanding of the situation. So the company was characterized by isolated shifts/teams and very little communication and understanding among the different departments. Thus while the focus on establishing communities of practice within each shift enabled learning and knowledge sharing within the shifts, it had proved to be counterproductive in terms of supporting the type of learning organisation to which management aspired.

The study described in this paper was planned and executed in order to address this issue—in other words, to help the company become a learning organisation. Much of the study focused on providing the employees with an understanding of the importance of sharing knowledge and experiences between the shifts and the related departments, and at the same time focus on the development of learning and problem solving skills. Primarily, this process was accomplished through workshops that followed a Problem-based and Project Organised Learning (PBL) (Kolmos et al., 2004) approach, similar to that used in the engineering education at Aalborg University. The overall aim of one of the workshops was for the shifts and the connected departments to develop an understanding of their own learning process, how they could develop new knowledge in groups/teams and share knowledge with other shifts, an understanding of own role as part of a learning organisation, and a plan for developing different ways of crossing the border (e.g. get contact and understanding of departments with which they had to cooperate).

The paper contributes to both research and practice within the field of engineering education, as it demonstrates the utility of a relatively progressive approach to teaching and learning within engineering—namely, the use of PBL methods—in an organizational contexts.

Empirical Background

The research project was conducted during a period of five years in a mid-sized Danish processing company, which is a division of an international concern. There were approximately 250 employees, with more than half involved in the production activities. A very distinct division existed between the employees in the production compared to those performing the administrative and management functions within the company.

Due to many factors, the company had suffered the loss of its competitive edge and faced mandates to improve efficiency and effectiveness on all facets of its operations. The company culture was focused primarily on control and safety and there were numerous fixed rules and procedures connected to the work processes, especially those in the production area. Further, the culture rewarded reliability and “doing what you are told to do”. Most of the shift workers had worked more than 15 years in the company, and they were strongly socialized within their shifts to obey the culture. According to the company’s management, each shift had developed its own subculture within the organisational culture.

The question was how to establish an understanding among the employees and middle management of the organisation as a whole or as a team of teams, where sharing of knowledge and experience would be of vital importance. How could we design learning processes within the culture, without ruining the positive situation related to communities of practice (Lave & Wenger, 2002) established within the individual shifts, and also attempt to break through the borders created by those communities?

The Methods and Learning Theory Used in Workshops

The research team designed workshops for all teams, shifts and departments. The general approach to planning the workshops followed the Problem-based Learning (PBL) approach used in the Engineering program at Aalborg University in Denmark (Busk Kofoed *et al*, 2001). Central to this approach is the facilitation of experiential learning cycles (Kolb, 1984; Schön, 1984), which is discussed in more detail below. Further, due to the company’s desire to establish a learning culture, the activities planned for the workshop relied heavily on the idea of shared visions and common mental models developed by Stacey (2003).

On this theoretical framework, then, the overall goal for the workshops was to create a learning situation in which participants had the opportunity to develop, experiment with, and evaluate new ideas or solve problems associated with their daily work activities. A precondition for the learning

experience was that participants felt secure within the learning arena. For this reason, it should be stated clearly that "mistakes" were not only allowed – but even expected – as potential solutions to work related problems were tested in a simulated work environment. It was imperative that participants in the workshops would also be encouraged to view themselves and their co-workers as experts, each possessing unique ideas, talents, and skills, which could positively influence the learning in the workshop and the developing process. The workshop was inspired from and built on the ideas used in other pedagogical instances within the participative-socio-technical tradition (Rosenbock, 1980; Ehn, 1988 and 1992; Corbett *et al*, 1991 and for further description, see Busk Kofoed *et al*, 2000). This approach focuses on developing learning processes, with participants assuming responsibility and ownership for their own learning and the projects on which they want to focus in the workshop. At the same time, we chose to include aspects of specific competence development into the learning process, because we considered this development as an important part of taking responsibility not only for the daily work processes but also for initiating possible improvements.

Because it was critical for participants to assume responsibility for their own learning process and also for learning to occur in the context of real work issues, the participants themselves had to select existing problems from their daily work from which they would learn through analysis and formulation of potential solutions to find improvements. By centring the project exercises on their normal work functions, the participating teams could also gain experience in such areas as communication and problem-solving without fear of negative consequences on their productivity (DeGeus, 1997). Participants were told that the chosen project could, for example, be a new work method targeting aspects of an improved performance they wished to explore and possibly find solutions together for. This approach was based on project work and problem-based learning (Kolmos, 1996).

As previously mentioned, the theoretical approach on which the workshops was based was taken from Schön's theories about the reflective learner, combined with Kolb's (1984) learning cycle, which in the interpretation of Cowan (1998) and consists of four phases: 1) experience, 2) reflection, 3) generalization, and 4) test. In essence, this approach involves facilitated pre-planned reflections aimed at supporting the learning process. In other words, the workshop participants were facilitated in considering their previous experiences and the consequences of them (e.g. problems that had arisen) and the context in which these experiences occurred. Cowan (1998) considers the reflection as the central issue in the learning process, which is why he also describes his learning concept as "reflective learning". Schön (1978) distinguishes between reflection related to action and reflection related to experience, described as reflection-in-action and reflection-on-action. These types of reflection are mostly retrospective in their attempt to analyze actions for the purpose of using the gained experience and the deducted theories in future learning situations. Cowan then adds a third learning distinction, reflection-for-action which is a reflection typically made before starting a project. Our learning approach, based on Schön, Kolb, and Cowan, thus, encompasses 3 pre-planned reflection loops:

- Reflection – for – action
- Reflection – in – action
- Reflection – on - action

The workshops in this study were based on a model in which the following three processes operate concurrently:

- Project work: Group identification of a work related problem to serve as the focus for a project (problem based project)
- Group work: Participants actively working together as a group (group organized project work)
- The learning process: Learning processes with awareness of the meta-learning which supports development of individual and group problem-solving skills (learning how to learn), and a strong focus on pre-planned reflections.

The design and context of the workshops were very context dependent and all aspects of the organisational environment, including the company culture, political processes, and management style

largely dictate the possibilities available for the workshops. One significant way in which the environmental conditions affected the learning process concerned the practical arrangements of the workshop. Such factors as the resources the organisation could allocate to the activities in terms of time for meetings, space for the participants to meet, and the duration of time in which the workshop would be permitted all had a bearing on the course of the workshops.

The Process and Outcome of the Workshops

Participants in the different workshops formed groups and worked with a specific problem that they chose by themselves according to some given themes related to their work situation. Each project period consisted of three full workshop days where participants were introduced to the pedagogical model: how to work in a group, how to organize a project, how to choose a problem, how to analyse a problem, and how to find and test solutions. Participants also learned how to evaluate and present their solutions. The workshop was a mixture of lecturing, exercises and work with the projects. In addition, the groups were provided with supervision during the project period: each group had 2-3 meetings with a supervisor from the research group, and they were allowed to contact the supervisor and ask questions via mail or phone. During the supervisor meetings the groups reflected on the progress of their project and possible problems they wanted to discuss. Furthermore they also reflected on the cooperation and communication in the group as well as their learning process. The last subject was rather difficult until the research group developed a game about the theoretical learning aspect based on the Kolb learning cycle. (For further description see Busk Kofoed & Rosenørn, 2003).

Most of the groups developed quite good projects, and some of them were implemented immediately in the workplace. On this level, the PBL – learning experience could be seen as a success. Some groups even made a project about a plan for knowledge exchange between the shifts and between the shifts and the laboratory.

Still there was a major problem concerning a lack of communication between the departments and understanding of each department's problems. So the research group decided to make a special workshop with the aim of crossing the borders. This special action started with a workshop for representatives from each department, where a 'reflection for action' plan involving the following problems:

- Where are the borders to other departments?
- Which departments do we have to be in close contact with?
- What important information and knowledge are needed from the different departments so they understand our need and we understand their need?
- What do each department expect from the other department and what are the departments able to deliver according the common goals?

This 'reflection for action' was an eye-opener for all participants, including the representatives from the management group. They suddenly recognised why it was sometimes problematic for instance to get timely test results from one department. Another department also found that they had to be much more specific when they asked for information if it should be useful for a planning task. One department realized that they had not known what support they actually could get from the IT-department until they had participated in this exercise.

After this special workshop each department started to formulate a project to solve. They did their project work according to the previously learned PBL method, and quite quickly had solutions to be tested and implemented in their daily work. These included projects about an improved planning system for the production process and the planning department, and projects about how to share knowledge and information between three departments. One project was about efficiency at the laboratory, which had always received complaints. All departments wanted their test to be prioritised A1. When the different departments worked together on a solution they developed a priority system and recommended that an extra laboratory assistant was absolutely necessary. The management agreed with all the projects, and they were all implemented. A summary of the workshops is shown below in Table 1.

Workshop	Purpose	Methods	Outcome
Full day	Introduction to PBL; forming of groups; project orientation; methods for selection, analyzing, and solving problems	Lecture, group exercises (e.g. brainstorming for problem areas to be tackled)	Project groups formed and problem areas selected
Supervisor Meetings (1-2 with each group)	Provide "one-on-one" facilitation of development of problem solutions; to make group learning processes explicit	Facilitated reflection regarding methods, experiences, and their consequences (e.g. what is the difference between symptoms of the problem and root causes; how can all in the group contribute; how can ideas be further developed by full group participation)	Project groups learned to analyze and solve selected problem relevant to their work and gained understanding of group learning
Full day	Provide experience in communicating and presenting solutions, obtaining feedback	Lecture (e.g. effective communication, methods for providing constructive feedback), group exercises (e.g. presenting solutions, providing and receiving feedback)	Project groups gained experience in providing and receiving concrete feedback on problem solutions as well as experience in presenting their ideas
Supervisor Meetings (1-2 with each group)	Provide "one-on-one" facilitation to modification of problem solution, based on feedback and to discuss learning opportunities from having presented solutions	Facilitated reflection regarding methods, experiences, and their consequences (e.g. what type of feedback is most helpful, how can important issues be stressed more effectively)	
Full day	Summary of process, learning, and outcomes to support continued use	Lecture (e.g. review of methods and processes; summarizing of experiences across groups); group exercises (e.g. making list of most important lessons learned and methods to be used in future projects)	
"Special" full day	Facilitation of cross-boundary cooperation	Group exercises using PBL methods	Project groups gained an understanding of their co-workers work situation, including the tasks and demands they are subjected to, gained more respect for co-workers; developed practical projects involving cross-functional efforts and solutions

Table 1. Summary of PBL-based process with employees

The Role of the Management

One of the issues brought to light in this study was how important it was for top-management to understand the substance of the different problems experienced by the teams/shifts and to agree on the way we wanted to try solving some of these problems. In this case we wanted to introduce PBL as a method to get the employees to understand their own as well as the company's situation and to work out potential problem solutions. Therefore the management also had to learn about the PBL approach, so a special workshop was conducted for the top-management. This workshop was an eye-opener! The participants learned about PBL in the workshops described above, and through problem analysis and the use of other tools, management was able to recognize many of their own weaknesses and issues they had struggled with for years. For example, it suddenly became clear to some managers why they had a lot of unfinished projects, and that they needed to have much more focus on the financial aspects of management instead of only concentrating on innovation.

The important role of management in facilitating and supporting the development of learning within the organisation also became clear when a top management representative participated in each of the workshops held with the shifts, because this forum allowed for communication of top management's vision for the company. Moreover, the representatives' participation demonstrated management's commitment to establishing a learning environment, and emphasised learning as being vital to the company's long term success. Lastly, because the management representatives were involved in the workshops, the shifts were able to receive immediate feedback on their ideas and suggestions. This practice was new and rather difficult for the management because they lacked the communicative skills needed for providing constructive feedback, and they were not used to working with these types of projects (i.e. projects aimed at supporting continuous learning and process improvement). Facilitation of the feedback process provided the representatives with experience they would be able to use in the future.

The attitude of the top-management as well as the middle management was considered extremely important in this case study, because the employees understand this as a signal that what they are working with has big influence on the future of the company.

Conclusion

The aim of this paper was to present experiences with applying a PBL approach in an industrial setting, for the purpose of developing a learning environment characterised by sharing of knowledge and experiences 'across the border' between shifts and departments. Through workshops targeting problem analysis and problem solving, members of the organisation successfully developed and implemented a number of projects. Moreover, through this process, individual shifts that had been successful in adopting communities of practice behaviours related to exchange of learning experiences gained a greater awareness and appreciation for the work processes occurring in other departments or parts of the company. For the first time, they could also see that keeping knowledge within the team or the department only could be detrimental for the other departments, and that this would inevitably lead to poorer performance for both shifts/teams/departments. Thus they were able to recognize the negative chain effect from keeping knowledge within the boundaries of the individual shifts/teams. This awareness is viewed as being vital to the establishment of a learning environment, so that problem solving efforts are no longer hindered by functional boundaries and learning and exchange of experiences can benefit all areas of the company.

Perhaps more importantly, participation in the workshops provided employees as well as members of top management with an awareness of the importance of learning for the survival and success of the organization. Because all the workshop were based on the PBL approach, using concrete tools and methods to analyse and solve problems relevant to the employees' own work situations, the expectation is high that employees will be able to continue their efforts long past the completion of the study. During the project presentations they explained the problem to management, stating that they would like to continue to work with a project so they could find better ways to share knowledge and experience with the purpose of functioning better. In this process, the borders were very clear, but the teams were able to cross them as they continued to work together with other teams or departments.

Establishing the meta-learning processes gave the employees new identity and self-assurance. They became proud of being able to create knowledge that was important for other departments and the whole organisation.

The role of the top-management as well as the middle management in this change and learning process was also shown to be crucial for the success of the workshops. As soon as the top-management showed their interest by being visible it was very motivating. The additional learning for the top-management about the PBL method was very much appreciated, and they tried to continue with this process in new projects.

Although the focus of this paper is not specifically on engineering education, the methods by which the study presented were derived directly from the PBL approach to teaching and learning that is used in the Department of Engineering and Science at Aalborg University in Denmark. The two authors of the paper have extensive experience in using the methods within an academic context, but feel that gaining experience in a practical setting has enriched subsequent teaching experience. In addition, the teachers have been able to provide real world examples of how PBL can be applied in different settings, and this is apparently meaningful for students concerned with the relevance of certain teaching practices in their future careers.

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