PBL in Context – Bridging Work and Education

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THE STRATEGIC POINTS OF PROBLEM-BASED LEARNING
– organising curricula and assessment

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Problem-based learning (PBL) has been applied for over twenty years in different fields of education in many countries. The first and best-known applications of PBL are in the study of medicine during the1960s (Barrows 1985; Barrows 1996). Since then PBL has spread worldwide to other disciplines in higher education such as architecture, economics, engineering, mathematics and law. Problem-based learning has often been understood only as a method of learning. What distinguishes PBL as a teaching technique, as an educational strategy, or even as a philosophy are the changes in the whole learning environment that the approach requires. Defining PBL as an educational philosophy means holistically considering a number of elements: the organisational context; curriculum content and design; and the teaching and learning approach, including the method of assessment and evaluation.

Although problem-based learning has been investigated in the context of education, the theoretical basis of PBL is closely connected to learning in the work place. PBL runs the same risks as any other progressive pedagogical idea: the baby might be thrown out with the bath water. PBL can fail, for instance, because of mechanical application, or because no changes have been made on the curriculum level or because the assessment and evaluation system has not been developed in response to the new ideas about learning. In this article we examine the basis of PBL knowledge and the prerequisites for the development of curricula and for the assessment of problem-based learning. We conclude the article with the heading 'PBL – bridging work and education' which is the theme of the conference and of this book. The concluding chapter also provides an orientation to the articles in the book.

The basics of problem-based learning

The basic premise of problem-based learning (PBL) is that learning starts from dealing with problems that arise from professional practice. Traditionally, education has been organized according to the logic of separate disciplines and subjects. However, because professional practice and individual learning processes do not follow such divisions, this has led to a widening gap between education and professional practice in the work place (Boud 1985; Boud & Feletti 1991; Poikela, E. & Poikela, S. 1997; Poikela, S. 2003.) PBL gathers and integrates many elements regarded as essential in effective, high quality learning, such as self-directed or autonomous learning, critical and reflective thinking skills, and the integration of disciplines.

In epistemological discussion knowledge is usually divided into theory and practice. Theory is understood as propositional knowledge (knowing-what), and practice as procedural understanding (knowing-how) (Ryle 1949, Eraut 1994). In a broader sense the relationship between knowledge (what) and knowing (how) can be understood as a debate between Cartesian finite and Heideggerian changing knowledge. The former represents the modern idea of permanent knowledge and the latter the post-modern way of apprehending knowledge as changing and dependent on the context of the activity rather than on facts or truth. In PBL knowledge is seen as being more closely aligned to the post-modern than the modern view of epistemology. (Cowdroy 1994.)

Few scholars have attempted to distinguish between the epistemological and ontological dimensions of knowledge. However, Nonaka and Takeuchi (1995) do make this distinction. They argue that the epistemological dimension describes conversion processes from implicit (tacit) to explicit knowledge, and vice versa, from explicit to implicit knowledge. The result of this conversion is new knowledge and a new way of knowing and acting. The ontological dimension, on the other hand, describes knowing processes that take place between an individual, a group and an organisation. Cook and Brown (1999) also make the same kind of distinction between the mode of knowledge and the possession of knowledge. According to them, knowledge can be explicit or implicit and is possessed by an individual or a group. (Poikela, E. & Poikela, S. 2001.)

There are many conventional distinctions between what-knowledge and how-knowledge. The former is evident in expressing propositional or declarative knowledge, and the latter refers to procedural or practical knowledge. These dimensional distinctions are problematic because of the concept of *tacit knowledge*. Individual or shared knowing includes implicit, non-verbal and invisible elements, for example the skills of experts at a high level of competence. Tacit knowledge is hidden in the acting body and in the thinking mind (Zuboff 1988). Cook and Brown (1999) use the expression 'epistemic work' to describe the conversion of tacit knowledge into explicit knowledge and vice versa which takes place between the individual and the group.

Conceptual knowledge in a textual, codified or any other symbolic form is not the same as it is in the memory of an individual, a group or an organisation. Correspondingly, practical knowledge is not only in the possession of a professional, but it can be embedded in artefacts produced by humans or in objects of nature. So, knowledge from theory or praxis is objective because it is not dependent on an individual person (see Figure 1). From the point of view of the learner, practice and theory, like any other kinds of information, are sources of *potential knowledge*, the goal of learning outside her or himself. The integrative knowledge from and between theory and praxis is needed for constructing experience, the mode of subjective experiential knowledge,

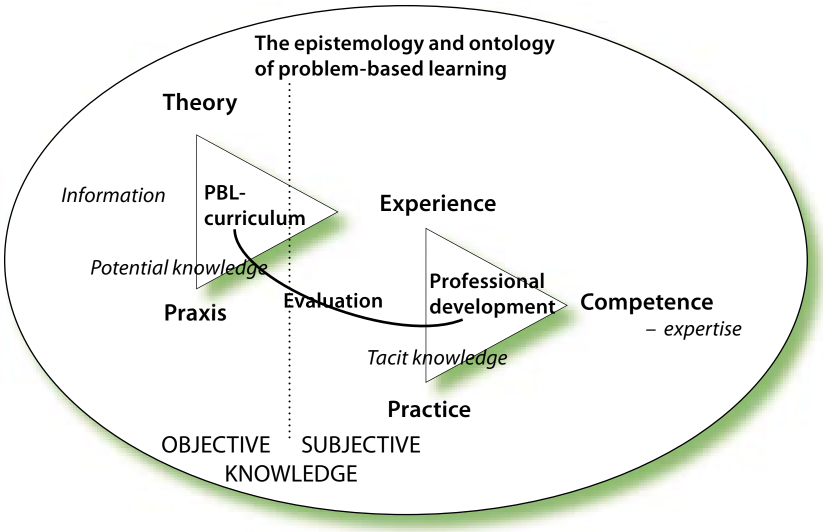

FIGURE 1. The contextual basis of problem-based learning

including the highly personal elements of *tacit knowledge*. Instead of the traditional two-dimensional description, a three-dimensional view of knowledge consisting of *theory, praxis and experience* should be adopted. Burnard (1987) had the same idea of three defining elements, but only on the subjective dimension: theoretical, practical and experiential knowledge.

In the traditional curriculum practical knowledge is separated from theoretical knowledge. It is impossible for the learner to integrate these two aspects into experiential knowledge. Learners are not able to apply theories and models in order to solve problems in practical situations, and knowledge implanted into the memory is easily forgotten. Correspondingly, emotional events are just experiences; there is no theoretical understanding. Conventional education fails in two areas: firstly, learners will not learn to solve problems in professional practice and secondly, they will not learn skills of 'learning to learn' which are essential in the climate of continuous change that characterises working life and professional development.

In Figure 1 the left-hand triangle depicts what can be achieved through a good education, and the right-hand triangle depicts those skills which can be learned through professional practice. Education itself cannot produce complete professional competence, but there should be an awareness of the dimensions and processes taking place between the *PBL curriculum* and *professional development*, and also pay attention to the meaning of tacit knowledge. *Evaluation* is the means of producing knowledge about those processes which occur between education and working life.

The use of PBL as a tool for the individual teacher has only minor implications for the curriculum, the method of assessment and the education system as a whole. However, defining PBL more as an educational philosophy means adopting a framework which holistically considers a range of elements: the organisational context; curriculum content and design; the teaching and learning approach – understanding PBL as a pedagogy; and the need to develop the curriculum as well as quality systems. This creates new challenges for developing assessment and evaluation at all levels of the curriculum process.

PBL as a strategy for curriculum development

From the postmodern point of view PBL is a strategic answer to the competence needs of the information society (Cowdroy 1994). These competences emphasise the skills of knowledge processing, communication, interaction and problem solving. The shift from knowledge to knowing is reflected in the demand for continuous learning and in the need to repeatedly develop or even change a professional orientation. Education has to be able to respond in a new way to the demands of knowing. It is not enough that education provides sufficient knowledge to be applied in professional practice; education itself has to be able to produce the core competences needed in the future.

A curriculum normally consists of certain points of departure, aims and principles formed by the particular ideology of a specific era. It forms a general reference point for discussion and working in the field of education. The basic principles of a curriculum also determine, how the learning environment is organised. (Goodson 1989; Bernstein 1990; Tompkins 2001). The essential characteristics of a PBL curriculum are:

a) The curriculum is organised around problems that are relevant to desired learning outcomes, rather than being organised according to topic or academic discipline.

b) The creation of conditions that promote small-group work, self-directed learning, independent study, contextual knowledge, critical thinking, life-long learning and self-evaluation.

c) The construction of a student-centred learning environment.

Students are allowed to recognise and find knowledge for themselves when approaching the problem and building a bridge between theory and reality (Hannafin & Land 1997). In PBL, knowledge is a subject for perceiving, analysing, integrating and synthesising than rather an object for memorising. Shared knowledge construction is an essential element for producing scientific and multi-professional competence. In PBL-cycles, individual learning (independent knowledge acquisition) and joint learning (setting learning tasks, knowledge sharing and construction in tutorials) are separate processes. Together, these processes can have a profound impact on the development of professional competence.

As a resource and catalyst of learning, the nature of knowledge is *contextual.* It is not only a conceptual, symbolic or formal fact, but it is embedded as potential in objects, artefacts, human activity or in the structure of an organisation. This explains why education should teach students to "read" the context of the future profession – the complex knowledge environment of work. At first sight this might appear to be a recipe for chaos, rather than a well-organized curriculum (see Figure 2). However, the development of this kind of competence does require an organised curriculum (Poikela & Poikela 2001).

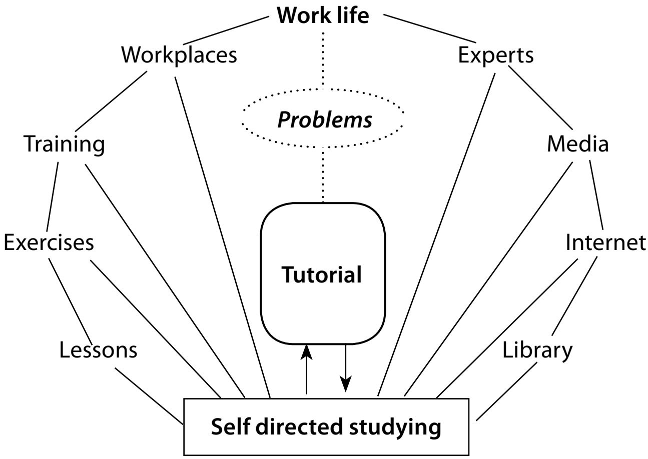

FIGURE 2. The PBL-curriculum as a knowledge and learning environment

The problem-based curriculum should be organised as a student-centered learning environment. In concrete terms, this means knowledge acquisition from books in the library and information seeking from the internet, the media and from professional experts in working life. It means that lessons and exercises in school are no longer causes of learning, but resources for learning. Training connected to workplaces and real work life is an essential means of achieving practical knowing in professions.

Organising evaluation in PBL

There is a common idea about the curriculum directing both teachers' work and students' work. Boud (1995) argues that the curriculum directs only teachers' actions not students' learning. The most powerful means for guiding students' work are assessment procedures. Traditionally, students are the objects of the assessment, which makes them feel controlled by teachers. Today, students are seen as subjects, not only in learning processes, but in assessment processes, too. This insight highlights the most important difference between traditional learning conceptions and problem-based learning.

The changing evaluation paradigm can be seen as a transition from scientific measurement towards judgemental (qualitative) assessment (see Hager & Butler 1994; Hager 1999). The focus of scientific assessment is only on results, which are measured as objectively as possible. With judgemental assessment, on the other hand, the focus is on the process of producing results. This means that subjective factors can be taken into account, too. Boud (2000) argues that assessment involves identifying appropriate standards and criteria, and making judgments about quality. The meaning and forms of assessment should be extended and seen as an indispensable factor in all forms of lifelong learning.

Esa Poikela (2003, 2004) identifies an analogical relationship between judgmental assessment and contextual analysis. According to Pettigrew (1985), the starting point of analysis is in the description of the process according to the external societal context and the internal organisational context. One of the tasks of analysis is to develop criteria for evaluating activity and its effects on the process. Poikela presents the idea of context-based assessment (CBA) which requires that situational and contextual factors are carefully considered. This offers a very broad perspective on assessment and also facilitates the development of quality systems.

Zones and mirrors for assessment and evaluation

The theoretical basis for developing ideas about contextual assessment and quality systems in problem-based learning can be found in experiential learning. This approach provides a framework and a starting point for further development and research, making explicit good practices and quality factors connected with evaluation and pedagogy.

According to Kolb (1984), reflective observation is an essential part of a learner's activities. In this way, it can be seen as a factor uniting the processes of learning and assessment. The learner is not only the owner of the learning process, but s/he owns the processes of assessment as well. The learner's ability to assess his/her own knowing is the most important factor in understanding and influencing the situation and the context of action. Process assessment creates a basis for guiding self-assessment and for assessing the outcomes or products of learning activities (see Figure 3).

The core of Figure 3 is the cycle of experiential learning with reflective observation as an essential part of the process. Self-assessment is the central zone of the core, process assessment is in the middle and product assessment is in the outer zone. Between them are the boundaries needed for developing the learner's assessment skills. Below, we examine this theoretical framework in the light of Sari Poikela's (2003) research results.

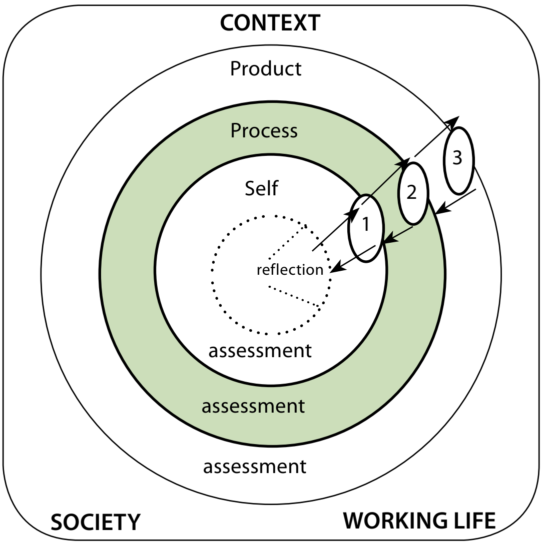

FIGURE 3. The mirrors of the assessment process

The first mirror

The boundary between self- and process assessment provides *a mirror* which helps learners to learn reflective skills for assessing themselves, their performances and their relations to other actors. The most essential mechanism for reflection is *feedback*. Learners can observe themselves and others in action with the help, for example, of the study or work journal. They can receive and consider instant feedback from the supervisor, other students or work colleagues, and from the peer group. Improving self-assessment and process assessment skills is important both for teachers and students. Because PBL demands skills of reflection, interaction and collaboration, effective tools for improving the quality of individual and shared learning processes are needed.

According the study, changes brought about by PBL prompted feelings of uncertainty in both teachers and students. The change and development had to be supported. Otherwise, there seemed to be a risk that both teachers and students would retain their former secure roles, with the result that the so-called change was little more than 'cosmetic'. Students had to be encouraged to take part in self- and group reflection, and these skills had to practised systematically in tutorials (group situations facilitated by a tutor). This was done via systematically given and perceived feedback: peer assessment between tutorial members and the tutor's feedback for individuals and the whole group. Tutorial members also gave feedback to the tutor. Feedback forms, learning journals and discussions were used in this process.

The second mirror

The aim of the mirror between process and product assessment is to examine the means involved in setting goals and the *criteria* for achieving them. Usually the setting of goals and assessment criteria is not carried out in cooperation with the learners. Rather, it is assumed that the learners' task is simply to accept them and act accordingly. In order to improve motivation, commitment and responsibility for reflective learning, the premises and means of assessment need to be made explicit and clear. Even if the criteria already exist, the learners need to recreate them in order to engage in the processes of learning and assessment.

The integration of process and product assessment in the PBL curriculum proved to be problematic. Finding the means of assessing learning outcomes was difficult. Tutors and students wanted to get rid off old methods of assessment such as book exams. 'Soft' means of assessment were desired. Although measuring learning outcomes is necessary, it has to be done in a harmony with the principles of PBL. The worst experiences for students occurred when assessment was conducted in a traditional way that undermined the credibility of the entire process of curriculum reform. Students were not involved in the process of creating the criteria for assessment. Teachers were unwilling or incapable of sharing the criteria they used with students or with colleagues. In this case, assessment still retained its old meaning as a means of 'power and control'. However, PBL demands transparency: processes of learning, facilitating and assessment need to be shared with and between students, teachers and experts.

The third mirror

The third mirror exists between product assessment and contexts (society and working life), meaning that learners are engaged in a process of relating their own actions and achievements to the requirements of working life and society. Employers are interested in the *knowing* and competence of the learner. They expect that employees are competent not only in technical skills, but also possess social and learning skills. The main question here concerns the examination system and the ability of an examination to measure exactly what is needed in working life.

The integration of product assessment within the context of working life is related to students' professional knowing and competence. Tutors clearly noted that students' professional skills started to develop during the process of education. This was also mentioned in the feedback students received from their training periods. Tutors realised, too, that to be able to guide students effectively, the facilitators in the work place needed to know the basics of PBL. Some of the tutors argued that students were so reflective and competent that they would not be able to use their full potential when they moved into working life.

Knowing can be characterised as a process involving decision making and problem solving while accessing increasing amounts of tacit knowledge located in individual, group and cultural knowing. As with explicit knowledge, tacit knowledge is owned not only by individuals, but by communities of workers and by the whole organisation. Measuring knowing is difficult because tacit knowledge becomes visible only in fluent personal or shared actions. Therefore, it is understandable that assessment is focused on measuring the outcomes of actions. However, this kind of assessment is ineffective from the point of view of learning. Learners are left alone with their difficulties because they do not receive enough information about their knowing. Those developing education are also left without the relevant information they require.

An assessment concentrated on measuring qualifications has its own mirror *only* between the products and contexts. This results in a control system focusing on the individual qualifications of learners secured by very detailed control. Instead of this, an assessment system based on generating learning and knowing provides an opportunity for examining learning processes in the whole education system, and for justifying the pedagogical changes needed. (Poikela, E. 2004.)

The principles and criteria of assessment and evaluation have necessarily to be described in the PBL curriculum. A useful theoretical tool for developing assessment practices within the frame of PBL is described in our paper as “zones and mirrors of assessment”. This enables further research and development of procedures of self-assessment, process assessment and assessment of outcomes, which benefits learners, facilitators, designers of curricula and developers of organisations.

PBL in context – bridging work and education

The aim of problem-based learning is build a bridge between working life and education. Research and evaluation is needed to examine how well this succeeds. Do PBL students gain better qualifications for working and professional life than students pursuing a so-called traditional curriculum? The next chapter, which is the second article of the book, provides one answer to this question. Researchers from the University of Linköping, Sweden compare how the students of a PBL program in Psychology and students from a conventional program in mechanical engineering manage the transition from education to working life.

The third article deals with a transition from conventional teaching to problem-based pedagogy. Using the metaphor of a journey, researchers of early childhood education at the University of Tampere, Finland analyse the obstacles, negotiations and solutions arising from a shift to a PBL curriculum. The fourth article by researchers from the University of Leicester, UK also deals with tackling obstacles encountered in using PBL, this time in the context of a Physics curriculum. PBL is applied in different ways and it is also rejected in many ways. Some of the difficulties may be self-made if the principles and criteria of evaluation are not placed at the heart of the curriculum.

The PBL curriculum offers knowledge and learning environments for students' shared and individual learning. It is also a learning environment for teachers in which they can develop their own understanding of PBL and improve their own skills in facilitating students' learning. The PBL curriculum is also a joint tool for teachers wishing to change the learning and teaching culture. If changes are made on the level of the curriculum, it is more likely that they are permanent. However, if changes are dependent on some individual teachers, they are more easily forgotten, especially if the teacher moves to a new workplace.

The fifth article describes the lessons learnt from applying PBL in Mechatronics at Lahti Polytechnic, Finland. Creating a curriculum according the principles of PBL and project-oriented learning means facing many kinds of difficulties. The curriculum has to be understood as a tool both for teachers and students. Also, the assessment of the learning process has to be valued at least as much as the evaluation of learning outcomes which dominated the earlier curriculum. The sixth article shows how PBL is implemented in engineering education at Turku Polytechnic, Finland. The feedback questionnaire from the trial program reveals how PBL tutorials guide students' homework compared to other forms of teaching.

The seventh article is written by researchers from the National Taiwan Normal University. They offer a view of the design and construction of problems in PBL teaching. Selecting a problem, designing actions, determining learning objectives and linking contents are described as the four main phases of constructing problems. The eighth article describes the adoption of the PBL model in Medical Education at the University of Tampere, Finland. This model is based on two well-known models: the seven-jump model from the University of Maastricht, and the cyclical or scenario model from the University of Linköping. The ninth article by researchers from McMaster University, recounts how PBL is applied in Medicine and especially how students' experiences are measured.

The best way to adapt problem-based pedagogy as a teacher is to gain first-hand experience as a learner in the PBL process. This is not easy because it involves the difficult process of changing one's own identity as a teacher. The tenth article describes how teachers in Dublin, Ireland experience PBL study as demanding fun, which is essential in shaping the identity of the teacher. The last article analyses the professional development from teacher to tutor as experienced by teachers of medicine (the Faculty of Medicine at the University of Tampere) and physiotherapy (the Department of Physiotherapy Education at the Pirkanmaa Polytechnic, Tampere). Analysis is conducted within the framework of theories of learning at work.

Building a bridge between working life and education requires that teaching and facilitating are seen as activities that support teachers' own learning and professional development. PBL does not simply coach students for the future; it has already become the future for many working teachers.

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THE TRANSITION FROM HIGHER EDUCATION TO WORK LIFE

the outcomes of a PBL programme and a conventional programme

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This longitudinal study focuses on the transition from higher education to work life. There is still sparse knowledge about how students in PBL programmes cope with the transition process. The transition is viewed as a trajectory between different communities of practice. Two different Master's programmes at Linköping university are focused and compared; Psychology and Mechanical Engineering. The Psychology programme has a PBL design; the Mechanical Engineering have a conventional educational design. The specific aims are to (i) identify aspects of identity and knowledge formation as reported by informants as senior students and later as novice workers with 18 months of work life experience. (ii) Identify features of discourses of knowledge and competence operating in the programmes and work life, and (iii) to relate the results to differences in the way the programmes are designed. The results indicate that the PBL-programme is preparing for work life in a rational way, both regarding generic skills and substantive knowledge. The conventional programme stand out as preparing for work life providing generic skills and by having a ritual character.

Introduction

The idea and role of universities as educational institutions has under the recent decades been debated intensely in relation to societal change and changing demands of work life (Barnett 1994). Besides, the percentage enrolled in higher education has been multiplied several times during this period. The working forms in universities have also been debated and at times critiqued internally. The increasing interest in student centred pedagogics in higher education during the last three decades could be seen as an expression of the universities ways of responding to these demands. There is growing awareness that not only the content of educational programmes, but also their design and forms of delivery may contribute to students' learning.

The relationship between higher education and work life is an area of research that has gained increasing interest among researchers during the last years (c.f. Brennan, Kogan & Teichler 1996). Research on the transition from higher education to work life includes both texts on a system level, reporting enquires on the match between the output of higher education and the societal demands for academically trained manpower, as well as studies on the expediency of higher education as assessed retroactively by professional novices.

A complicating factor when assessing the feasibility of study programmes with regard to requirements in work life is the lack of stable forecasts about the nature of future tasks in working-life and qualifications (Barnett 1994, 2000a). In a recent Swedish state survey about the new conditions for learning in higher education (SOU 2001:13), it is argued that work in qualified positions in contemporary work life requires a perspective on competence that besides specific knowledge and skills also includes abilities of independent learning as well as the ability of formulating, analysing and solving of problems. This includes an emphasis on accessibility, transferable skills, competency formation, modularization, student profiling and the development of reflective practitioners (Boud & Symes 2000, p. 16). Becoming professional includes engagement with a wider set of discourses, a responsibility that moves beyond the limits of a local professional-client transaction (Barnett 1997).

Johnston (2003) points at the fact that there is still little information in the research literature on graduate employment from the graduates' perspective. There is a need for research focusing on experiences of graduates in their early employment years, she argues, particularly as regards their working conditions and culture, the relationships between their higher education and work, fulfilment issues such as the nature and extent of their job expectations, satisfaction and commitment, and relationships between employers explicit expectations and graduates' experienced expectations.

A recent study by Kaufman and Feldman (2004) applies a symbolic interactionist perspective in researching senior students' experiences as regards the development of identity formation in the college years. The results show that the experience of college plays an important constitutive role in forming the felt identities of students. This was particularly evident in three domains; intelligence and knowledgeability, occupation, and cosmopolitanism. Within the domain of occupation, the interaction with peers stood out as an important feature in forming felt occupational identities. Kaufman and Feldman argue that college provides students the 'situational contexts within which a variety of identities may be negotiated, experienced, and ultimately constructed' (p. 481). An interesting finding is also that the experience of college for some students constituted a symbolic entitlement for certain occupations and careers, they perceived themselves to deserve the better jobs because they were highly educated.

The interaction with peers as important for learning is one of the features put forward in many so called student centred pedagogical approaches within higher education, such as problem based learning (PBL). The use of real-life scenarios as the point of departure for learning, thereby emphasising contextually situated learning, is also put forward as a typical feature bridging theory and practice. Furthermore, the use of small tutorial groups as the basic working form stresses the importance of interaction and communication for the learning process and could be viewed as a social constructivist approach to learning. A third feature of PBL is a strong emphasis on the importance of students developing metacognitive skills through reoccurring evaluations of the outcome and processes of learning, group dynamics and problem solving in the tutorial groups (Barrows 1980; 1985).

In the last decade, there have been some attempts at collating the research on impact of problem-based learning through extensive literature reviews and meta-analyses (Albanese & Mitchell 1993; Vernon & Blake 1993; Colliver 2000). Research on PBL, as well as on other teaching methods in higher education, has hitherto focused most on students' learning and the internal process of higher education. Abrandt Dahlgren (2000, 2002, 2003) has also shown that ways of implementing student centred pedagogics are affected by specific contextual factors and conditions of different fields of knowledge in higher education. The review articles comprise mostly evaluations of medical programmes and are often comparisons with traditional curricula. A majority of the studies show that differences in learning outcome between traditional and PBL programmes are generally small. There is some evidence that PBL impacts on students' study strategies towards a deep approach to learning (Rahimi 1995; Abrandt Dahlgren & Öberg 2001), but further research in this area is, however, needed to conclude whether PBL students achieve a better understanding of the learning task than their counterparts in conventional programmes.

Research on the impact of PBL on graduates' employment is still sparse, particularly in comparison with conventional education. Some studies available are focusing particularly on the field of medical education. The results suggest that PBL might impact positively on graduates' perceptions of communication and generally on the feeling of preparedness for medical practice (Antepohl, Domeij, Forsberg & Ludvigsson 2003; Jones, McArdle & O'Neill 2002; Willis, Jones & O'Neill 2003).

Theoretical and methodological frame of reference

Communities of practice

The transition from higher education to work life is in this study viewed as a trajectory from one community with a particular set of boundaries and traditions to another community of practice with a different location and different boundaries, activities and traditions (Wenger 1998). Trajectories are seen as motions over time, not necessarily following a predestined course, but open to the interaction with and influence of a multitude of sources. A central source of identity formation in the community of practice is participation; the identity is constituted through the recognition of mutuality in relations of participation. Another source complementary to participation is reification. Reification refers to the abstractions such as tools, symbols, terms, concepts produced by the community to reify something of this practice in a congealed form.

In this study, we have chosen two different study programmes, building on the assumption that their characteristics as communities of practice in the university vary. More specifically, we are assuming that educational design; expectations of knowledge formation and identity building in students will vary among the programmes. Similarly, it is our assumption that the graduates will enter different sectors of work life that have different requirements on them as novices in work life that not necessarily match the presupposed outcome of the study programme.

Identity formation

Bauman (1991) claims that in the change to the modern functionally differentiated society, individual persons are no longer firmly rooted in one single location or subsystem of society, but rather must be regarded as socially displaced. The individual needs to establish a stable and defensible identity to differentiate the self from the outer world, but at the same time needs the affirmation of social approval.

Wenger (1998) describes the identity formation in a community of practice as a nexus of multimembership. As such a nexus an identity is not a coherent unity, nor is it simply fragmented. Wenger claims that identities are at the same time one and multiple. We are reasoning along with Wenger, and are aware that identities described in this study are only partial and contextually situated to the realm of studies and work.

Discourses

The concept of discourse could be described as having two meanings. Discourse could be defined as the use of language as a social practice that is both constituted and constituting. Discourse is also a way of talking, rending meaning to experiences from a certain perspective (Winter Jørgensen & Phillips 2000). The programmes included in this study could also be seen as different discursive practices, in which participation and reification influences the informants' ways of talking about their experiences.

The implications of this for the present study are that the informants' individual constructions, and the reifications in terms of educational design, are also considered to reflect features of discourses of knowledge and competence operating within the different programmes. Through the individual perspectives of the informants as students and later as novices, we will also disclose some of the relationships of the educational programmes to the broader constellation of practices constituted by work life and attempt at describing typical characteristics of the trajectories between the different communities of higher education and work.

The informants in the study are senior students, and later novices in work life, graduated from two academic master's programmes at Linköping University, Sweden. The programmes are masters' programmes in Psychology, and Mechanical Engineering. Results reported here constitute a part of a comprehensive research project in collaboration between four research teams from Sweden, Norway, Germany and Poland in research into the transition between higher education and working life (project *Students as Journeymen between Communities of Higher Education and Work* within the EU 5^{th} Framework Programme, contract no. HPSE CT-2000-00068).

Aims and Methods

The aim of this paper is to further examine and compare the transition from higher education to work life in two different study programmes at Linköping university. The specific aims are to (i) identify features of discourses of knowledge and competence operating in the programmes and work life, and aspects of identity as reported by informants as senior students and later as novice workers with 18 months of work life experience. (ii) to relate the results of this comparison to differences in the way the programmes are designed.

Design and data collection

Twelve students from each programme were interviewed at two occasions, the first time during their last year of studies (early 2002) and the second time after approximately 15–18 months of professional work (medio 2003). The sample is approximately a representative proportion of gender according to the composition of the population in each programme.

The age of the informants from the Psychology programme varies between 24 and 46 years of age; more than half of them are between 24 and 26 years of age. The age of the informants from the Mechanical engineering programme varies between 24 and 31 years with an average age of 27.

Interviews were taped and subsequently transcribed verbatim. The duration of an interview varied between 45 and 90 minutes.

Data analyses

The methodology and analytical procedure applied in the project is multi-layered. The primary analysis of interview data is inspired by the rigorous procedure of phenomenography as a first step on the way towards understanding socially (institutionally) and culturally situated and constructed meanings. ADDIN (Dahlgren & Fallsberg 1991; Marton 1981). In our study, provisional categories obtained through the primary analysis represent only the first stage of a process of analysis and interpretation. In the second step of the analysis, we have linked the individual and social constructions in data interpretation by a procedure designed on the basis of the methodologies of discourse analysis (c.f. Gee 1999; Talja 1999).

The context of the study

Linköping university has four faculties, the Faculty of Engineering, the Faculty of Arts and Sciences, the Faculty of Educational Sciences, and the Faculty of Health Sciences. About twenty per cent of the students at Linköping University are enrolled in PBL-programmes. Of the programmes included in this study, Psychology is a problem-based programme, while Mechanical Engineering could be considered a conventional programme.

Psychology

The educational programme for training of psychologists pertains to the Faculty of Arts and Sciences and is a five-year problem based programme. The overall characteristics are claimed to stimulate critical reflection through an emphasis on learning through problem-solving, experiential and self-directed learning. Theories, methods and problems within the field of psychology are dealt with from a research perspective. It is also claimed that, since the scientific basis of the profession is rapidly developing and changing, it is important to develop the ability of lifelong and independent learning within the programme. Such a competence is defined as the students' ability to identify their own needs of learning, choose, make use of, critically assess different sources of knowledge, and evaluate learning processes and their outcome. There is also a requirement on the students to actively seek knowledge, with the aim of developing into independent problem solvers, capable of investigation and intervention. The programme is organised in larger learning modules (table 1), where subdisciplinary perspectives of psychology are moulded into themes. The students also have periods of clinical placements as a part of every module.

TABLE 1. Masters' programme in psychology. Thematic learning modules.

	7 weeks	Introduction to psychology
Module I	23	Cognitive psychology and the biological bases of behaviour
Module II	40	Human development and educational psychology
Module III	56	Sociology, organisational psychology and group psychology
Module IV	47	Personality theory, psychopathology and psychotherapy
Module V	27	Research methodology and Masters' thesis

Mechanical engineering

The Mechanical Engineering programme pertains to the Institute of Technology and comprises four and a half years. 'Rapid advances in technology require an engineer to be capable in computation, design, production, economics and management'. The the first two and a half years of the Mechanical Engineering programme is designated to laying a basic foundation for the forthcoming studies (table 2). After completing the basic studies, the mechanical engineering student can choose one of six branches of specialisation. This means that the content of the first part of the Mechanical Engineering programme is organised in a large number of both sequential and parallel courses. The working forms are typically lectures, exercises and laboratory work.

TABLE 2. Masters' programme in mechanical engineering

Year 1–2	60 weeks	Predefined curriculum for all students. Basic foundation studies. Introduction of various technologies.
Year 2	20 weeks	Choice of optional branch. Five general mandatory courses plus several electives for each branch.
Year 3	40 weeks	Continued studies within a chosen branch. Three general mandatory courses plus several electives for each branch.
Year 4	40 weeks	Selection of specialisation project work, 13 electives available (20 weeks), Elective courses (20 weeks)
Year 5	20 weeks	Master's thesis

During the final two years there are ten optional profiles of engineering that students can choose from. The studies are conducted in project form where theoretical learning is integrated with laboratory work, computer practice and field trips to industrial sites. A profile represents 20 weeks of study in the fourth year, including an 8–10 weeks project course. The concluding Masters' thesis is carried out within the specific area of specialization chosen. The project work is predominantly conducted in companies within the industrial sector.

Results

First we account for the different areas of employment of the graduates from the two programmes. This is followed by an analysis and interpretation of two dimensions of the trajectory from education to work life, i.e. aspects of identity formation and knowledge formation. The programmes are then compared as regards the characteristics of the educational design, and on a meta-level regarding the respective relationships between education and work.

Psychologists

Areas of employment

The typical area of operation for the novice psychologists is that of the clinical consultants. Fields of operation are hospitals, particularly the psychiatric area concerning children, teenagers and adults and schools.

Trajectory in terms of identity formation

The psychology programme could be claimed to prepare for the requirements of clinical work. During the trajectory of the programme, the psychology students compose a kind of *professional fellowmen* character comprising elements both from the private personality as well as the professional role. The concept comprises the meaning of the helper and the social engineer capable of moderating people's behaviour. Periods of clinical internships have made it necessary to separate the private and the professional sphere. A quotation from one of the informants illustrates this:

> *It is important to be involved and empathic, without losing your critical attitude, to be able to keep a certain distance, even if you are very close/.../ It's in a way a basic condition for being able to do the job, to feel and to analyse, but also to be able to come home and not be a psychologist after work (PSY8).*

The typical characteristic of the discourses in work life about the professional role of a psychologist is the *ability of reflection*, both on the individual and the collective level. On the individual level, reflection constitutes both a way to synthesise and understand the client's problems and a way of scrutinising their own thoughts and feelings.

> *It is important that I dare to be a human being in the encounter with other people, it is not only about techniques, technical knowledge, facts and methods, but that I as a human being allow myself to get moved by the meeting with the clients, but also that I use my humanity to feel and reflect, to draw conclusions*

> *from the meeting. To develop in my professional role, it is clear to me that I need that I also need to develop my personal identity (PSY10).*

Reflection also stands out as a hallmark of a good psychologist at the collective level. Some statements in the interviews indicate that the ability to contribute valuable reflections to a discussion between the team or between colleagues gives a feeling of being professional.

> *I feel like a good psychologist sometimes when I meet clients and I feel I can help them in some way...or if I can contribute good reflections in treatment conferences where we are discussing various cases. I sometimes feel that I can contribute to someone else's case (PSY3).*

The trajectory in terms of knowledge formation

Two ways of relating to the theoretical body of knowledge are discernible. The *eclectic mode* means that fragments of knowledge from different theoretical schools are moulded ad hoc in the application to be applied in a specific case. The *pluralistic mode* means a repertoire of perspectives that from with the professional selects a specific theoretical perspective to a specific case. The awareness of pluralism, i.e. the existence of competing theoretical schools of psychology and the application of these in clinical practice stands out as the most important feature of the novices' answers to the questions about what kind of knowledge is acquired through the educational programme. The trajectory from the educational programme to working life is characterised by *continuity and confirmation* of the knowledge base achieved during the educational process. Some of the interviews are also very convincing as regards students feeling of being prepared, of putting into practice the knowledge they have developed during their studies.

> *I was surprised by, partly how easily I was entering the professional role and felt confident, and partly by that I could convey my knowledge to the people I met, I was a school psychologist, and there was no doubt about it (PSY 6)*

The feeling of being put to test rather than socialised into the professional work, leads to a legitimate participation in the professional community shortly after the entrance into work-life, indicating a close power/knowledge relationship.

Mechanical Engineers

Employment areas

Most of the novice engineers are at the time of the interview typically working in mid-size and larger private enterprises. Two of the novice engineers describe their work with the words calculating and constructing, two are developing products and/or computer programmes, one is a doctoral student, two are trainees, two are certifying and evaluating processes and products and one is a worker in a factory.

Trajectory in terms of identity formation

The discourses operating in the educational programme of what constitutes a mechanical engineer is typically that of being representatives of an *intellectual elite*, mastering complex theoretical problems with the task of *building society*. This is illustrated by the following quotations:

> *Sometimes you get the feeling that they would like to have many top students, to kind of show off to other technical schools in Sweden and in the rest of the world. It is not my point of view, but it seems to be important to them to get some kind of elite in certain ways. (.) It is important with the career thing, it is mentioned already in the information brochures, it is very focused on careerists and that kind of persons (ENG 21)*

> *The engineers solve problems for the ordinary people. Engineers solve problems in their own ways, but it is for the benefit of the whole society. All products that we have, cars, telephones, are developed by engineers. So engineers make things easier for the whole society. That is what develops engineering itself too (ENG24).*

As novices, the typical interpretations of the discourses operating in work life about what constitutes a mechanical engineer has been replaced by that of an employable trainee with *generic problem-solving capabilities.* The mechanical engineer is also typically flexible and interchangeable, with the capabilities of entering a multitude of different projects and take on the responsibility for a delimited part of those. The ability to be flexible is considered important and in a way creates a dilemma in the novices' choices between specialisation, which would mean the acquirement of expertise within a certain area, but at the same time be to the detriment of the generic flexibility.

The uniqueness of the discourses operating in work life about the professional role characteristics is the one of being an *exclusive thinker.* The informants claim that there is a typical "engineering-thinking" that seeks the *optimal* and most *pragmatic solution* to any problem. Two informants give their notions of what this could mean:

> *But what you are good at is above all to think like a mechanical engineer. Think about something, you see something and you do not only look at the external, but you think about it in an engineering way, like, this can be changed. The most important is to learn a certain way of thinking about things (ENG 28)*

> *Critical thinking, the way engineers are thinking maybe.... if one have a problem, to be able to sort it out, and divide it into different sub problems, is actually possible to solve, because if one have a new problem, then one must divide it to be able to find a solution and solve the problem (ENG 31).*

However, the characteristics of the work task for most of the novices are typically that the novices get well-defined and limited tasks as parts of bigger projects of which they do not have full understanding of or responsibilities for. Only gradually do they get working tasks of a more complex nature.

The trajectory in terms of knowledge formation

The trajectory from education to work life appears for the mechanical engineers as a *discontinuity in scope and responsibility* of the professional role. This could be interpreted to mean that passing the programme leads to a formal legitimacy that in itself is a merit and, thereby leads to a peripheral legitimate participation in the professional community of engineering. It also indicates that parts of the trajectory in terms of knowledge formation are ritual. The ritual feature of the programme is strongest in the beginning, where also students are put to the hardest test by taking the massive initial courses.

> *Engineers have a similar training, you have been through courses of similar difficulty, I think that is why you feel like an engineer, you have made it, there are several who don't think they will make it when they start on the programme, because it is really hard work. Very few really make it, and that is perhaps why you feel that you kind of are of the same kind (ENG29).*

The experience of intensity in the programme is decreasing in the latter part as the students learn how to cope with the demands and the ritual courses are less prevalent.

Educational design and process

Psychologists

The discourses operating in the psychology programme about educational design have a *professional and clinical focus* that is present from the outset of the program through the use of real-life scenarios as the point of departure for learning. There is also a *focus on the individual*; students are selected after individual interviews. The *interaction between fellow students* that is emphasised from the outset of the programme in the small group tutorials seems to have an impact as regards the ability to prioritise, look for causal relationships as well as relationships between parts and wholes. The feedback between students is considered very important, and students emphasise the importance of being well prepared and contributing to discussion. A discourse about an engaged, talkative and capable student is operating strongly in the programme. The discourses operating in the programme about learning psychology are two, to learn and discern differences between the relevant theories and to integrate them into themselves as persons. Clinical placements seem to have played a role in integrating the content learning with the learning about the own person.

Mechanical engineering

The discourse about educational design operating within the Engineering programme rests on the notion of providing students with a *basic knowledge from the outset* of the program. The large amount of specific and parallel courses, the large classes and the lecture format contribute to form a very competitive learning climate in the sense that students have to prioritise their engagement and discern their individual focus and understanding of the field of engineering in the trajectory through the programme. The discourse about the knowledge base in engineering appears as fragmented and multiple.

Discussion

In the following, we discuss the trajectories from higher education to work life and try to summarise the key findings. We also make some comparative notes on the impact of the educational design it the two studied programmes.

Identity formation and knowledge formation

The psychology programme has the most obvious professional focus. There is a high degree of *continuity* between being a student and being a professional novice. The socialisation and transition to work is immediate, when the novices show evidence of professional skills in practice, this leads to legitimate participation in the professional community (Wenger 1998). The emphasis on contextualisation to the diverse field of psychology all through the programme contributes hereto. The findings regarding feelings of preparedness for work as has been indicated in previously cited follow-up studies on PBL graduates within medical education (Antepohl et al. 2003; Jones et al. 2002; Willis et al. 2002) is also repeated in within psychology.

Students from the Mechanical Engineering programme have experienced the transition from higher education to work as a process involving a kind of *discontinuity.* Engineering novices achieve a formal legitimacy through their passing of the programme, which is an indicator of being able to learn fast and work hard and thereby functions as a door opener to the labour market. The character of the working tasks as delimited parts of larger projects could be seen as the novices reaching what in Wenger's (1998) terminology could be described as a peripheral legitimate participation in the professional community.

Parallel or thematic organisation of content

The organisation of the content in the two programmes could be described as *parallel and thematic* respectively. The Mechanical Engineering programme has an academic focus. This focus is, however, blurred by the parallel organisation of courses. The contextualisation of knowledge to work life occurs, if at all, late in the programme or is left to the novices to handle individually. The thematic organisation of the Psychology programme is on the other hand integrating the academic and professional foci in a way that enhances the possibilities for contextualisation through the use of real-life scenarios as the point of departure for learning.

Rational or ritual relationship between higher education and work

The relationships between education and work could also be described in a more abstract way. It is reasonable to assume that all educational programmes include knowledge and skills that are *rational* in character with regard to their relation to work life, in that they are preparing for a specific field of knowledge or professional field of work, emphasising the utility value of knowledge. It is also reasonable to assume that programmes include knowledge and skills that are rather *ritual* in character, where the connection to a specific context of application is lacking and the most important feature is instead the exchange value of knowledge. The impact of education could be claimed to encompass *substantive skills* that are content specific and contextually situated. On the other hand the impact of education may also comprise *generic skills*, which are transferable between different contexts. Such skills may likewise be acquired in various contexts and developed through different contents.

In the case of the Psychology programme, the relationships between higher education and work life could be described differently. A similarity is that that the contents of the programme is mainly rational, but the emphasis is high on both generic skills, as e.g. the capability of communicating and interacting with clients, as well as a high emphasis on substantive knowledge, e.g. the competing schools of knowledge within psychology and the consequences of their application in the individual case.

The Mechanical engineering programme, on the other hand, display another emphasis on the different aspects of knowledge. The exchange value of passing the programme is in all likelihood revealed by an emphasis on the ritual aspects of knowledge. At the same time, the content of the programme appears indeed rational in order for students to develop the generic problem-solving skill that is seen as a hallmark of the competence of the professional engineer. The achievement of a formal legitimacy as a ritual door opener to the labour market could be compared to the symbolic entitlement to a certain career or occupation as found in Kaufman and Feldman's study (2004).

There are suggestions in the literature that if higher education should respond to the demands from the labour market, this would lead to an emphasis on operational competence that would be a reductionistic perspective and to the detriment of traditions of knowledge and learning in universities

(Barnett 1994). On the other hand, too much emphasis on the university traditions might lead to an academic competence that might be of less value in the labour market. The challenge for universities is to find ways to bridge these demands and find a way to prepare for a changing and supercomplex society (Barnett 1994, 2000b) that is based on

> ..a view of human being located neither in operations and technique nor in intellectual paradigms and disciplinary competence but in the total world experience of human beings. (Barnett 1994, p. 178.)

The rational generic relationship between higher education and work in the Mechanical Engineering programme could be seen as one example of how academic competence is transformed through experiences of work. This result gives some support to Barnett's way of reasoning, that what constitutes an 'academic' is not à priori given but a matter of *"dynamic relationships between social and epistemological interests and structures"* (ibid. p. 256). The rational substantive and rational generic relationships between higher education and work found as an outcome of the PBL design in the Psychology programme could be viewed as one example of how operational and academic competences are bridged. The differences between the programmes as regards design, i.e. the parallel and thematic structure, may be seen as reflecting the notions of professional preparedness embedded in the various discourses of higher education. The Mechanical Engineering programme rather expose an academic notion about what is characteristic of communities of practice encountered by professionals in the field. The Psychology programme, on the other hand, represents an attempt at depicting the professional community of practice within the academic context, which is illustrated e.g. by the broad themes in the programme which also correspond to professional specialities. These findings provide some support for the feasibility of problem based learning as an educational design.

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NEGOTIATING A PROBLEM-BASED CURRICULUM
– a reflective learning process of renewing the culture of teaching and learning

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Problem-Based Learning (PBL) has been mentioned as the most important educational innovation during the last decades expecially in the context of the professional education. It has also been seen as a stratetegy for renewing the educational and learning culture by integrating the competence demands of the education and of work life during the process of education. The research concerning in problem based learning has mainly been interested in the pedagogical processes and assessement of PBL curriculum. Althouhg the developing and implementation of PBL curriculum is effecting deeply on the educational and pedagogical culture, the themas of organizations own learning processes are minor in PBL literature. In this article we describe the process of developing a problem-based curriculum in the Unit of Early Childhood Education at the University of Tampere during 1999–2003. The basic principles of PBL were applied in the developing process. In our reflections we will focus on the learning at work processes when developing a multi subject curriculum and multi professional work culture. The aim of the article is to model the PBL curriculum process.

The changing interpretations of the curriculum

The curriculum in generally and the PBL curriculum specially has been understood and conceptualised in many different ways. A curriculum may be defined simply as a plan about what is taught and what should be learned. The modern curriculum is generally understood as the rational pre-plan for the goals and objectives of instruction and instructional content, as well as teaching methods and the organisation of teaching. The critics of such a rational curriculum idea have, however, pointed out that the complex and unpredictable nature of teaching situations renders any kind of preplanning – if not impossible – at least ethically questionable. Furthermore, clear-cut plans may also effectively restrict students' individual opportunities.

In post modern teaching and particularly in problem-based learning (PBL), the entire traditional curriculum and the hidden curriculum regulating it are expected to be able to meet the various demands presented by learner-centred perspectives and experiences. Therefore, the practical realisation of the curriculum has served as the object of particular interest. However, scholarly interest in the meta-curriculum – the thought processes, perspectives, reasoning, interests and differences in opinion underlying curricula – is increasing. The emphasis is shifting from the more technical development of a curriculum to understanding curriculum. In this sense, the concept of curriculum is clearly widening in scope. (Goodson 1989, 13–25; Hlebowitsh 1997, 507–511; Pinar et al. 1995, 3–11.)

According to Hannafin and Land (1997) the curriculum can be conceptualised as a learning environment based on five foundations: psychological, pedagogical, technological, cultural and pragmatic. The psychological foundation reflects underlying beliefs about how individuals acquire, organize and develop knowledge and competencies. Pedagogical aspects focus on the activities, methods and structures of a learning environment and technological capabilities suggest what is possible through advanced technology. On the organisational level, the cultural foundations of a learning environment reflect prevailing beliefs about education, teaching and learning, in addition to promoting the values and roles of the organization. There are also various pragmatic foundations which bridge the gap between theory and reality. Understanding the PBL curriculum as a learning environment emphasizes the strategical and methodological views on the development of multi-subject knowledge, shared expertise and a multiprofessional work culture.

Who are the learners within the curriculum process?

Curriculum development – designing a learning environment – may be approached as a learning process where the workplace community and the assisting network of experts use interaction, knowledge-sharing and constant negotiation to develop the curriculum and, simultaneously, their own professional practice. Among the objects of learning at work are the following aspects: the colleagues', team's or expert network's shared interpretations about the expertise and competence presupposed by a given course or degree programme; negotiation on an appropriate curriculum for the programme; the concrete composing of the curriculum; visualisation of the beliefs concerning teaching and learning; and practical implementation of the curriculum as well as the development of the structures and activities at the workplace as presupposed by curriculum implementation, etc. Within this framework of processes, the various dimensions of the learning environment – psychological, pedagogical, cultural, technological and pragmatic – serve as the objects of constant, collaborative discussions and development activities.

In work life, a meaningful carrying-out of work assignments increasingly presupposes new forms of working and new work cultures. This also applies to the contexts of teaching and research. New kinds of work cultures are manifested in, for example, various combinations of teachers' and researchers' professional know-how, collaborative forms of working, and increase in shared responsibility and new forms of working with students. Instead of individual education, the development of teachers' and researchers' competence requires collaborative learning as a community, where the study and development of local/contextual knowledge constitute the foundation for learning.

The diverse know-how of the various members of a learning community can, at its best, serve as a resource for collaborative learning. The development of workplace communities and organisations in interactive relationships – learning partnerships and the processes connected with them – have been conceptualised in various ways. Flechter (1996) characterises developmental interaction as interaction whose typical features include shared commitment and dependence. Interaction that promotes development entails a reciprocal system of giving and receiving as well as shared responsibility. Reciprocity is formed by the willingness of all parties to cross their own boundaries and share their competence.

Learning as a participatory process and defines the workplace community as the context of learning. According to Wenger (1998) three factors are especially central to learning. Firstly, a community has a shared, agreed-upon task or project for which the community takes responsibility. The members of the community commit themselves to realising the project. Secondly, the community commits to working together through reciprocal activities. The community is bound together by common procedures and a need to keep the community together. Thirdly, a workplace community possesses a shared set of tools which entails stories, discourses, styles, functions, artefacts and concepts.

Reflective development is based on a process of participation and a reflective attitude to the work; an organisation or unit is not given ready-made solutions, but it is assisted in studying, analysing and understanding its own problems. Keating, Robinson and Clemson (1996) describe the pursuit of change and the reflective development involved in organisational change in the following way:

- Outsiders are not the experts who know or can find solutions to organisational problems.
- The members of an organisation are the experts who know and can find solutions to organisational problems.

- An organisation encounters several learning obstacles, which may prevent it from effectively utilising its own know-how for developing its activities.
- A structured, repeated process of deep reflection can uncover previously existing, tacit knowledge, which the organisation needs in order to analyse its problems and develop its activities.

The idea of reflective development is partially based on the general theory on reflective and transformative adult learning, which serves as a platform for analysing job-embedded learning. (Mezirow 1991.)

Curriculum development is often connected to some kind of pursuit of change, which is initiated by either external or internal factors. The point of departure for developing the degree programme for kindergarten teachers at the University of Tampere was, on the one hand, the change the programme went through when it evolved from the secondary institute level to university education in 1995 and, on the other hand, the evaluations of education and teaching conducted in 1998–1999. One of the evaluations concentrated on university-level teacher education (Jussila & Saari 1999), and the other, on a general assessment of the teaching at the University of Tampere (Lehtinen et al. 2000). Both also entailed a wide self-evaluation process conducted by the Unit of Early Childhood Education, which then brought up development needs concerned with the curriculum of our programme and the quality of instruction. Our unit began to use the basic ideas of reflective development to examine how these needs could be met.

We have demonstrated the various phases of our curriculum development with the help of a roadmap (Figure 1). The map entails several natural obstacles (1–7) and pitstops (1–7).

The natural obstacles represent the questions or problems of curriculum development which we have encountered in our organisation. There are also pitstops in the vicinity of the obstacles where various, specifically directed reflective questions or interventions have been used to clarify certain issues concerning curriculum. Our roadmap is not by any means meant to be per-

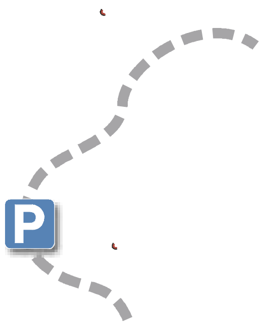

FIGURE 1. Developing PBL curriculum and a new culture of teaching and learning Obstacles (1–7) and pitstops (1-7)

fect or complete; rather, it is an outline of a few possible obstacles and pitstops involved in the process of developing a PBL curriculum (see Nummenmaa & Virtanen 2002.)

Do we want to transform the curriculum?

The first question or natural obstacle in curriculum development is often whether the organisation/unit sees a need for transforming their curriculum and whether people are willing to undertake the task. In relatively static everyday work environments, there is a level of routine that often lays a solid foundation for professional practices. When the activities are directed according to a given predictable programme, certain thought and action schemes are also easily established for dealing with various situations. These practical routines – community practices – are often taken for granted, and the objective of organisational learning is to emphasise the stability of the prevailing situation. (Ruohotie 2000, 253; Wenger 1998.) As work environments, university departments are often quite typical examples of the kind of static organisation described above – an organisation built on established routines and work culture – community practices, the curriculum representing one form of such routines and culture.

At the first obstacle, the organisation usually faces a number of individual and institutional doubts and statements of disbelief: *'The old curriculum works just fine! But we have already applied this curriculum model! Does any of this make any sense?'* Such doubts are understandable and even necessary, for they form the point of departure for the process in which the organisation begins to examine their relationship with teaching, learning and curriculum. On the individual level the chance can be seen as a threat for the own teacher identity (Wenger 1998). Ideas about a good curriculum, good teaching and learning also involve various beliefs and thought paradigms. They form the landscape that structures the activities, and the content of this landscape is part individual and part shared by different groups of employees. The staff members' various beliefs, assumptions and thought patterns form the first object of reflection (pitstop), as the workplace community begins to evaluate its work and to find possible paths to change. The examination of conceptions and beliefs can be promoted with various kinds of reflective interventions (see, e.g., Karila & Nummenmaa 2001; Wenger 1998).

Embarking on this journey presupposes commitment and an evaluation of resources. This is why, particularly with a long-term process of change, it is important to start with a broad discussion about the expectations the various parties have and the kinds of commitments they are prepared to make (Baker 1985; Cockman et al. 1999). The significance of commitment is multifaceted – it is the first phase in the organisation's pursuit of a common goal (Kozlowski, Gully, Nason & Smith 1999, 275), it orients the staff to the common goals and commits them to a shared project. At times, it may be appropriate to seal staff commitment with personal, written development agreements. Documented 'working agreements' concerning cooperation and collaboration serve as the guiding principles for the learning and group process of the organisation or team. When the common journey reaches a certain point of evaluation, the agreement drafted at the point of departure may be taken as one of the dimensions for evaluation.

What kind of expertise and competence should education develop?

The starting point for developing the content of a curriculum is a collaboratively formed interpretation about what kind of expertise and competence the degree programme is to develop. After examining the basic educational task from different points of view, the organisation begins to examine the following questions: What kind of competence does our programme produce? What general goals can be set for the programme?

Allan (1996) describes the general qualifications and competencies which university education should produce. He divides them into three groups: disciplinary competence, transferable and generic skills and academic competence. The transferable and generic skills as well as academic competence include competencies such as critical thought, reflection, knowledge management, and cooperation and communication skills. These skills and competencies come very close to the qualifications experts are required to have when they enter the labour market. The central questions are, therefore, how can university education be developed so that it promotes the development of competence relevant to work life, and how does it promote the competence a particular course is designed for? In this respect, the curriculum and its pedagogical implementation in particular play a central role.

In recent discussions about expertise, an increasing amount of attention has been paid to shared expertise. Experts are more and more rarely alone in analysing work situations, solving problems and developing their practices. Building multidisciplinary and shared expertise, which breaks the boundaries of different academic disciplines and educational orientations, is one of the most essential future challenges for the concept of expertise. This shift in the point of view in expert education is quite significant in terms of curriculum as well as the learning processes accommodated by a curriculum. After all, the object of any examination on such issues is not the individual structures of knowledge and subjective meaning, but participatory structures, shared cognition and organisational work principles. Therefore, good communication and interaction skills form one of the essential core competencies of expertise. If expertise is understood not only as an individual dimension but also as a shared phenomenon, the pedagogical processes outlined by curriculum must be equipped with ingredients which help us grow into collaboration and a sense of community.

Because the ideas on expertise have been subjected to changes in recent years, the educational communities have had the challenging task of constructing their own interpretations about expertise and competence. The challenge is increased by the fact that in nearly all educational units, people have various kinds of views on the present nature of expertise and its future challenges. At times the reflections on these issues may also receive quite minimal attention. Educators are often representatives of a certain, specific area of content, which may be reflected as a situation in which the perspective of content competence alone is emphasised in working on the curriculum. The planning and implementation of education cannot, however, rest merely upon content competence; the composition and implementation of a curriculum also require expert work and expert education, in addition to reflection on learning processes and curricular solutions.

There are various kinds of official and unofficial interpretations about the work of kindergarten teachers, which have been presented at various times. These have also served as guidelines for curricular content. Structuring an optimally uniform interpretation about expertise is one of the most central tasks in structuring a curriculum. In this process, one easily runs into various inter-disciplinary boundaries, whose existence can be questioned by beginning to plan and work in a problem-based learning and knowledge environment (Karila & Nummenmaa 2002). Although we have conducted broad discussions about our unit's basic task, the interpretations still vary in ways reflected in the curriculum development work. Differing interpretations about expertise and competence in early childhood education thus form a natural obstacle where our organisation is obliged to make a pitstop over and over again.

What kind of curriculum would suit our education?

The points of departure, objectives and principles entailed in curricula play a part in what kind of learning environment is formed at a given time (Bernstein 1990; Goodson 1989). Various kinds of curricula implicitly entail differing assumptions about knowledge and learning (the psychological foundation of a learning environment) and usually lead to differing pedagogical solutions (the pedagogical foundation of a learning environment). When it comes to the conceptions inherent in their theoretical backgrounds, curricula can be divided into three different epistemological categories or meta-orientations. This categorisation enables us to examine the characteristics of different types of curricula and to describe the change occurring when we shift from the tradition of one-way knowledge transmission towards emphasising the learner's own active role.

The transmission orientation reflects the mechanistic thinking of modern times. Learning is described as a transmission of knowledge, and the task of teaching is to influence the learner's actions in such a way that education produces certain kinds of reactions and behaviour. Instruction is thus organised by subject, and the teacher has centre stage in the teaching situation. Learning is not conceived as a personal experience, but knowledge is seen to be general and objective in nature.

The transaction orientation is based on the humanistic conception of man. Here, learning is seen as a construction of knowledge occurring in interaction and dialogue with the learner's environment. The individual is seen as a rational being capable of intellectual problem-solving. Teaching need not always abide by the content of a single subject, but can be multidisciplinary in character. When it comes to teaching, this orientation does not make a clear distinction between individual and social learning. The teacher's role is to encourage the development of students' problem-solving skills. Although the forms of instruction may be collaborative, the teacher is, however, responsible for selecting the contents and formulating the goals of learning. In the transaction orientation, learning is not seen as a transmission of knowledge, but knowledge is seen to have a subjective and experiential nature. Collaborative problem-solving is given central significance.

The transformation orientation emphasises a personal and social change and comes closest to the problem-based principle. This orientation involves three particular intentions. The first goal is to teach students skills which promote personal and social development. Secondly, there is an attempt to communicate a view of social change as a means of reaching a balance with the environment, instead of trying to control the environment. The third intention is to create a transpersonal orientation, the objective of which is to reach a balanced interaction with one's environment as well as an ecological respect for the environment. (Poikela, S. 1998.)

In *a traditional course-based curriculum divided by subject,* studies leading to a degree are listed by subject as courses and classes, and the course handbook lists the contents of the classes (often as mere titles). The overall principle may be, for example, the intra-subject classification. The curriculum may also entail multiprofessional study entities. In a *module curriculum* (or block curriculum), courses are combined into compulsory or optional study modules, each module forming an independent area of competence to be completed in full. In a *path curriculum,* studies are not defined as independent modules or areas of competence, but as multidisciplinary or multi-subject core entities of expertise which are carried throughout the degree programme (or part of it). The path scheme is especially utilised in problem-based instruction. The paths of a curriculum may extend throughout the entire degree programme. The project curriculum is one type of path curriculum. (Karjalainen 2003.)

When the idea of designing a learning environment from the point of view of learning processes is embedded into a curriculum, the curriculum itself will also entail the principles and guidelines for constructing the whole of the educational unit's learning environment. In addition to the goals and content of instruction, this type of curriculum also describes those learning processes which the instruction seeks to inspire. (Pinar et al. 1996; Ropo 2001, 8.)

The curriculum transformation process sought not only changes in the content but also in the design of the curriculum. Our unit began to orientate towards the philosophical and theoretical perspectives and pedagogical principles of problem-based learning in an experiential fashion. As the objects of our scenario work, we choose the core elements of PBL: What is problem-based learning? What kind a curriculum is problem-based curriculum? How is learning directed? Where do problems arise? As the scenario work progressed, the conceptions about PBL as a curriculum development strategy began to become structured.

How is curriculum (PBL) actually composed?

As the basic unit of problem-based curriculum is the tutorial and the knowledge and learning environment surrounding it. After all, posing problems which activate and direct students' learning is a quite essential question and challenge in the problem-based learning process. How might we formulate problems in a way that they produce a meaningful learning process from the point of view of our learning goals and so that the students develop a professionally relevant competence when working on the problems? Formulating learning-motivating problems and scenarios to serve as the basis for learning is one of the corner stones of problem-based learning. According to Dolmans, Snellen-Balendong, Wolfhagen and van der Vleuten (1997), a good problem entails the following criteria:

- It combines students' experiences and knowledge
- It is complex enough but not overly loaded
- It arises from future work life or is otherwise authentic
- It encourages self-directed learning
- It brings up relevant basic concepts
- It involves the general learning goals.

Designing a problem-based curriculum for university education is quite feasible, provided that the goal of education is seen broadly as providing qualifications for work life. Relevant and authentic problems can be found even if they did not so clearly arise from the practices of actual occupations.

The problems concerning the adoption and application of problem-based learning essentially have to do with whether or not the method is applied broadly to the entire curriculum or more narrowly to, for example, certain classes. Even if the benefits of PBL were acknowledged, the organisational level may be reluctant to fully adopt the new scheme all at once. At the Unit of Early Childhood Education, we directed the transformation to the entire curriculum of the Bachelor of Education degree (120 credit units) for training kindergarten teachers, which entailed both basic and subject studies in education, vocational studies qualifying for work in early childhood and preschool education, as well as courses in both preschool and initial education. When the curriculum becomes the object of an overall reform, the question is not only of a new way of learning and teaching. It has to do with a change in the culture of learning and working – one requiring a re-evaluation and rearrangement of many procedures. (See Nummenmaa & Virtanen 2002.)

What kind of new pedagogical competence we need?

The pedagogical foundations of a learning environment have to do with the activities, methods and structures at play within the learning environment. Traditional, teacher-centred pedagogy stresses strategies which direct learning, such as the hierarchical structure of the content to be learned (e.g., various taxonomies), 'objective' and relevant questions, and direct feedback to students as well as the external assessment of learning. Student-centred pedagogy, for its part, pays attention to the practising of learning strategies and to the learner's own choices. Designing learning environments aims at the empowerment of students. (Hannafin & Land 1997.)

The basic philosophical assumption in PBL is the adoption of a student-centred approach to learning, as opposed to the teacher-centred approach. The student-centred nature enables the students to become aware of their own initial understanding, to be active parties in the learning process and to construct their own understanding and knowledge within a social context. (Silen 2002.) The tutorial teacher has a significant role in the students' learning process. The tutor's central task is to promote the self-directed learning of the students. Skilfully conducted tutorials help students to become motivated, take responsibility for their own learning in addition to that of others, and commit themselves to a shared problem-solving process, thereby reaching personal learning outcomes, as well. Pedagogy based on the utilisation of group processes and the supporting of self-direction has to overcome the boundaries of traditional expert teacherhood and take responsibility for collaborative teaching. (Poikela, S.1998.)

The shift from a teacher-centred orientation to a student-centred approach awakens many kinds of feelings. When the function of the tutor is primarily that of a process leader (problem-solving, learning and group processes), the issue of the teacher's own competence easily triggers insecurity. (Poikela, S. 1998; 2003). Among teachers, a frequently voiced issue is the confusion about where a teacher's own expertise and adopted teacher identity fits into the equation. This is a great challenge for a personal learning and identity project: How to change "old good practices" and adopt a new orientation to teach.

How do we implement the curriculum into the practice?

The practical implementation of a curriculum requires a bringing together of multidisciplinary and multiprofessional expert competence. Multidisciplinary competence refers to the attempt to approach and develop competence with the help of knowledge and methods from various academic fields. Multiprofessionalism refers to employees of various educational backgrounds examining their work and competence, as well as sharing their competence with colleagues in order to create new kinds of competence. (Karila & Nummenmaa 2001.) Here, we are faced with one of the pitfalls of developing and implementing a university curriculum; the freedom of research and teaching has been a central, guiding principle in academic work, which has influenced the formation of curricular contents as well as the practices of teaching. The development of individual and shared (multiprofessional) expertise and competence is an essential pedagogical challenge.

The discourse on expertise can, however, become a problem from the point of view of curriculum implementation, if we adhere to the traditional definitions of expertise, according to which an expert is a person skilled and knowledgeable in a particular field who can use his/her training and vast experience to give very detailed accounts about and answers to the specialised questions of that field. In the recent literature on expertise, it is often pointed out that traditional expertise is in a state of transformation. According to Launis (1997, 122–128), experts are no longer the ones whose training and strictly guarded territory of professional practice guarantee a dominant position. Expertise has evolved into sharing, interpreting and gathering information, and an expert is not always necessarily right. The implementation of a curriculum requires such evolved expertise. An expert is more and more frequently involved in various projects where diverse forms of expertise need to be accommodated for. Expertise should therefore entail flexible, anticipating and broad know-how. A large part of this is the ability to evaluate one's own competence and development, that is, self-reflection. Expertise combines self-direction and collaboration.

A unit or institution implementing a curriculum often forms a multiprofessional workplace community, whose entire staff participates in carrying out the common educational task. The successful completion of this task, utilisation of diverse competence and support for the individual's professional competence require a self-reflective, developmental workplace community as well as active on-the-job learning. Through the process of job-embedded learning, the development of the shared learning and working culture as well as the utilisation of the know-how of a genuinely multiprofessional community can be promoted with the implementation of the curriculum. The promotion of a collaboratively interpreted expertise in multiprofessional teams may, among other issues, be selected as the curricular objective of developing multiprofessional competence.

The Unit of Early Childhood Education is a community where various kinds of competence are represented; staff with various educational backgrounds and experiences examine their work from various perspectives, in addition to sharing their own know-how. The active change from traditional, teacher-centred work to student-centred work presents us with a constant challenge to work on our own orientation. Furthermore, the implementation of a PBL curriculum also requires the participation of all members of our community in developing a multiprofessional work culture. The teachers of each course work as educational teams, and the core process of development is formed by the community's/team's examination of their own practices – the learning occurs within the educational teams. From the point of view of constant curriculum development, it is important that the teachers' individual competencies as well as team competence develop further and become visible in the overall framework of the curriculum (Wenger 1998).

How do we assess teaching and learning and improve its quality?

In the Finnish policy on university education, quality improvement has represented one of the significant projects of the last ten years. The quality and quality systems of teaching have been evaluated on many levels, and quality assessment has also employed several varying methods (see Liuhanen 1997; Hämäläinen & Moitus 1998; Lehtinen, Kess, Ståhle & Urponen 2000). On the curriculum level, the central issues concerning quality-assessment of teaching are:

- The design, content and organisation of the curriculum
- Teaching, learning and assessment
- Student progress and achievement

- The tutoring and guidance of students
- Learning resources (library, computers, etc.)
- Quality control and improvement.

The curriculum is realised in various interpretations and arrangements concerning the learning and knowledge environment as well as the assessment of learning. Assessment, then, directs the learning process – what is learned corresponds with what is assessed. In our PBL curriculum reformation, the basic underlying assumption about *learning can be defined in terms of changes in the student's knowledge, skills, understanding and attitudes, which are induced as a result of experience and reflection.* Such a conception of learning entails that the learner is actively committed to the learning and assessment process, in addition to regulating his/her own learning. This conception is based on an experiential and constructivist conception of learning and knowledge, according to which learning occurs when an active, self-directed learner solves conflicts between ideas and reflects on theoretical explanations, thus constructing personal knowledge (see, e.g. Boud & Fales 1983; Boud & Feletti 1999.) In our institution, the tutorial groups serve as the essential knowledge-construction sites.

The central goal of teaching is the empowerment of students. This is why *the assessment process itself should be an empowering experience.* When assessment is approached and defined in terms of empowerment, various perspectives on assessment arise. In developing the evaluation methods for learning, we have stated the following principles:

- The system of learning assessment is to cohere with the conception of knowledge and learning underlying the curriculum;
- The assessment of learning is to have several perspectives and voices;
- Various kinds of methods which apply to the learning goals of courses are used in the assessment (self-assessment, collaborative assessment, written products, learning measurements);

- The development and acquired competencies in several core areas of expertise are evaluated at various stages of the programme (the professional growth portfolio).

Our curriculum is subjected to constant evaluation, development and updates. Feedback from the student and teacher interest groups as well as their participation in planning structures and content represent an integral part of improving the quality of teaching.

Lessons learned when negotiating the curriculum

We have described the curriculum as a learning environment and curriculum development as learning at work process and reflective development. The emphasis has been shifted from the traditional examination of the student's learning process to the teachers' learning process. In conclusion, we can present a few central working principles and challenges for learning.

First and foremost, the point of departure is the assumption that high-quality teaching and learning develop within the *context* in which they are planned and implemented. Curriculum development, therefore, begins with an open examination of the prevailing situation and practices.

Secondly, the curriculum development process produces a system of learning based on collaboration (*learning as belonging)* – a learning partnership, where the various actors (teachers, students, administration) are all involved and committed. A learning partnership is, on the one hand, an internal process of the workplace community and, on the other, a reciprocal partnership with the outside parties (administration, developers of teaching). Discussion occurs in regular meetings and in work counselling sessions.

Thirdly, curriculum development rests on the principles of reflective development (Keating, Robinson & Clemson 1996). The process takes advantage of the teaching staff's personal experiences, through which interpretations about the curriculum as a learning environment are collaboratively produced. According to Wenger (1998) it is a question *of learning as experience* with shared meaning making. The implementation of PBL curriculum means above all adopting new community practices – *learning by doing.*

The curriculum development process produces new and further develops the old tools for the improvement of teaching, learning and the work culture. The staff are challenged through discussions and various activities (observation, interviews, metaphors, writing, portfolios, concept maps, etc.) to examine and evaluate their everyday teaching and actions (attitudes, knowledge and skills) from new perspectives, as well as to develop new ways to learn and teach. Various developmental interventions are also used to uncover the tacit knowledge within the workplace community and create new ways of analysing one's own interpretations and actions. On the personal level the most challenging learning *is learning as identity* work - the adoption of a student-centred approach to learning as opposed to the teacher-centred approach earlier used.

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EXPERIENCES OF PBL IN PHYSICS IN UK HIGHER EDUCATION

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Project LeAP is a three-year nationally-funded project to promote and investigate qualitatively problem-based learning in physics and astronomy in UK universities. In its final year, the results and experiences from the Project offer an insight into the early stages of adopting problem-based learning in a subject traditionally taught by lectures and scripted laboratory work. The Project has compiled its findings by drawing on PBL implementations in a range of higher education institutions with varying needs, resources, and situations.

We discuss indicators of departmental readiness for movement towards PBL, reasons for resistance to change in teaching methods and whether they can be overcome, the impact of the Project's Practice Guide (a practical manual for developers and implementers), and the results of a survey of PBL-like activities in UK physics and astronomy departments.

We also comment on the challenge of modifying teaching strategies at a departmental level, describe how varieties of PBL have been introduced into areas of undergraduate physics teaching (for example core and options modules covering many fields of study, laboratory work, skills, and mathematics), and conclude that PBL could offer the opportunity both to integrate and align teaching and assessment elements across the curriculum and also to address the learning and personal development needs of science undergraduates.

Introduction

The desirability of a broad-based skills component is a widely recognised feature of UK physics degrees. Thus all programmes include elements of group work, presentation and negotiation skills, time management, problem solving and leadership skills as demanded by UK employers (Institute of Physics 2002a). Problem-based learning (PBL), in which students work in groups to search out and apply the knowledge required to solve 'real-world' problems, brings these elements together in a coherent and integrated way. Nevertheless, as far as UK physics is concerned, PBL is an idea whose time has not yet come. In this paper we explore the barriers to change as experienced through a three-year nationally funded project to promote and investigate qualitatively PBL in physics and astronomy in UK universities (Project LeAP 2005). The project, which began in 2002, involves a consortium of physics departments at four UK universities led by Leicester. The aim of the project was to pilot and report on a wide variety of approaches to PBL in undergraduate physics teaching. The pilots involved a total of about 300 students in years 1 and 2 of a standard UK degree programme and a total of 20 staff, to varying degrees, in the four consortium institutions.

Our discussion is based on staff perceptions gathered from visits, by invitation, to ten UK physics departments as part of the dissemination activities of the project. These departments had expressed an interest in learning about PBL, although they were not in general committed to significant implementation. It will become clear that the LeAP project was intended to disseminate information about PBL and did not include a rigorous educational research component. Nevertheless we believe that the reports of staff at these institutions and within the consortium, provide an insight into the process of change. The evidence we summarise has been gathered in part by an external evaluator, through questionnaires and structured interviews with students and staff, and in part by informal interviews carried out by the project team themselves.

Curriculum change begins with the recognition of a curriculum problem. In medicine and, possibly to a lesser extent, in engineering, and now in nursing and other professional occupational training, the curriculum problem that underlies the motivation for the introduction of PBL was (and is) obvious: students cannot learn to respond appropriately in the professional environment if the whole of their undergraduate experience excludes that environment. Educational researchers, but apparently not all practitioners, have known since Dewey that "students learn what they do, not what they are told" (Dewey 1963). In contrast, in training students for physics research, we tend to concentrate in the undergraduate years almost exclusively on the knowledge base for its own sake. To criticise this, as we shall see, is not to deny the compulsory requirement of a reservoir of memorised proofs and model examples. The curriculum problem that it raises, however, is to deny students the experience of the art of the formulation of a problem in theoretical work and the design of an experiment in practical work. In short, it tends to deny students any insight into the professional experience of physicists.

Recognising the curriculum challenge

Our survey of PBL activities in the UK shows that the problem is recognised to some extent, particularly in the lack of stimulation provided by the traditional laboratory programme. Thus, many physics departments have introduced not only the final year project, but also laboratory project work earlier in their programmes, for example in first year laboratories (see the clickable map on the Project LeAP website (Project LeAP 2005)). Some, at least, of these are of a type that we would not consider to be that much of an improvement, tending to be variations on the traditional theme in that they merely require known, and hence apparently pointless, experiments to be carried out with a less than traditional amount of prior information; but they are at least a start. Incidentally, the European qualifications framework is particularly unhelpful here, with its emphasis on core material early on and project work only in later years. We want to argue for a research approach to learning from the beginning of a programme.

The traditional approach is reinforced through one of the main curriculum challenges in the UK and elsewhere, namely the so-called mathematics problem amongst aspiring physics students. This is not new; apparently Pierre Curie is said to have despaired at teaching physics to students with inadequate mathematics, and no doubt he was not the first. Unfortunately it begets the desire to sit students down and tell them in minute and almost endless detail all the mathematics they will need. The material differs from degree programme to degree programme, but is invariably more that many of the students at any given institution can cope with. We do not know if PBL can be used to alleviate the suffering (that is the subject of a different project), but the current approach does have the effect of reinforcing the notion, to both staff and students, that a physics education is an exercise in enhancing the passive absorbency of the brain.

Perhaps the main obstacle to the recognition of curriculum challenge is the success that UK physics departments have enjoyed in national quality assurance exercises (Institute of Physics 2002b) A higher fraction of physics departments were judged to be excellent in their undergraduate provision than in other disciplines. It is easy to understand the rationale for the methodology of these assessments, namely that Departments were judged against their own aims and objectives, not against any external standards, but the results therefore do not justify the conclusion that physics higher education is of the highest quality.

A further obstacle to recognition of the need for change unearthed by the project is student expectations. The school system in the UK (and elsewhere) is now dominated by a national curriculum, and league tables of results, which focuses attention on ‘getting it learnt’ or ‘teaching to the test’. Especially in physics, students experience a lot of keeping to task, which is usually that of finding the right formula in which to make a numerical substitution. Our experience is that students come to higher education not knowing what to expect, but latch on very quickly to any hint that it could be ‘more of the same’. Thus, although there are exceptions, implementations of PBL in physics that have been successful have tended to be those designed around PBL rather than those into which some PBL has been shoe-horned, as students are quick to wonder why PBL is used for some activities rather than others. It follows that student satisfaction is not a good indicator of the need for ‘no change’.

In the UK twenty-six departments of physics have been closed or have ceased to offer single discipline degrees in the last ten years, with difficulties in recruitment being a significant factor in many cases. There is unfortunately no evidence, so far, that changes to the physics curriculum impact on recruitment; indeed the growth of the larger, traditionally structured, departments might be cited to indicate the opposite. Thus in physics we lack what could have been one of the main drivers, namely evidence of enhanced recruitment to the discipline through PBL.

Obstacles to change

Given though that the absence of evidence of motivators to change is not evidence of their absence, we turn next to other obstacles to change even were the need for change to be recognised. The principle reaction we found on our visits was the unhelpful influence of the Research Assessment Exercise on teaching quality. (The RAE is a periodic peer review of UK research outputs with the grading of departments determining a large component of future base funding.) The impression is that the focus on RAE scores appears to drain resources from teaching developments, for which staff believe that there is limited personal or professional reward. This is particularly acute in smaller departments under pressure, which may recognise the potential opportunities of curriculum change but lack the resources to respond.

A second major obstacle we found was the perceived effort in setting up a PBL component. We have argued that, beyond the initial learning curve perhaps, this is not much different from the effort involved in writing a lecture course and its associated problem sets and on-line support materials from scratch. Nor is the recurrent effort much different in PBL than it is in conventional formats. Rather, what is lacking for PBL, in contrast to traditional approaches, is a fund of shared experience in the physics community. Project LeAP has attempted to provide some support in this area through a web bank of a variety of physics problems and a practice guide to implementation (Raine & Symons 2005). It is too early to determine the impact of this resource.

Finally, accreditation by professional bodies in the UK is often cited as a potential difficulty because it is said to impose certain curriculum requirements. Experience in engineering would seem to indicate otherwise, and universities outside the UK have reported no difficulties in accreditation of PBL physics courses.

Varietes of PBL

Given this apparent negativity it is interesting to note the number of departments that reported the use of 'PBL-like' activities in Project LeAP's survey of physics departments in England. Eighteen departments out of thirty-seven replied to the survey with only one seeing no use at all for PBL. When prompted, staff often responded readily with lists of the advantages to students of a PBL approach (although we should note that they were often equally quick to propose disadvantages to staff). Nevertheless, we interpret these responses as a willingness to embrace PBL as a larger or smaller component of a programme provided that certain conditions are met. These would include evidence that it has no negative impact on the quantity (or quality) of student learning and no negative impact on staff time for research. While it is not possible to grant these wishes in precisely this form, the PBL practice guide authored by the project team and their collaborators does provide a narrative of the introduction of PBL into a variety of programmes in a variety of ways and is a resource for the implementation of PBL.

We can divide the modes of implementation into the following categories:

1) PBL at the programme level, where the course is designed round PBL. This does not exclude the possibility that some components are taught in a more conventional manner where there is a pedagogic rationale for this. Examples are Dublin Institute of Technology in Ireland, where years one and two of a four year physics programme are PBL, including, most recently, the laboratory component (Bowe & Cowan 2004), and Delaware, where the laboratory component and the advanced level courses are traditional even within an 'all-PBL' campus (Duch et al. 2001).

2) PBL at the component level. In this case one might convert one or more components of a programme to PBL. Examples might be all core theory up to some level, or all laboratory work. Implementations of this are hard to find since the successful conversion of one component puts pressure on others. Dundalk Institute of Technology in Ireland is an example where the introduction of PBL for the first year core material led rapidly to the conversion of the laboratory work also (Lennon 2005).

3) PBL at module level. There are many examples. These work best when there is an academic reason for treating one or more modules differently. For example, Paul van Kampen at DCU teaches thermal physics to a class of physics education students using PBL (van Kampen et al. 2004). They work worst when a single member of staff decides to go it alone (with implicit criticism of the rest of the teaching). The most common form involves a module devoted to problem-solving. Many of these modules could in our view be improved by a more rigorous dose of PBL, which would provide some motivation and open-ended-ness (discussion points) for the problems. Another common area for single module PBL is scientific ethics. A design study at the University of Hertfordshire is another example, which has the additional interesting feature that students from different departments (physics and design) work together. At Leicester we have a business skills module that

teaches management in the context of running an internet training company. The worst of these, in our view, is the 'skills module' that is intended to hive off the delivery of various skills (group, presentation etc) in the absence of any professional context.

4) PBL at sub-module level. This might be considered as a relatively minor curriculum change, but it can be more than that. For example, at Leicester we have a component of each of the core modules in years one and two that links theory, laboratory and computational work through PBL problems. There is also a rolling programme to deliver the laboratory component of the specialist options (astrophysics, space science etc.) in PBL form.

5) Individual PBL events. These can vary from a part of a class to a day (or more). They can make impressive outreach activities and can be useful starting points (Raine & Collett 2003).

The student view

It is a common experience that the initial implementation of PBL throws up problems that have to be addressed next time round (although in this respect it is scarcely much different from the traditional lecture course). Adjustments are usually found to be necessary to problem statements and sometimes also to assessment and scheduling. Nevertheless student reaction to these examples of PBL have generally been positive. (They have varied from, at one extreme, a student attempting, unsuccessfully, to organise a petition to put a stop to PBL to, at the other, students volunteering their help to extend its implementation.)

While most implementers report little if no immediate influence on examination performance, there are notable exceptions, for example Dundalk Institute of Technology reported an increase in pass rate in first year physics from 60% in 2002/3 (using traditional teaching methods) to 84% in 2003/4, the year in which problem-based learning was introduced (Lennon 2005).

However, most research on the influence of PBL on physics students has been qualitative. In our own project, reactions collected through 18 focus groups totalling about 60 physics students (some seen more than once) in the consortium Universities of Leicester, Sheffield, and Hertfordshire by Project LeAP's external evaluators (the Centre for Recording Achievement) show that students quickly identify the skills and personal development benefits of PBL and its ability to model a real working environment:

> 'it's better in a group…with everyone's input…you can bounce ideas off each other…and others' ideas might be better. In industry you work in teams'

> 'better equipped for the future. In the future we'll know (when confronted with real problems) we've done something similar. It gives us group working skills'.

Some appreciation of the differences in approaches to learning between lectures and PBL was also immediately obvious to the students:

> '[With PBL] there's a lot more discussion about what's happening'.

> 'To learn the computational method at the same time as the problem is helpful.'

> 'it helped us to realise – we can do it'.

> 'practical learning… it really helped me to understand and apply the theory…I understand a lot more'

Other benefits were only realised by students in hindsight. These quotes are from third year students at Leicester who had participated in four two-week PBL problems during their first and second years but who were interviewed during their third year project;

> 'we felt we needed preparation for PBL but, actually, PBL was a preparation for now'
>
> 'you have to learn it for yourself, not by preaching…you have to have the experience before you can see how good it is'
>
> '[it was] excellent learning in a different style'

Conclusions

Our conclusions both from our survey of current practice and experience of implementing PBL in our own Department, is that PBL can serve to integrate and align teaching and assessment elements across the curriculum. By highlighting issues in current practice, the engagement of academic staff with the PBL philosophy can lead to a beneficial impact even on traditional teaching whether or not this is seen as a first step to implementation of PBL. The particular issues include the alignment of the assessment practice with the intended learning outcomes, including the skills element of a programme, which can serve to move assessment from a process of recall to a demonstration of understanding through application of knowledge. In addition, PBL highlights the efficacy of a strategy for developing student skills that is truly embedded in course design. In terms of re-invigorating the discipline, we have found that most students engage much more fully with material that has a context and that this approach should not be restricted to recruitment and outreach activities alone!

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IMPLEMENTATION OF PROBLEM-BASED LEARNING IN ENGINEERING EDUCATION

– PBL curriculum in Mechatronics

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After four years of hard studies newly-qualified engineer Michael Mechatronic steps in his first workplace Plywood Production Development (PPD) Inc. The new desk shines bright and the colleagues welcome Michael friendly. The head of division calls to him and congratulates about the nomination as a project engineer: "Welcome to PPD. We hope that you will enjoy working with us. We have just made a contract of mid-scale plywood production line to Australia. You will take over this project under management of engineer in chief. You and the engineer in chief will start to form the team for the project at starting meeting tomorrow morning at 9. Have a nice day!". Michael collapses in his chair, takes a long breath and has a cup coffee. While drinking his coffee he thought: What have I learned during these four years? Will I manage this?

Introduction

The scientists and professionals in education should emphasize the relevance of the learning results of educational system more: does it produce the competencies to the students, which are relevant to the qualifications from the work-life? In engineering this question is perhaps even more crucial than in other domains. The competence of the engineers reflects directly to the competitiveness of the company. In engineering education the competence has been determined mainly from the point of view of science and technology. On the other hand especially during the 90ties the spectrum of competence of engineers expanded to concern more social items (teamwork, management), communication (foreign languages, presentations), acquisition of knowledge and problem solving: from Theory to Skills. Traditional engineering curriculum cannot properly face this challenge: there is a need for a fundamental update in engineering curriculum.

PBL is one promising strategy to meet new post-modern qualifications of the professionals coming from the changes of work-life. Lahti Polytechnic Faculty of Technology (Mechatronics) is a pioneer applying PBL in Engineering in Finland. PBL has been used as a curriculum strategy in our education for 4 years. To change the strategy of curriculum totally will start the massive change process, which will cover the whole organisation. All changes create instability to the organisation: the sense of insecurity, incompetence and lack of professionalism. Therefore the change management is essential to ensure the continuation of the process.

In this paper I will tell our story: how we did it. I will give you a short historical preview of our project and present the main result: the features of our PBL Curriculum. For closing I try to serve some hints and learning results to those who would be interesting to convert their curriculum to PBL Curriculum. The approach of this paper is very practical: the statements are mainly based on our experiences. Two master theses (University of Tampere/ Department of Education) have been done during the project so far. The first one focused on the evaluation and assessment process and the second one on curriculum as a tool for common knowledge creation. The main results of those studies will be presented.

The motivation for the change process

“The traditional system is still working quite OK”. “Don’t fix the operative machine”. “We have done this with these methods for ages and we will do it also in the future”. These are main arguments against the change from the teachers. “It is easier to follow lectures than to learn all by myself”. “Are we really going to graduate some day as qualified engineers”, will the students ask. “PBL is more expensive than the traditional teaching methods”, argues the administration. Why bother?

We are in the vortex of increasing speed of changes around us. The technological, demographical and social changes transform the world: many societies have developed from the modern to post-modern. During this process the concept of knowledge is not as before: it has contextualized. The traditional curriculum is mainly based on “the metaphor” of transmission of knowledge: an expert transmits his or her knowledge to a student. The contextual idea of the knowledge leads to a constructivistic approach of learning: the students have to construct the knowledge in a team and as an individual in a real context. The ideal result of this process would be a shared common knowledge: a tacit knowledge (Nonaka & Takeuchi 1995, 10). Teachers should step aside and build up the genuine student-centred learning environment.

Changes in international markets and competition (“China Phenomenon”) force the companies to seek productivity from organisational rearrangements: The Lean Production. The result is a wider spectrum of qualifications to engineers. The main part of the work of the engineers is done in projects: teamwork, communication (negotiation), acquisition of knowledge and problem solving. In post-modern world we do not carry same values of life. There is a vast variety of choices to pick up. The educational institutes have to compete of students minds with entertainment industry and hobbies. The students are seeking for experiences. The education should produce positive experiences to the students as well. The days of lectures as a main teaching method are over.

One strategic tool to meet these global changes is PBL. From the widest aspect PBL can be seen as a total change and development strategy rather than an operational teaching method. PBL can work as a tool in change management: to manage the changes in a) concept of knowledge, b) working environment of engineers (new qualifications) and c) students.

Problems or projects

Would Project Learning do the same than PBL or even better? Perrenet, Bouhuijs and Smits enlighten some special aspects to be taken into account when redesigning the curriculum in engineering (Perrenet, Bouhuijs & Smits 2000). They suggest in their study that in engineering the combination of PBL and Projects could be a starting point to PBL Curriculum design. Our experiences confirm this idea. We see the PBL-learning cycle as an educationally "tuned" problem solving process. The main difference between these processes is the focus. The focus of PBL is learning: in the starting tutorial the ownership of the task should be transferred to the students in form of learning objectives. In projects the "raw" problem solving process is used, while the focus lies on problem solving. In PBL-process the assessment (self-, peer- and tutorial assessment) is highlighted.

In Lahti Polytechnic Faculty of Technology (Mechatronics) we have used PBL as a curriculum strategy in our education for 4 years. First PBL students graduated in May 2004. We have developed a study system which is the combination of problem and project based learning. During the first and second study year the basic knowledge and skills are studied mainly with Problem Based Learning. The focus is in the development of study skills and the basics of mechatronics. The students do larger project in groups, which are planned by the tutors (teachers).

The main idea is that the students will learn to run the more comprehensive PBL process in two years and get some experiences of the project work. In project we would like to arrange experiences of the implementation process: on the computer display everything works, but when you construct your plan, there is totally new world to face. In 3rd and 4th study year we do practical projects with the companies. The projects are ordered by the company and the students have to negotiate about timetables, objectives and finance trough the project. The focus in here is to learn in the real environment with real projects: the adaptation of knowledge. These company projects last normally six months. The "real" engineering is so demanding and time consuming that it should be learned by real projects. In the early stages of engineering education PBL is a useful learning strategy.

Our story: a short historical preview

Traditional curriculum of engineering starts with a strong package of theory: mathematics, physics, chemistry and the basics of engineering. The practical skills were studied mainly in the laboratories. In the beginning of 90ties we noticed that our students were overwhelmed by the mass of theory studies. They asked: when we will start to study the real engineering? According to this we added some practical projects into our curriculum. In the late 90ties there was an increased frustration and a lack of motivation of the students. After analyzing the situation we found out that:

- The students had problems to learn two basic and divergent approaches (Mechanical and Automation Technological) to Mechatronics simultaneously.
- The intake was doubled, which reinforced the number of drop-outs.

"Houston! We have a problem." Something had to be done and fast. After survey, we found PBL. In autumn 1999 we started to study PBL and in the next year (Autumn 2000) first student groups were established. The first year was chaotic. We did not have enough experience about case (problem) writing, assessment and guidance of the student groups. We tried to integrate mathematics and physics with the professional core studies, but after two months we had to draw back: only the professional core studies followed the PBL-process and mathematics and physics were learned by traditional method (lectures and exercises). To summarize the results of the first year of our project:

- We collected knowledge and experiences, how PBL should be implemented in practise in Mechatronics.
- We trained ourselves to run PBL-process (coaching and assessment)
- We were able to start redesigning of our curriculum
- The students could not finish all study courses (-20%)
- In the student group assessment and guidance there were major defects
- The study materials should be improved
- Facilities were under construction

The first year of implementing PBL was total and aggressive learning process for us all. Finally we knew what PBL requires: almost everything has to be changed. To manage this massive change process it was obvious that curriculum should be redesigned. To begun with we thought that updating of curriculum should be sufficient, but very soon we dropped out the idea. In the spring 2002 the collaboration with University of Tampere started (ProBell Research Group of PBL) and this was the turning-point of our project. Especially the consultancy of Professor Esa Poikela and Professor (acting) Sari Poikela formed a backbone to our curriculum development work.

The first major task for us was to research, what we have done so far and what we should do in the future. We decided to order two studies from the University of Tampere, Department of Education. The first study was a qualitative evaluation research (Koskinen 2003). The purpose of this study was to research how it is possible to develop learning through the evaluation and assessment of the pedagogical process. The study examined the evaluation and assessment process in the problem based learning in the Faculty of Technology at Lahti Polytechnic. The aim was to describe the evaluation and assessment methods used in the faculty. The study took into consider both tutors' and students' point of views. The aim was also to produce development ideas for the evaluation of the problem based learning.

"According to tutors' and students' conceptions of the assessment of the pedagogical process in the problem based learning was still mostly result evaluation. Process assessment was not working very well yet. Operational and cognitive processes were taken into consideration but social and reflective processes were mostly ignored. Both tutors and students were how-ever ready to develop evaluation methods. Tutors saw that in the future students should take more responsibility of their own learning. Students in the other hand didn't always understand that giving up the traditional evaluation methods could improve their learning. However, it is possible to understand the individual and shared knowing and learning only through the assessment of the social, reflective, cognitive and operational processes. Process assessment is also a key to self and product evaluation. That is the way evaluation could be the source of learning (Koskinen 2003)".

The main result of the study was that we had evaluation but not assessment. According to this knowledge we rewrote our evaluation and assessment system. This system will be more detailed discussed in the next chapter. The study gave us also the point-of-view of the "outsider": the study produced also auditing information for us.

The second Master thesis study started in January 2004 (Forsberg-Mikkonen 2004). This study was focused on a curriculum as a tool for common knowledge creation. The main objective was to create ideas for future development of our curriculum. The study showed that we still have defects in the level of integration, guidance of the students (assessment and self-study) and collaboration of the tutors (with each other and with the staff). This study gave us a valuable check-list of the defects in our system. On the other hand, when implementing PBL, you have to prioritize what to do: first things first. With the present resources is impossible to put everything in order in the same time.

Another result was that all tutors consider the students as "customers": we are working for the students and we are interested how they are doing. According to study the tutors and students recognize the same problems in the system, but from the different point of view. This demonstrates that we were able to build up the open and informal learning environment, where the feedback in both directions can freely be presented.

According to the student feedback we corrected the content and implementation of Orientating Studies in autumn 2004. We also improved the scheduling of study modules and updated the content. What we have to do in the near future is to strengthen the instruction of self-study and to revive the evaluation and assessment system. This requires pedagogical training of the tutors. The first version of our PBL-curriculum was completed in February 2003 and it is developing continuously. In September 2003 new students put the curriculum in practice and the results are encouraging. We are finally on the right road. In our curriculum we point out the difference of characteristics of planning and implementing process. This concerns also the developing process of PBL-Curriculum. In the paper everything looks great, but in the implementation process the Quality and Change Management will produce a massive burden of problems to solve.

When converting the curriculum from traditional to PBL, you will face the extensive change process. The change process has effects on many levels: social (community level), organisational and individual (students, tutors and staff) level. In the beginning it is impossible to know and even identify all of these changes. Therefore you have to be open-minded, collect feedback and confirm quality management. As pioneers we did not have too many references to start with: we had to do a lot of by ourselves. From these studies we got great ideas and valuable auditing information.

The features of our curriculum

Before starting to design the actual learning system, we have to answer the following questions:

- How to understand the concept of knowledge?
- How students should learn (how we see students as individuals)?

We arrived at a result that the knowledge is contextualized: we emphasize the knowledge, which is relevant to the engineer's every-day life. The learning strategy is based on the experimental learning (system) and constructivistic approach (students). In the curriculum level the experimental learning model can be argumented by pointing out the Praxis: skills should have the same weight than theoretical studies. The constructivistic learning strategy leads us to build up a genuine student-centred learning environment.

The starting-point to our curriculum development work is the Kolb's Cycle: the model of the Experiential Learning by David Kolb (see Figure 1). The experiential learning model by Kolb has four phases: a) experience, b) observation (reflection), c) conceptualization and d) action. This is described in the inner circle of Figure 1. The action-observation pair forms the transformation of experiences axis, which is very strongly related to the Praxis. On the other hand the experiences–conceptualization pair states for recognition (or

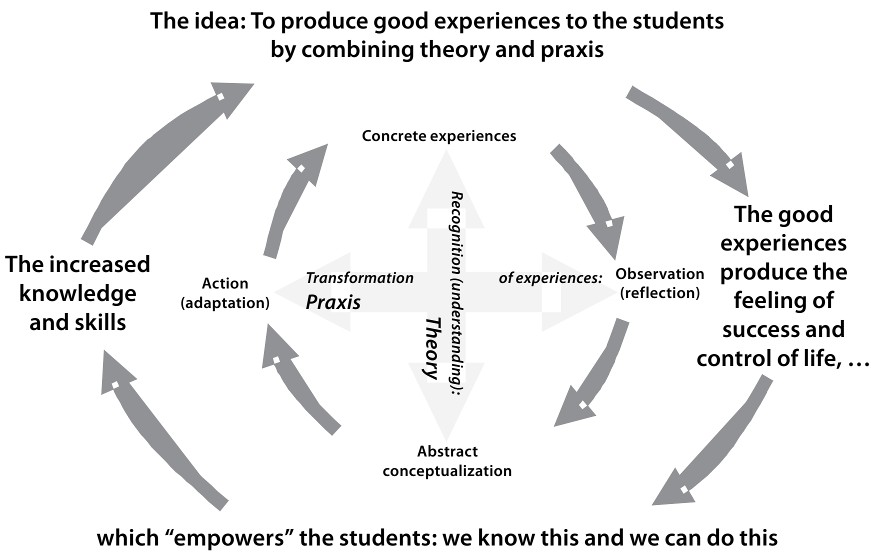

FIGURE 1. The Experiential Learning (Kolb) and Mechatronics

understanding) axis, which is based on the Theory. The outer circle of Figure 1 shows how we have adapted this model. By combining Theory and Praxis in every case or problem the students can apply learned theory immediately (not after two years of studies).

The structure of the curriculum is presented in figure 2. The main features of curriculum are:

- The integration of the core professional studies in three system blocks: Automation Systems, Mechanical Systems and Production Technology
- The same, cyclic body structure every study year: in every study year the whole planning and implementation process of automatic device or system takes place (projects)
- Increasing complexity: more demanding tasks every year (accumulating knowledge)
- Flexible and administrative: content management
- Understandable for the students ("a road map")
- Versatile assessment and evaluation system
- Both process and content objectives for every study year (objectives in operational and functional form)

Mechatronics can be described as "the decathlon of the Engineering". The system thinking is one core concept in our curriculum: the students should learn that the systems in Mechatronics form an integrated whole rather than a massive body of components. The most of the engineers in Mechatronics in Finland plan and implement projects. In Lahti region many companies export over 80% of their production. That is why the engineers should learn, how to run international projects. This planning and implementation process of "real projects" was a model for us: in every study year we complete one.

1	2	Study Year	3	4
Project 1 (4 cu)	Project 2 (4 cu)		Project 3 (5 cu)	Project 4 (5 cu)
Automation Systems Module 2 (5 cu)	Automation Systems Module 4 (5 cu)	Spring	Optional Studies (4 cu)	Specializing Studies (6 cu)
Mechanical Systems Module 2 (5 cu)	Mechanical Systems Module 4 (5 cu)		Mechanical Systems Module 5 (5 cu)	Optional Studies (4 cu)
Professional Basic Studies (5 cu)	Professional Basic Studies (6 cu)		Professional Basic Studies (5 cu)	Diploma Thesis (5 cu)
Automation Systems Module 1 (4 cu)	Optional Studies (2 cu)		Production Technology Module 1 (4 cu)	Automation Systems Module 6 (5 cu)
Mechanical Systems Module 1 (4 cu)	Automation Systems Module 3 (4 cu)	Autumn	Professional Basic Studies (5 cu)	Professional Basic Studies (4 cu)
Complementary Studies (5 cu)	Mechanical Systems Module 3 (5 cu)		Automation Systems Module 5 (5 cu)	Diploma Thesis (5 cu)
Orientating Studies (5 cu)	Professional Basic Studies (5 cu)		Practising (4 cu)	Practising (4 cu)
Practising (4 cu)		Practising (4 cu)	Practising (4 cu)	

FIGURE 2. The Structure of Curriculum in Mechatronics

The title for the first year project is "an Automatic Device": the students should be able to plan and construct such a device as a team. During the second year they are expected to finish a project, which is a system of a few independent devices. During later phases of studies the students will make "real" company projects. This preconceives that students are capable to accumulate knowledge in layers.

Nowadays many teachers are extra frustrated for the increasing administrative work. In many cases there is not enough time for "the real work": coaching the students to learn. Therefore the main features of the curriculum should be easy content management and flexibility: we can update the content of study modules without disturbing the body structure of the curriculum. To enable the genuine participation of the students in curriculum development, the curriculum should be understandable (linguistically) for them. The ideas, meaning and structure of the curriculum should be clarified in the Orientating Studies.

The assessment and evaluation guides the students work more than we think: what you order, is what you get. The wider spectrum of qualifications postulates wider spectrum of means in assessment and evaluation. The assessment system in our curriculum has two major components: a) the process assessment and b) the result evaluation, which are equally weighted. The process assessment is based on:

- The students self-assessment (form) and feedback discussions
- The peer assessment among the study groups and feedback discussions
- The assessment of the tutorial performance by the tutor
- Personal and group interviews twice a year.

The components of the result evaluation are tests, skill tests and reports. The last but not the least feature is the classification of objectives. There are general objectives for the whole four year education and process and content objectives for every study year. Every study module has objectives of its own as well as every case or problem. The documents of the curriculum are a) curriculum description in the student's guide book (general description of the studies and study modules), b) study module manuals (tutor and student versions) and c) cases (case description, implementation plan and the guide for reporting, assessment and evaluation).

Mini Manual

From the literature you can find papers or manuals how to design the PBL Curriculum in Medicine (Bouhuijs & alii 1993, 69–91) and in Business Education (Fagerholm & Helelä 2003). For the engineering not too many of such papers can be found. By referring those papers and our experiences I will write down the process of designing the PBL Curriculum in Engineering.

The Phases of Curriculum Design:

Phase 1: Find out what the graduated student should be able to do (qualifications).

- This means that "novice knowledge" should be determined. The good idea is to make this in the collaboration with the companies. The results should be linked to the objectives.

Phase 2: Survey the data from the working environment (companies) of the engineers.

Phase 3: Split the data from phases 1 and 2 into circumstantial tasks.

- You may try to do this by forming the objectives operational and functional. You can also "distribute" the objectives of every study module in sub objectives for the actual cases or problems.

Phase 4: Analyze the components of knowledge, skills and attitudes of each task.

Phase 5: Classify the content

- This can be done inside of each study module.

Phase 6: Phasing the content

- This is scheduling: what and when? This can be done also inside of each study module.

Phase 7: Pick up proper learning procedures.

Phase 8: Design the assessment and evaluation system in general and for every task (case or problem).

It is important to write the objectives in the operational or functional form (especially the process objectives). This will smoothen the way to discover the suitable assessment methods. The general description of the education is a good idea: the required core knowledge can be expressed. The implementation of the studies should be planned (both the study modules and cases/problems). If you are able to describe "the internal" logic of the field of education from collected data and experiences, you have a very strong tool for your curriculum development work. You are able assess and evaluate the achieving of the objectives by the method which will match to that logic.

Conclusion

In PBL-learning process the tutorials form the focus and starting point to learning. To work and to develop as a tutor is not easy. Extra attention should be paid on the personal development of the tutors. One guideline to this is a route from teaching to mentoring (see Figure 3).

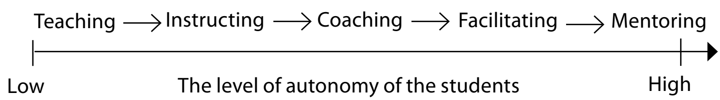

FIGURE 3. "Couching Strategy" of the tutors

In the student group the students are individuals: "Couching Strategy" should be selected according to the level of autonomy of the student. There should be more instructive approach to the students of low-level of autonomy. If the autonomy is high, such a student knows by him/herself what to do: mentoring can be used.

Professor Wim Gijselaers from the University of Maastricht has researched the impact of learning and contact time to the learning results (Edineb Workshops, June 2004). The main result is that by increasing learning time, you will get better learning results. According to our experiences the ratio between learning time and contact time should be at least 1.0 for the first year students. For the last year students it could be much higher (around 2.0).

It would help to commence the development project, if the initiative comes from the team: commitment to the project. There are both internal and external pressures that will cause the need for a change. The change in organizations always creates instability. To manage this aggressive and total change process the tools to increase stability should be developed: the change management is vital. To implement PBL in Engineering Education is very challenging but rewarding process. Under the proper organizational circumstances it can be successfully carried out.

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EXPERIENCES ON A PBL IMPLEMENTATION IN ENGINEERING EDUCATION

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In September 2003, a problem-based learning (PBL) pilot with 92 new students and 8 tutors was started in Degree Programme in Information Technology at Turku Polytechnic. The main goals of the project were to decrease discontinuation and delayed graduations, as well as to improve the students' abilities to work in a team and to learn and think by themselves already from the early phase of their studies. In this paper, the background and structure of the pilot as well as the experiences gathered during the project are presented. In addition, certain guidelines for related trials from engineering education's perspective are proposed.

Introduction

Like many other degree programmes on the higher educational level in Finland, the Degree Programme in Information Technology at Turku Polytechnic has experienced many students dropping out during the first and second years of study. Some students do not simply seem not to be as active and motivated as they should in order to study forty hours a week, do the homework and attend the lectures. Accordingly, course examinations are often delayed from the planned schedule. This is one of the main reasons behind the fact that too many students are unable to pass the courses in the planned order and, thus, to graduate within four years. (Ministry of Education 2003)

Naturally, the problem as such has a very complex nature and certain dropouts have a quite acceptable background, at least from a teacher's perspective. Some students try after the first study year to enrol themselves, for example, in some university or another polytechnic, which they primarily preferred. Others may have found out that studies in information technology were not their true calling in the first place. These students are better not to be prevented from leaving the degree programme; although their presence as such clearly indicates – if nothing else – that the role and quality of study counselling during the preceding levels of study should be improved to decrease the amount of incorrect path selections.

However, despite the rather significant amount of students leaving due to acceptable causes, the problem still exists. Especially for the first and second year teachers the situation is frustrating. They may start their lectures with full classrooms but after some weeks the amount of absent students gradually grows and, finally, too many students do not pass the courses. The postponement of the studies as well as the poor ratio between the students starting their education and the ones celebrating graduation from the original institution affect on the financial situation of the degree programme. The governmental support to the polytechnics in Finland is directly proportional to the amount of active students within the ideal duration of the program. In addition, the negative impact also exists on national economic level.

In this paper, practical experiences from a development project addressing the described problem by the means of introducing the problem based learning paradigm are presented. The background and structure of the pilot are explained and the experiences gathered during the project discussed. Finally, certain guidelines for related trials from engineering education's perspective are proposed. The main goal of this paper is to make the information available to others who are planning similar implementations especially in the field of engineering education.

Background

Prior to any dedicated development project activities several discussions upon the problem took place, and various improvement actions were implemented within the continuous development work of the degree programme. For instance, different rules and recommendations for teaching Mathematics and Physics were given because they were experienced as the most difficult subjects for the students. The lecturers also thought about teaching Computer Software Programming and asked: how to start and in what language?

Moreover, it was realized that the structure of the curriculum was rather theoretical and fragmentary especially during the first two years of study. The students' schedule included mainly Mathematics, Physics, Circuit Theory and introductory courses in Information Technology accompanied by compulsory language studies (Turku Polytechnic, 2002). More practical aspects and connections to working life were needed to motivate the first and second year students.

The Rector of Turku Polytechnic also expressed that discontinuation and delayed studies should be prevented by all means available. In autumn 2002, additional project financing targeted to development of new teaching methods was announced to motivate the degree programmes and their staff to make it happen (Rauhala et al. 2004). This worked. Also the Degree Programme in Information Technology filed an application for a teaching method development project for 2003. The application was accepted with EUR 49 000 financial support given on top of the annual budget frame. (City of Turku 2003)

The project started in February 2003. The plan was to experiment one kind of problem based teaching and learning to motivate the students. The teachers Keijo Leinonen, Olli Ojala and Raija Tuohi (the degree programme manager at that time) had attended a six day course in PBL organized by Professor Esa Poikela during the summer and autumn 2002. The way of connecting the professional reality to studies via problems (Poikela & Poikela 1997a) was found very interesting. A strategic intent towards PBL-oriented method selection was mentioned in the pedagogical strategy of Turku Polytechnic, too (Turku Polytechnic 2003). So it was natural to at least try these methods. Moreover, the research results concluding that PBL can be successfully applied in engineering programmes supported the process (Perrenet, Bouhuijs & Smits 2000). Still, the project started with no eager anticipations. It was known that there would be a lot of work. That proved to be true and, despite of the financial support, a significant amount of work was done without any extra lines in the pay check.

Elaboration phase

The project consisted of two main parts. The first half of the year was scheduled to be spent in establishing a detailed plan for the actual implementation pilot to be started in September 2003. A vital part and goal of this elaboration phase was also to introduce the PBL-methodology to the staff and inspire them to take the challenge in jumping into something still rather unknown and risky.

Pre-study – could we learn from other's mistakes?

The first step to do was to find out whether there was any practical experience of PBL in the Finnish polytechnics in the field of engineering education. It was thought that maybe some models could be found and applied to the information technology curriculum. Thus, a brief survey was made in March mainly focusing on contacting a set of institutions known to been active in the teaching method development. The survey showed that there were not so many polytechnics or related institutions in Finland that actually had carried out practical PBL-based pilots on degree programme level. However, interesting implementations were found in Lahti and Jyväskylä Polytechnics.

Teachers Janne Roslöf and Juha Helenius visited Lahti Polytechnic where Teijo Lahtinen kindly introduced the Lahti model in the Degree Programme Machine and Production Technology and its specialization Mechatronics. Keijo Leinonen and Olli Ojala visited Jyväskylä Polytechnic where Maritta Pirhonen introduced their project-oriented model. Although these implementations were not directly in the same field of engineering, they provided an important reference on a true PBL-trial. Especially the practical experiences in Lahti (Lahti Polytechnic 2003 and 2005), as well as Teijo Lahtinen's inspiring but practical perspective encouraged the staff at least not to give up before the implementation even had started.

Staff training – what was hiding behind the three magic words?

At the end of April, a course in PBL for the teachers started in Turku Polytechnic. In total, twelve teachers from the degree programme attended the course tailored to our requirements by the Eduta Institute of the University Tampere (University of Tampere 2005). The topics of the six course days included the following: Basics of PBL and the theoretical background, Tutoring and guiding of a group of students, PBL curriculum, Assessment of learning, Planning and constructing the problems, and PBL & change management. The training included also self studies and homework between the contact days. During May and July the participants considered the possibilities of co-operation, different kinds of PBL packages and different ways to coach the learning process. The way towards the changes had started.

To promote the project and to conclude the main part of the planning work before switching into the summer vacation season, a PBL seminar was organized in Turku Polytechnic on 20 May. The representatives of Lahti and Jyväskylä Polytechnics introduced their models and methods to the teachers of the Degree Programmes in Information Technology and Electronics. How the PBL was put into practice was very interesting to all participants and, perhaps, it was the point where a quiet agreement about starting PBL was obtained. On the other hand, neither the training opportunity nor the seminar earned full support from all the staff members in the two degree programmes. Many colleagues did not participate in any of the events organised, or dropped out during the first day of training.

Planning the implementation – endless (?) meetings and class room scheduling problems

The planning process included a significant amount of hours spent in various discussions; both in formal meetings and in more ad-hoc type of events. From the project planning perspective a series of workshops took place during the spring and early summer months. The first meeting gathering all the teachers in the Degree Programme in Information Technology was held at the beginning of April. The visitors to Lahti and Jyväskylä Polytechnics and teacher responsible to study the timetable problems were chosen. The overall situation about the established teaching method development projects was presented and discussed.

The second meeting was held after the two first days of the PBL course. Now it was clear that a practical realization plan on how to apply PBL in practice was indeed necessary to keep the project on track. Two groups of teachers were chosen for this task. The first group consisted of three teachers representing Mathematics, Programming and Computer Design. The second group consisted of three other teachers in Mathematics, Electronics and Circuit Theory. It was thought that PBL problems could be constructed covering suitable integrated themes in these subjects.

The following gathering took place two days after the PBL-seminar. The results of the meeting were very important. The seminar had influenced everybody and now it was feasible to discuss the PBL model of the degree programme reflecting the ideas towards the practical viewpoints presented at the seminar. The direction of the discussion jumped back and forth between the finest details and large principles. Finally, a decision was made: the PBL pilot would cover all the first year students; there would be 9 PBL groups with 10 students in each; a new problem would be presented weekly during the academic year 2003-2004 and a group study session between the tutorials would be used according to the Lahti model (Lahti Polytechnic 2003 and 2005). Seven teachers volunteered to tutor the groups. Some possibilities to form the weekly learning problems were considered. However, this work was left for smaller groups formed in the earlier meeting. Moreover, the potential timetable related problems were taken up in the discussion.

It was known in an early stage that there could be problems with the timetable and other practical arrangements. Approximately 90 students start their studies in the Degree Programme in Information Technology annually. The first year students are usually divided into three groups. If PBL was truly started and the students further divided into 9 teams simultaneously, 9 teachers and classrooms would be needed at the same time instead of three as in the conventional case. Furthermore, the very same classrooms were used daily by six other degree programmes. This problem was seriously looked at. The conclusion was that timetables can be written if the PBL places and times are located into the schedules first and all other lectures are allocated thereafter without breaking the PBL-structure.

At the beginning of June the groups presented the problems planned for the three first study weeks in September. The ideas of the problems were considered feasible but the problems still required more detailed formulations; two teachers were chosen for each problem to work it out. The assessment was also discussed. It was impossible to tune the curriculum for the academic year 2003–2004 anymore. Thus, it was also thought how many hours the students should work with a PBL-problem and how many hours should be reserved for the old, traditional teacher-lead way, respectively. The students' guidance to the new method was also planned. Nearly every teacher in the degree programme was given some work to do before the next meeting in ten days.

In the fifth and the final elaboration phase meeting the three first problems were presented in detail and accepted. The subjects of the problems were studying skills (how to study), engineering profession (what and why to study) and reporting (how to write a good report). The lecturers, or the responsible persons to contact specialists to give the lectures between the tutorials, were chosen. The rules and formal guidelines for preparing the problems were discussed. It was found necessary to attach a guide for the tutors to each problem description. This was to highlight the ideas behind the problem and to lead the tutors into the topic at least on a level required to guide the students during the sessions. One of the tutors' tasks was still to supervise that the students identified the important facts in the problem representations (Egidius 1991). In this meeting also the ideas of the problems in the autumn semester were considered.

Two weeks before the start of the autumn semester 2003 a list of problems with responsible teachers for the following 15 weeks finally existed. Also the lecture timetable was ready. First versions of the guides for tutors and students were written and the tutors had started to plan the schedule of the new students' first three days. Students were divided to groups. It was thought from the very beginning that the students should not self-select their teams (Beaumont & Sackville 2003). Working rules and guidelines for the groups (for example how to behave in case of absence or being late for the tutorial sessions) were discussed. A day before the starting day of new students even the responsible teachers for the assessment process were agreed on.

First year of implementation 2003–2004

The structure of the pilot

The pilot was built on weekly problems. One problem was planned to involve approximately 11 hours week workload for each student. The weekly PBL-oriented program was structured for each team of students as follows:

- Tutorial session (2 x 45 min with the tutor)
- Lectures (2 x 45 min)
- Self-study (3 x 45 min, teachers available during the first weeks)
- Group study session (45 min with the tutor)
- Self-study (3 x 45 min, teachers available during the first weeks)

An example of the weekly schedule from the PBL-implementation's view-point is presented in Figure 1.

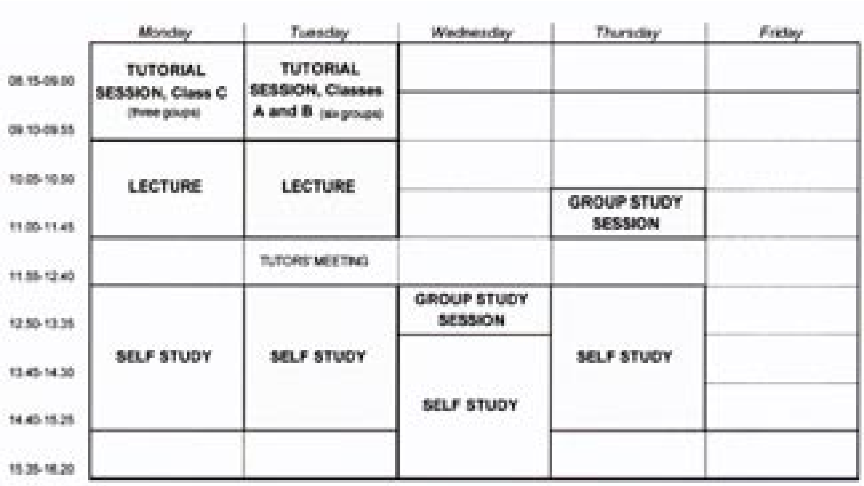

FIGURE 1. The PBL-pilot's weekly schedule

In order to coordinate the practical arrangements and to be able to discuss eventual problems and other findings, the tutors had their own 45 minute meeting once a week. There were nine teams with about ten students each but only eight tutors. So, one tutor had two teams and the other tutors had one team each. The total amount of students was 92 and there were neither available class rooms large enough to gather all the students together for the lectures, nor enough separate class rooms to run the tutorial session simultaneously. Thus, the timetable was planned so that three groups had their meetings on Mondays and Wednesdays and the others on Tuesdays and Thursdays.

An example of a schedule for a class of students (further divided in three PBL-groups) is given in Figure 2.

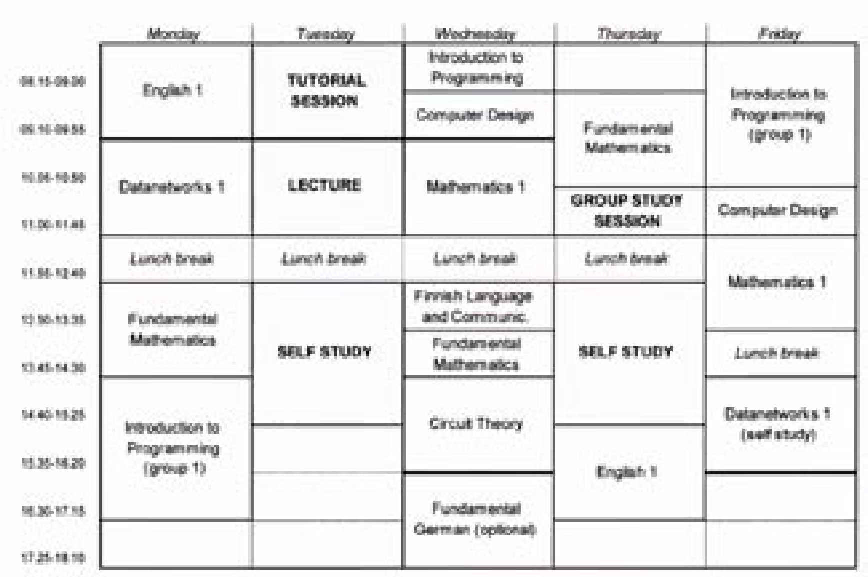

FIGURE 2. An example of a class group 220AS03's weekly schedule, autumn 2003

The pilot was integrated with the courses:

- Information Management (1.5 ECTS)
- Study Skills and Professional Growth (3 ECTS)

and partly with the courses :

- Mathematics 1 (4.5 ECTS)
- Introduction to Programming (4.5 ECTS)
- Computer Design (6 ECTS),
- Finnish Language and Communication (3 ETCS)
- Data Structures and Algorithms (4.5 ECTS)
- Mathematics 2 (6 ECTS)
- Introduction to Electronics (3 ECTS)
- Circuit Theory 1 (3 ECTS).

The structure of the integration is illustrated in Table 1.

TABLE 1. A list of problem topics in the autumn semester 2003

Week	*Title of the problem*	*Courses involved*
36	How do I learn?	Study Skills and Professional Growth, Information Management
37	What should I learn?	Study Skills and Professional Growth, Information Management
38	How do I report high-quality	Finnish Language and Communication, Study Skills and Professional Growth, Information Management
39	Where is the turtle hiding?	Introduction to Programming, Study Skills and Professional Growth, Information Management
40	0 or 1?	Computer Design, Study Skills and Professional Growth
41	Matrix*Matrix Reloaded + Keanu Reeves = ?	Mathematics 1, Study Skills and Professional Growth
42	Should I write a novel, a poem or hypertext?	Introduction to Programming, Study Skills and Professional Growth
(43)	(Vacation)	
44	How do I find a job?	Study Skills and Professional Growth
45	Matlab Masters Ltd.	Mathematics 1, Introduction to Programming, Study Skills and Professional Growth
46	Connecting people! = tyrH kAhva uRHoset	Mathematics 1, Introduction to Programming, Study Skills and Professional Growth
47	Mesh current method	Circuit Theory 1, Study Skills and Professional Growth
48	Java programming	Introduction to Programming, Study Skills and Professional Growth
49	From problem to expression	Computer Design, Study Skills and Professional Growth
50	1+1+1>4?	Study Skills and Professional Growth
51	Reflection and feedback	Study Skills and Professional Growth

The applied PBL-cycle consisted of the following steps: 1) Clarifying concepts, 2) Defining the problem, 3) Brainstorming, 4) Systematic classification, 5) Formulating learning objectives, 6) Lectures and self study, 7) Clearing up, and 8) Reporting. The teachers had studied, for example, the work of Poikela and Poikela (1997b), which influenced the form of the chosen PBL-cycle.

At the beginning of a cycle the tutor gave the problem to the students. It was written on paper and copied to every student in the group. First the students used some minutes to read the problem. Then they discussed the concepts they found difficult. After getting the terminology in place they could reformulate the problem and, by brainstorming, find different aspects to the problem. During the brainstorming phase the students wrote keywords on post-it stickers to find ideas and subjects connected to the problem. The stickers were placed on a blackboard and clustered according to their content. Using these classifications the students were able to recognize the items necessary or helpful in the problem solving. Furthermore, they also had the opportunity to identify less familiar themes behind the problem. Based on this reasoning they formulated their learning objectives for the cycle.

These steps took about 45 minutes of the tutorial session. Immediately after the session a lecture on a theme related to the problem was given. After the lecture the students had a three hour reservation for self studies aimed at applying the knowledge they had obtained as well as seeking for additional information from different sources. After two days the students and the tutor met again and the students discussed the problem and their progress so far. When required, the tutor could give some help and encouragement. After this check-up session of 45 minutes, the students had another three hour reservation for self studies.

The PBL-cycle ended in the following tutorial session where students had a concluding discussion summarizing what they had learnt and how they had solved the problem. This part took about 45 minutes. After that a new cycle was started, i.e. the session continued with a new problem. Finally, every student wrote a report about the problem, its solution and his or her own conclusions.

Students changed roles in tutorial sessions weekly. Everybody could practice at least twice the roles of a chairman, a secretary, an observer and of course a member of the group. As a chairman the student was responsible for the steps of a tutorial session and the timetable. The chairman also had to encourage the members to express their opinions and give the members the floor equally. The secretary handled the post-it-papers and worked by the blackboard during the classification step. He or she also took up the notes of the session to the extent the members wanted. At the end of each tutorial session the observer reflected the work of the whole group and the work of the members separately.

The structure of the PBL pilot in spring 2004 was quite similar to the one in the autumn 2003. Some changes in the tutor groups were made, though. Also some new subjects were connected with the PBL problems and, accordingly, some new teachers got involved with planning the problems and the assessment procedures.

At the beginning of the autumn the students were told that the teams would be changed at the beginning 2004. This was also done. The tutors tried to use their knowledge on the students in forming the new teams in the best possible way. The goal was that the new groups would consist of students with different specialities covering the subjects to be studied during the spring term.

Assessment

In autumn 2003 the problems were multidisciplinary but in spring the problems were mainly connected to one subject. In other words, all tutorial sessions including reporting were obligatory for all students in the autumn semester. In the spring, students who had passed a certain course already did not have to attend the tutorials were problems connected to this course were handled. For example, some students had already passed the course in Introduction to Electronics and thus, they did not need to take part in the related tutorials.

The courses Information Management (1.5 ECTS) and Study Skills and Professional Growth (3 ECTS) were assessed on a scale 'failed–passed'. A student passed these courses if he or she had attended all the related tutorial sessions in autumn and had written approved reports about the respective problems. The teachers of Information Management were responsible to assess the reports connected to the course, whereas the group tutors assessed the reports on Study Skills and Professional Growth.

Other courses were assessed on a scale ‘0–5’ (0 = failed). Even in these courses approved reports on the problems connected with the courses were obligatory. The teachers of the respective courses defined the rules for obtaining different grades. In addition, all the courses included compulsory written exams and some mandatory exercises, too. Some teachers assessed the PBL reports on a scale ‘0–5’ and some on ‘failed–passed’. Naturally, each teacher explained the students how the assessment was to be performed in their course.

Students were guided into team work skills by using a peer assessment procedure based on observing the action in the groups. It was assumed that the students were not used to peer assessment. To make it easier a form for the observer’s assessment was utilized. The following leading questions were raised in the form:

- How did the process succeed?
- How did the team work?
- How did the members of the group work?
    - Was s/he widely familiarized with the topic?
    - Did s/he provide information to others?
    - Did s/he ask questions?
    - Did s/he draw conclusions?
    - Did s/he listen to the opinions of the other team members?
    - Did s/he have a good effect on the overall atmosphere?
- Was there something else in the session to be mentioned?

Students were to assess themselves, too. For this purpose they were given another form with questions related to their level of motivation, the amount hours spent for their self-study, their contribution as a team member, and their professional behaviour (punctuality, respect for others, polite behaviour etc.).

Neither the observer's assessment nor the self-assessment had any direct impact on the course grades. However, an indirect influence in the form of making the students to actively evaluate their study process was hoped for.

Experiences and recommendations

Despite the rather thorough preparation of the pilot, applying the PBL-oriented method in real-life was something totally new for the students, the teachers and other members of the staff. The academic year 2003–2004 will not be remembered as a too calm and boring period of time. On the contrary – the project spirit fluctuated from great enthusiasm to deep frustration, both among the students and the teachers. At the edge of a new summer each and everyone could still notice, luckily enough, that we had survived.

The feed-back of the students

The students' feed-back on the pilot varied significantly. As Paanu (2005) concludes, some students found the method a very useful way of learning: *"I like working in a team. It is also nice to notice the different view points on the topic that are found in the discussions. There is almost always somebody in the team who can help in understanding the problem. Thus, no frustration can emerge."* On the other hand, some students experienced that their freedom to learn disappeared and the subject itself faded away whereas the method dominated the whole process: *"This is nothing for me: I learn more efficiently on traditional lectures and the formality of the PBL does not work in most of the given topics. My motivation has rocked the bottom. The whole does not work. Filling reports and diaries every week is useless, one learns nothing."* The results of a feed-back questionnaire are summarized in Table 2.

TABLE 2. A summary of the results of a feed-back questionnaire, autumn 2003 (Paanu, 2005)

The suitability of the PBL-method to me (scale 0-5)

Grade	0	1	2	3	4	5
N	6	14	21	19	17	3
%	7.5	17.5	26.3	23.7	21.3	3.7

Evaluation of the learning results

Grade	0	1	2	3	4	5
N	2	7	16	23	28	4
%	2.5	8.8	20.0	28.7	35	5.0

Utilisation of the time used for self studies

Grade	0	1	2	3	4	5
N	5	12	16	25	12	8
%	6.4	15.4	20.5	32.0	15.4	10.3

From the learning process's perspective perhaps the most significant challenge was to motivate each student to put enough effort on the common learning process of her/his team. Many students did not utilize the time reserved for self study for the actual purpose, or if they did true collaborative learning did take place in a very few teams. The tutor's reception hours that were meant to give the students the opportunity to get guidance in case of problems during the cycle was, in practice, not used at all and thus, the reception hours were not set anymore in the spring semester.

Despite some very critical opinions, the learning effect was still evaluated to be good or even excellent by the great majority (69 % gave grades 3–5) of the students that answered the autumn 2003 questionnaire (Paanu 2005). Spring 2004 the students were asked: In average, how many hours a week have you studied outside the lectures? The questionnaire also showed the courses where the students were given, besides the PBL problems, additional exercises and self study tasks. The answers of the students are presented in

Table 3 (Paanu 2005). The results show that the students used unexpectedly much time on PBL. It could be said that PBL dominated the usage of the students' time. On the other hand the answers showed that the students were not using enough time on given exercises and self study tasks. The course teachers complained about this and said that it was because of PBL. This is difficult to proof because the students' time usage has not been studied before and, thus, it is not known how much time the students have used on self study some years ago.

TABLE 3. A summary of the self study time usage, spring 2004 (52 answers) (Paanu, 2005)

Course	h	%
Mathematics 2	120	17.4
Data Structures and Algorithms	35	5.1
Circuit Theory 1	19	2.8
Computer Design	22	3.2
Introduction to Databases	49	7.1
Introduction to Electronics	83	12.0
PBL-cycles	280	40.6
Other courses	81	11.8
Total	689	100

Although no statistically significant results exist, it seemed that the overall team opinion played a role in the whole as well. One interesting finding was that a hidden message from certain students seemed to be that due to the group pressure it was not preferred to shout loud that the PBL actually was quite fun every now and then. This issue came up in a personal feed-back discussion between a tutor and a student.

Teachers' and institution's view-points

The tutors gave their opinions about the PBL pilot in April 2004. As Paanu (2005) states, the development of the students' team work and social skills was the most important advantage of the PBL from the tutors' point of view. It was seen that the team work supported the learning process of the individuals, too. Because every student reported his/her results separately, it also showed up problematic to motivate the students to share their knowledge between the group members. The tutors had good possibilities to get acquainted with the students, and their feedback could be taken into consideration very quickly.

The students' reporting skills developed but the tutors considered the number of reports too large. Actually, the rules of report writing were loosened already during the spring semester. That is, the students were allowed to write reports also in pairs. However, only few students took advantage of this new possibility because they were already used to report by themselves. In addition, the tutors considered the number of problems too large and proposed more attention to be set on the creation of the problems. The content of the problems should be more carefully considered.

The co-operation between teachers increased and grew deeper. The tutors also learned and studied with the students and got a better view to the students' study work as a whole. However, the implementation of the PBL with its many new aspects on teachers' work was considered laborious. One thing to remember was also that the curriculum actually was planned and set before the studying PBL-method had even started. That is, the accepted curriculum constrained the structure of the pilot significantly. The problems were mainly created based on the subjects and the issues as defined in the curriculum.

From the institution's point of view the pilot had many advantages. The teachers started to think about the learning process and found new aspects to teaching, coaching and learning. Many conversations and meetings were fruitful and showed the importance of co-operation and planning. The development of the curriculum has also become closer to every teacher than before.

However, the influence of the PBL method and the aroused interest in the development of the learning process and the ways of teaching cannot yet be seen as better learning results or decrease of drop-outs. For example, the average number of credits of passed courses during the first study year is approximately the same with the students of 2002–2003 and 2003–2004. Turku Polytechnic supported the pilot in 2003 and has now given support also for the years 2004 and 2005. It is known that the results may be visible after about three or four years.

Recommendations to related first-wave projects

The pilot of the Degree Programme in Information Technology was started without having lots of planning and considerations. The teachers thought that it is impossible to know the PBL-method without trying it in practice. This was true. Although the teachers studied the method and tested tutorial sessions in their own learning process, they could not know how it would work with students.

There has to be enough time reserved for studying the method, planning the curriculum and the problems as well as for figuring out the assessment guidelines. Many teachers have to be interested in the new method and they should not be too afraid of long working days. The support of the management is also necessary in order to carry out the required change in the first place. There is work enough in implementing the method and no need to political quarrels as Stephen Abrahamson describes (Abrahamson 2000).

The tutor groups were reformed at the beginning of the spring term 2004. Accordingly, the courses during the autumn were considered as one project and the ones during the spring another. Thus, even the project groups were in a way changed on-the-fly. This idea did not work as well as it was expected. The work of some new reformed teams did not progress well. The team-building process in some of the new groups even took two or three months. This experience made the teachers to change their ideas: Currently, the teams are set for the whole academic year. This change has already been praised by the students. As Rasinkangas (2004) states, the members of a tutor group need time to get acquainted with each others.

Discussion

In this paper, a pilot implementation of the problem based learning paradigm in the Degree Programme in Information Technology at Turku Polytechnic was presented. In order to provide tools for related projects in other institutions, the background of the pilot as well as the experiences gathered during the development project were discussed in detail. In addition, results based on the first PBL-oriented academic year were presented and certain guidelines for related trials were proposed.

The development of the learning and teaching methods in general and the PBL-implementation in particular in the degree programme continues. It seems that the problem based era has just begun although there still is much work to be done before the whole is a natural part of the process. The experiences gathered so far indicate that a suitable form in engineering education may be using PBL as one of the main methods during the first half of the studies, and then to focus on a project-oriented way of working as the day of graduation gets closer.

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FOUR PHASES TO CONSTRUCT PROBLEM-BASED LEARNING INSTRUCTION MATERIALS

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The rapid changes in technology, information and economy call for the new competence such as the skills of critical thinking, problem solving, decision making, team working, etc. Thus, how to equip our students with the requirements for graduate competence has become the most crucial responsibility in school education. Problem-based learning emphasizes a "real-world" approach to learning: a student-centred process that is both constructive and collaborative. It also based on the promise that students will be motivated to "want to know" and solve the problem posed because it is presented in a context that simulates real situations. As an effective pedagogy for improving students' critical problem solving and self-directed learning skills, PBL has been successful applied in many disciplines. This article proposed a systemic but simple procedure for instructor using to design a PBL lesson. By way of inductions, experiments and revisions, authors concluded and generalized some principles and proposed a process to construct the PBL instruction. These phases are: 1. Selecting problem and unit titles; 2. Designing acts, 3. Determining learning objectives; and 4. Linking contents. For each step, the principles and examples are illustrated and discussed.

Introduction

Traditional teaching strategies do not produce the desired outcomes of critical thinking, independent decision-making, and autonomy that are needed by today's graduates (Bentley & Nugent 1996; Biley & Smith 1998). Therefore, it is important to embark on major reforms on instruction mode and learning method in order to develop diverse capabilities among students (Tien, Chu & Liu 2002). In order to keep up with the pace of the constantly evolving society, each and every individual person must develop the ability of self-learning (Lee 2000).

Educational research demonstrates that active learning is the most effective technique for students to learn, apply, integrate, and retain information (Bonwell & Eison 1991; Johnson, Johnson & Smith 1990; Meyers & Thomas 1993). However, the key to effective learning and to successful assisting students "learning to learn" does not lie in the accumulation of knowledge itself. Instead, what instructors need is an appropriate pedagogy that could facilitate students to self-learning and transform knowledge into innovation capability needed for future. In other words, it is the ability of using the power of knowledge that teachers should help their students develop (Tzeng 2001).

Problem-Based Learning (PBL) is an efficient way to acquire new knowledge. It requires students to utilize all of their skills in order to answer a driving question. They must research, collect data, interview, and adept information in order to present a possible solution to the presented problem. Students tend to remember things they have experienced, or had to research on their own, because it feels like it is their own question, not just one presented during class (Robert 1997). PBL consists of three main characteristics. They include the engagement of students, the organization of the curriculum around a specific problem (perhaps even cross-curricular), and teachers becoming a coach, or a guide in their students' quest for a more expansive inquiry. PBL can be described as "minds on, hands on" learning. It gives students an authentic experience, while maintaining their interest; they become a part of active learning rather than passive note taking. This type of activity increases motivation and makes students feel responsible for the questions being pursued (Neal 1997).

Problem-oriented learning is active and applied rather than passive and absorbed. It combines aspects from the learning styles approach and from cooperative learning and focuses on teamwork, problem-solving skills and self-directive studies as well as reveals the importance of interdisciplinary knowledge for the understanding of problems (Wu 2002). Besides, as students have to work partly in groups, PBL supports the acquisition of social skills and the reflection and development of attitudes. During the process of PBL, they have to organize their learning process because the instructor does not determine what the students have to do. Consequently, students working with PBL are better equipped for the critical skills of "learning how to learn". In other words, PBL is an effective tool to help students develop critical and creative thinking skills and enhance students' innovation capabilities through the process of problem solving (Hong 2001).

In order to make a description of how to plan a PBL instruction, a set of terms with hierarchical relation, such as problem, units/unit titles and acts, are used to title some phases and instructional strategies. Basically, the problem is consisting of many units/unit titles, and each unit/unit title is composed of three to five acts. Their relationship is shown in Figure 1.

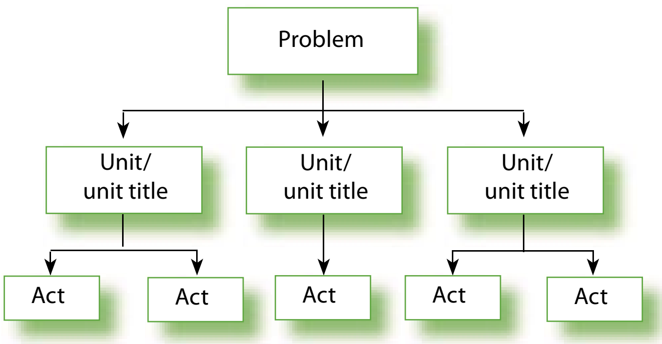


FIGURE 1. Hierarchical relationship between problem, units, and acts.

Four phases to construct PBL instruction

PBL is a teaching strategy that shifts the classroom focus from teaching to learning. Learning occurs best in context, by engaging students in authentic questions and by involving students in inquiry. There are two central principles of PBL that is open-ended problems and student study groups. Problems are vehicles for learning; groups are fuel. Problems transport students from the classroom to tangible, real-world situations that simulate their curiosity and creativity (Kurt, 2001). Therefore, the instructor can use appropriate problems which is provide insufficient information for immediate solution to serve as tangible and accessible entry points that leading students to develop the abstraction abilities, reasoning skills, etc.

There is a familiar cyclic process of PBL (EATMP 1999) shown Figure 2. The first and most important process is to determine the problems related to the subject matter because the problem provides the basis and framework for learning. Actually, one of the keys to success in implementing PBL is the type of problem you use. In a successful PBL course, the selection of appropriate problems and material is crucial to go beyond a superficial understanding of the important concepts and principles.

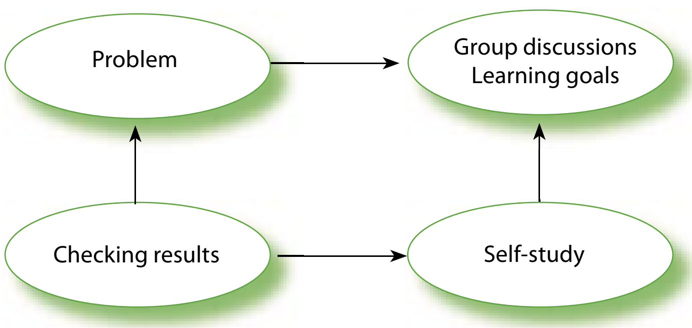


FIGURE 2. The cyclic process of PBL

Generally, the procedure of design and implementation of PBL including (Robert 1997; EATMP 1999): determine a relevant and appropriate problem of worth; develop the PBL learning adventure through groups and self-study; build the teaching and learning template; coach critical teaching and learning events; and embed periodic assessments and appropriate instruction. Based on previous works (Chu, Lin & Chu 2004), the authors have generalized and proposed a simple and easy to use process showing how to analyse a problem and break it into meaningful topics, then transform it and construct the instruction plan related to it. These steps and respective strategies are described as following.

Phase 1: selecting problem and unit titles

In PBL, complex, real-world and ill-structured problems are used to motivate students to identify and research the concepts and principles they need to work through those problems. It is the key point to implement a successful PBL instruction. However, finding a good PBL problem is a challenge for teachers in most disciplines. Typical problems do not foster the development of effective problem-solving and analytical skills nor do they challenge students to develop critical thinking skills and logical reasoning. The following are some important characteristics of a good PBL problem (Barbara 2001):

- An effective problem must first engage students' interest and motivate then to probe for deeper understanding of the concepts being introduced.
- Problems that work well sometimes require students to make decisions or judgments based on facts, information, logic and/or rationalization.
  The problem should be complex enough that cooperation from all member of the student group will be necessary in order for them to effectively work toward a solution.
- The initial questions in the first stage of a problem should be open-ended, based on previously learned knowledge, and/or be controver-

sial so that all students in the groups are initially drawn into a discussion of the topic.
- The content objectives of the course should be incorporated into the problems, connecting previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and/or disciplines.

However, with the exception of a few disciplines, good PBL problems usually do not appear in textbooks. As a consequence, an instructor needs to find problems, modify textbook problems, or write new problems that address the course content goals and learning objectives. Frequently, veteran PBL faculty may use a typical textbook problem and rewrite it as an open-ended, real-world problem (Harold 2001).

Besides problems, it is also very important to select the appropriate unit titles based on the problems which is attractting students with a great deal of attention. The unit titles of a defined problem should be one that students can easily relate to their experience or one that embodies a common problem that most students have met. The issues involved in each unit title should to capable to catch students' attention and describe the frequent problems occuring in daily life especially favorable with a touch of urgency, danger, and task orientation. It is always revealing to grapple with such questions as "How is the knowledge of this concept used in the world outside the classroom?" or "Why my students need to know this?" or "How will my students use this knowledge in future courses? (Harold 2001)" In general, principles to define problems and select appropriate unit titles are:

- Problems in daily life: What can I do if I have a flat tire, if the chain on my bicycle is loosened, if the car engine starts to overheat, if the printer has a paper jam, if blurry pictures come out from the printer or else.

- Social issues: Domestic violence, school violence, how students can relieve their schoolwork pressure, how to handle depression, suicide behaviour, jailbreak, juvenile sub-culture, and so on.

- Curricular related issues: Environment education, gender education, life education, information education,etc.
- Relevant tasks: Plan how to showcase a successful project such as how to establish a new club.

Phase 2: Designing acts

The problematic situation has the seeds of interest within it. Problematic situations are robust in that they contain within them signification concepts worth thinking about. Students can relate to people attempting to deal with the unknown and living under adverse conditions. The greater students' involvement in an issue, the greater their investment in its solution and the harder they will work (Barell 1995). According to selected unit titles, then, to design acts is depending on the size and requirement of each unit. Unit development also includes selecting appropriate information and community resources, and creating materials to support student learning (Robert 1997).

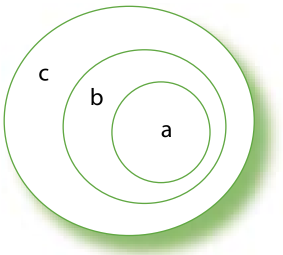
Mostly, each unit could be divided into three to five acts with different episodes or contexts through following strategies like the use of concept map to describe the core knowledge; the application of problem solving skills after having acquired the ability to employ the core knowledge; and the formulation of development plans for core knowledge expansion and enhancment. The naming of different acts should follow a hierarchical order and the titles should cover sufficient breadth and depth. Although it is the most difficult step to do that, nevertheless, the authors have proposed (Chu, Lin & Chu 2004) a thinking flow for act title selection. Through continuously revised of analysis and synthesis as well as conceptual, reflective, intuitive, and thinking creative thinking process, each unit title could be transformed into a top-down hierarchy linked by different titles of acts with the emphasis placed on core knowledge acquisition, unit comprehension and application, and knowledge expansion and enhancement respectively.

For example, a unit title like "What can we do when food gets mildewed?" could be divided into three acts: (1) How do we tell if the food is mildewed and what are the causes of mildew in food? (2) How should we deal with mildewed food? (3) How do we prevent food from mildewing? In Act 1, the focus should be on core knowledge acquisition-telling of, writing down, or drawing out a concept map; Act 2 should highlight comprehension and application of the unit content-proposing problem-solving methods and steps, or working out a problem directly; and Act 3 should be designed for knowledge expansion and enhancement-proposing solutions for development, drawing up a development plan.

Phase 3: Determining learning objectives

To determine learning objectives, a teacher would refer to curriculum developed by the state. The curricular frameworks also have lists of what students would be expected to know and do by the end of the course (Barell 1995). However, while implementing a PBL lesson, the learning objectives of each act is in fact decided by the students according to their own interest, as opposed to being predetermined by the teacher as is with conventional instruction. Normally, the learning content for each act is divided into the following three parts, shown in Figure 3, according to the difference between students' abilities:

- Must learn – the core know that all students must know;
- Should learn – content that students are supposed to know; and
- Nice to learn – content that it would be good for students to know.



"a" represents what students must learn
"b" represents what student should learn
"c" represents what it nice for students to learn

FIGURE 3. Levels of learning content

To ensure a thorough evaluation and careful selection of the various learning objects to be included in each level, the important task of the choice of learning objectives should be better left to the hands of those Curriculum Development Committee officers, who should decide through discussion a correct weighting to each of the various learning objectives under consideration according to their importance, demand, and possible obstacles involved or through voting (Huang 1996).

The learning objectives must be specific and include A, B, C, and D four statements to describe the specific behavioral objectives (Kang 1985):

- **A** (Audience) – "Who" expected to carry out the behaviour? This can be omitted if it's the students who execute the behaviour.
- **B** (Behaviour) – "Actual behaviours" needed to achieve the objectives, e.g. to list, to write, to tell, to select, to distinguish, to design, to use, to operate, to complete, etc.
- **C** (Condition) – "Relevant conditions" required to complete or achieve the behaviour, e.g. conditions provided by the teacher, the instructions in the manual, a given circumstance, error messages displayed on the computer screen, etc.
- **D** (Degree) – "Level" or "Standard" successfully achieved by the behaviour, e.g. accuracy, deployment and installation plan, problem solution, disassembling operation, etc.

Using the unit title "What do we do when food gets mildewed?" for instance, the specific learning objectives could be:

- Students can accurately from the appearance of food identify the
A **D** **C** **B**
characteristics of food mildewing.
C
- Students can accurately analyse and itemize the fungus types
A **D** **B** **C**
of mildew food.

Phase 4: Linking contents

A teacher should develop a question that will help students focus on their task after they become interested in the problem. Students who see the relevance of their work to their own lives are more likely to be active workers rather than passive observers, enthusiastic learners rather than reluctant listeners (Robert 1997). Think of a real-world context for the concept under consideration firstly, then, develop a storytelling aspect to an end-of-chapter problem, or research an actual case that can be adapted, adding some motivation for students to solve the problem. The problem also needs to be introduced and staged so that students will be able to identify learning issues that will lead them to research the targeted concepts (Barbara 2001). In this step, we can use the keywords and transitions to connect the contents of each act. A more detailed explanation in terms of how to link the contents of each act is given below.

Act 1: Emphasizes core knowledge acquisition

To identify possible causes of the problem, summarize the drivers behind the problem, and link in series the conceptual knowledge acquired using a concept map or other tools. In other words, in describing the context of the act, the teacher should use keywords or transitions as linkage to engage students and boost their interest in learning on the one hand, and to stimulate students to apply divergent thinking skills in problem discovering, raising, and listing through brainstorming on the other, thereby achieving the goal of active learning. For example:

> Thomas has long made it a habit to have a glass of milk at breakfast. On *the Dragon Boat Festival* however, he got up ten minutes late and was washing his face, brushing his teeth, and rushing to get everything done so that he could go to the library to study. He jammed the sandwich Mother just prepared into his book bag, and grabbed up the glass of milk, ready to gulp it down. But as soon as the first squirt of milk entered his mouth, Thomas felt a sour taste. He spit

it up and *saw chunky stuff in it*. He rushed over to the bathroom and madly rinsed out his mouth. Mother was coming out of her room, so Thomas grouched about the spoiled milk as he continued to rinse his mouth. Mother said to her feeling all puzzled, “I bought it yesterday. How can it get sour already?” And then she turned to Thomas, adding “Oh, don’t throw the milk away. Just leave it there.” Let’s say you are all good friends of Thomas’ discuss among yourselves how you should do about the sour milk.

Description:

- *The keywords of this act include “milk” and “Dragon Boat Festival”,* which can be used to guide students to diverge their thinking into other types of milk.
- The transitions of this act include *“saw chunky stuff in it (milk)”,* which can be associated with other fungus infections; and “*don’t throw it (milk) away, just leave it there”,* which can be associated with filing of a customer complaint or legal charges, or issues relating to environmental protection and waste recycling.

Act 2: Emphasizes knowledge comprehension and application

There are two ways to describe the learning objectives in Act 2. First is refer to the exploration of interdisciplinary problems – why or why does it not, what the influence would be.... and the second is relate to the problem solving – how to deal with or what to do.

I. Interdisciplinary problem exploration

Based on the conceptual knowledge acquired from the first act, the teacher can arrange a further brainstorming activity to allow students to explore the problem presented under the theme through cause determination and analysis, characteristics identification through experiments, and solution development from diverse angles of view. Therefore, in describing the context of the act, the teacher should use keywords or transitions as linkage to engage students and boost their interest in learning on the one hand, and to stimulate them to apply divergent thinking skills in problem discovering and listing through brainstorming on the other, thereby achieving the goal of active learning. For example:

> Thomas' father does morning exercises every day in the park. He came home that day after the exercise and noticed immediately as he arrived home that Thomas wasn't looking very good. Mother explained, "He just gulped down some sour milk." Father replied, "Indeed *milk is nutritional and has many uses*. But you always bought milk from your office and then took a bus home. You see *on such hot days*, exposing fresh milk to outdoor temperature can easily cause bacteria or virus contamination. "Spoiled milk can be harmful to our body." Thomas took the opportunity and said, "If you get it from the convenient store nearby, it can save you a lot of trouble and you can make sure that the milk is fresh. Besides, *skim milk helps me stay fit*." Let's say you are all good friends of Thomas' discuss among yourselves how to ensure freshness of milk and stay healthy.

Description:

- The keywords of this act include *"on such hot days"* and *"skim milk helps stay fit",* which can be used to guide students to diverge their thinking into topics relating to how milk contributes to health.
- The transitions of this act include *"milk is nutritional and has many uses"*, which can be associated with other uses of milk including as a cosmetic substitute or cooking material.

II. Problem solving

Based on the conceptual knowledge acquired from the first act, the teacher can arrange a further brainstorming activity to allow students to try solving the problem presented under the theme through raising possible remedies or figuring out how to remove/handle difficulties by themselves. In other words, in describing the context of the act, the teacher should use keywords or transitions as linkage to engage students and boost their interest in learning on the one hand, and to stimulate students to apply divergent thinking skills in problem solving through brainstorming on the other, thereby achieving the goal of active learning. For example:

> Thomas' father came home from work one day and saw Thomas sitting in front of a burned toaster and looking very lost. Although they had discussed about the causes of socket smoking at school, Thomas still had no idea about what to do when it did happen. Father told him that he could use *a multi electric meter* to find out which component had broken down and was in need of replacement. The father and son then started to *disassemble* the toaster in order to fix it. As they carried out the repair work, Father reminded him *to pay more attention in the future when using electrical appliances, so as to avoid similar incidents from occurring again*. Let's say you are all good friends of Thomas' discuss among yourselves how to ensure safe uses of electrical appliances around home.

Description:

- The keywords of this act include "*multi electric meter" and "disassemble"*, which can be used to guide students to diverge their thinking into the use of tools to solve problems.
- The transactions of this act include "*to pay more attention in the future when using electrical appliances, so as to avoid similar incidents from occurring again"*, which can be associated with the avoidance of improper operations that may lead to circuit shortages.

Act 3: Emphasizes knowledge expansion and enhancement -proposing development plans

Based on the conceptual knowledge acquired from the first act and the problem solving experiences from the second act, the teacher can arrange a further brainstorming activity to connect the previous two acts and to allow students to propose development plans or solutions, and raise issues with high levels of similarity with the current one for comparison and analysis in order to help students expand and increase their knowledge. In other words, in describing the context of the act, the teacher should use keywords or transitions as linkage to engage students and boost their interest in learning on the one hand, and to stimulate students to apply divergent thinking skills in problem solving through brainstorming on the other, thereby achieving the goal of active learning. For example:

> Thomas and his mother brought the sour *milk* back to the supermarket near his mother's office and inquired about the reason why the milk bought yesterday was already spoiled. A colleague of Thomas' mother's happened to be shopping near that supermarket personnel Thomas and his mother was inquiring. *"The milk I had this morning was sour too! But it was not spoiled."* The colleague said. Let's say you are all good friends of Thomas' discuss among yourselves what you think the supermarket personnel would explain to Thomas' mother about the differences in the views between Thomas' mother and her colleague.

Description:

- The keywords of this act include *"milk"*, which can be used to guide students to diverge their thinking into other types of milk.
- The transitions of this act include "*the milk I had this morning was sour too! But it was not spoiled"*, which can be associated with yogurt.

Conclusions

PBL is an effective instructional approach. It can improve students' critical thinking, problem solving and self-directed learning skills. Actually, for many decades, PBL has been successful applied in many professional disciplines especially in higher education such as the medical school and engineering education (Savin-Baden 2000; Cindy 1998; Linda, Gary & Roland 2000; Perrenet, Bouhuijs & Smits 2000; Mota, Mota & Morelato 2004).

Fundamentally, adopting PBL requires a transformation of the classroom role of the instructors from a "sage on the stage to a guide on the side.(King 1993)" The enhancement of learning by students "doing," as described by Dewey, is at the heart of most of the efforts to improve classroom experience. PBL offers an attractive alternative to traditional education by shifting the focus of education from what faculty teach to what students learn. With PBL, learning occurs as students move naturally from a tangible, engaging scenario to an increased understanding, and in the process gain experience with abstractions, generalization, and logical reasoning (Christine & Kathleen 2001).

This article have demonstrated a systemic four steps procedure for instructors with some useful guidelines respectively about how to plan a PBL instruction. By means of selecting problems and unit titles, designing acts, determining learning objectives, and linking contents, authors have illustrated some examples in accordance with these strategies. It is believed that PBL is an effective and exact tool. As an alternative pedagogy, PBL is recommended for wider promotion and application to foster students' skills of "learning to learn".

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A TUTORIAL SCRIPT IN MEDICAL EDUCATION
– the PBL-model designed for local needs

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To optimise the benefit of tutorial sessions, the problem handling process must be structured. The Medical School at the University of Tampere first applied the "Seven-jump model" from McMaster University and subsequently the "Linköping model" from Linköping University. Due to cultural differences there were difficulties in application of these established models and we designed our own model in 2003.

In Tampere model, the group problem handling process is structured to eight phases. *The Introduction*-phase of a new problem is short and leads straight to *the brainstorming*-phase. Discussion during brainstorming is analytical and leads to a preliminary hypothesis of the phenomena behind the problem. Thus, the next phase, *the review and organization of the existing information*, means organization of the notes according to the formed hypothesis. After this, learning needs are formulated in *the identification of learning objectives*-phase. With *the checking of the shared understanding of learning objectives*-phase we underline that it is crucial that all students are clearly aware of the learning issues at the end of the sessions. The next session begins with the phase *review of the information gathered* followed by *application of new knowledge to the problem*-phase. The phases are represented on circumference, which underlies that learning is a continuous process and the importance of continuous evaluation. In addition to evaluation of the quality of learning and group work, evaluation of the phase of *self-study* and sources of information used are emphasized.

The main functions of the tutor groups are systematic analysis with activating, collecting, processing and sharing of knowledge. The Tampere model has served its purpose well. This may be due to the fact that the model has been adapted for the local culture of the faculty. The own model also reflects the process of implementation of PBL in the community.

Introduction

The Medical School at University of Tampere has applied problem-based learning (PBL) in undergraduate medical curriculum since 1991. The curriculum was reformed totally along the principles of PBL in 1994. The first three and a half study years consist of integrated blocks in which biomedical and clinical sciences and public health are studied together with social and behavioural sciences. In the remaining two and a half years the students work in clinical wards and theoretical studies are integrated in seminars and assessments.

PBL emphasizes the role of the individual student in continually incorporating new knowledge into his/her pre-existing cognitive structures, thus keeping these structures in a constant emergence (Schmidt 1983, 1993; Norman 1992). In PBL the skills and the knowledge basis needed in professional practice are constructed in a novel way as far as cognitive processing and management of the student group are concerned. The key to successful learning in PBL lies in the interactiveness and function of its tutorial sessions (Virtanen 1999). PBL assumes that learning is effective when active and independent students handle problems together, inquire into the beliefs and arguments behind their own thinking and actions, deliberate about theoretical explanations for phenomena and thus construct their personal knowledge and understanding (Davis 1999).

The development of the PBL-model in medical education

The details of how PBL process is implemented differ from institution to institution. However the general principles remain the same. In practice, the problems are presented and processed in tutorial groups consisting of eight to ten students and meeting twice a week in a session lasting 1,5–2 hours. The sessions start with a review of the new knowledge that the students have learned about the issues defined in the previous session. The group then tackles a new problem with a brainstorming discussion, which is followed by organization of the existing knowledge activated by the brainstorming and by identification of the learning needs. Finally the students set up learning issues for the next session.

PBL emphasizes active generation of learning issues by students. Students learning activities cover an average 64 % of the intended course content (Dolmans 1993). This imposes demands on case planning and on tutors, both of which should lead students into right learning issues. To optimise the benefit of tutorial sessions, the problem handling process must be systematic and thus structured to give an explicit framework to the tutorial. For this purpose we used to apply the "Seven-jump model" from McMaster University (Barrows 1980; Schmidt 1983) and thereafter the "Linköping model" from Linköping University (Hård af Segerstad 1997).

However, the structure of the curriculum, the other learning methods used to support the acquiring of knowledge, the learning purposes imposed to tutorials and cases used as problems are unique in every university. Also the medical care and medical care systems, the ways how people approach problems, get down to work, think and discuss differ between countries. Due to these reasons there were difficulties in the application of both models designed in other cultures and we have used our own model since 2003.

The development of our Tampere model has been a long process. During the initiation of PBL, tutors were recruited from among volunteer faculty members who were especially interested in the new method. They were trained on PBL in courses given by experts from the Medical Faculties of

McMaster and Maastricht Universities. The Tampere Medical Faculty also obtained practical and theoretical advice from the Faculty of Education in Tampere University. These volunteer faculty members had an opportunity to practice the method during the traditional curriculum in a three-year problem-based study block “Early Clinical Studies”. As the number of practical PBL courses given and experience in tutoring increased, the experienced tutors decided to take the responsibility for tutor training. The course of time and increasing experience have lead to elaboration of the curriculum, the course of tutorial sessions and the cases used as problems.

As previously pointed out and found necessary (Kaufman 1996) our faculty has given all teachers an opportunity to take part not only in teaching and tutoring, but also in planning and administrative tasks on all levels. Thus, in addition to experience, knowledge and skills, the teachers have had authority to develop the curriculum, the tutor education and tutorial sessions. In training courses and teachers’ meetings tutors reported difficulties in problem handling process in tutorial sessions. The tutor trainers collected this information and in addition visited tutorial groups and observed how well tutorials adhered to the principles of problem-based learning. Students’ participation, interaction, discussion, the work of the tutor, student chairman and secretary, and the application of the learning model were observed with a follow-up form. In the form all important elements in a tutorial session were asked using structured and open questions. Collecting and utilizing all this information the tutor trainers developed a new problem handling model suitable for local needs and culture. The new model was then implemented by tutor trainers in training courses and by publishing a manual delivered to all faculty members.

Our Tampere model

In Tampere model, the group problem handling process is guided in 8 phases (see Figure 1). The phases are represented on circumference, which underlies that learning is a continuous process and the importance of continuous evaluation. In addition to evaluation of the quality of learning and group work, evaluation of the phase of self-study and sources of information used are emphasized.

In *the introduction* phase first the group selects the chair and the secretary. These roles take turns usually according to the list of students' names, and one chair-secretary-pair deals with one problem. Thus, the change of roles occurs when a new problem is presented. Next, the tutor distributes to the group a new problem and all read it. If there are unclear, unknown terms and concepts not readily comprehensible, they are quickly clarified by some of the students or by the tutor, so that everyone understands enough to be able to participate. The introduction phase is meant to be short and without debate.

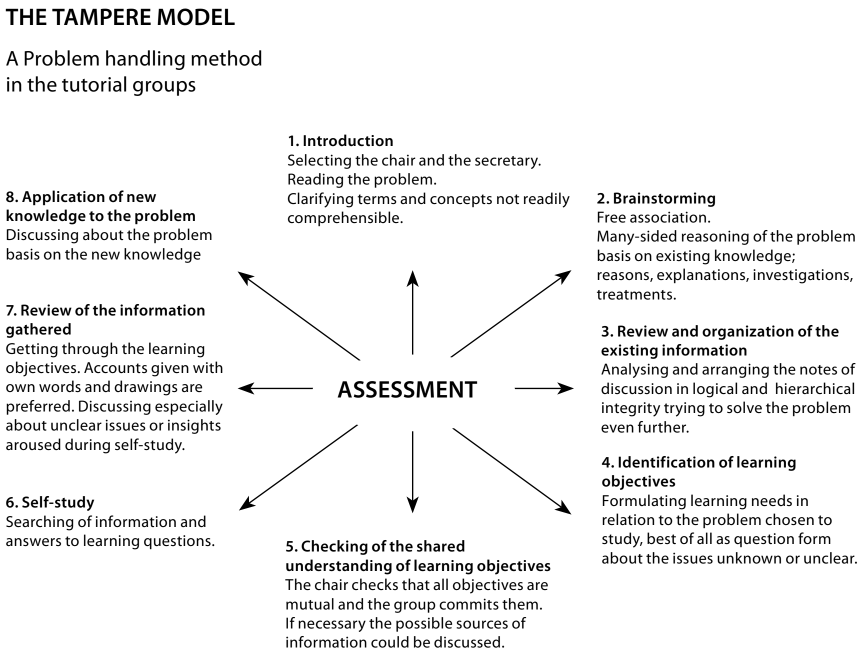

FIGURE 1. PBL-model in medical education, Tampere

Immediately after the group has been acquainted with the problem begins *the brainstorming* phase. It should be a totally free association of all aspects that the problem arouses. The group tries to think of all their experiences or knowledge related to the problem and to find out as many explanations they can imagine for phenomena, investigations they would make and treatments they would give. The secretary's role is crucial in this phase and it is to write down, on memo sticks, keywords of every thought and idea presented.

The review and organization of the existing information phase is the most difficult and laborious of all the phases. The notes of brainstorming are analysed and arranged in logical and hierarchical integrity on the whiteboard. The group tries to explain phenomena and make a sensible hypothesis of the reasons, consequences and solutions behind the problem. During this analysis they are inevitable also faced with the lack of their knowledge. If the group works hard and the analysis is successful, it is easy to formulate learning objectives about these unhandled questions. During *the identification of learning objectives* phase the formulation of learning needs should definitely be based on the discussion and the knowledge of the group, not on the general issues and branches of subjects that can easily but cursorily be deduced from the problems. *The checking of the shared understanding of learning objectives* phase ends the tutorial session. It is very important that the learning objectives are written down and that the chair checks the shared understanding and the commitment of the group. Sometimes it may be necessary also to speculate on the possible sources of information.

Between tutorial sessions in *the self-study phase* the students study individually and search for information in the literature. Also, all given teaching (lectures, laboratory- and clinical skills training groups, study visits) is scheduled between sessions and serves as source of information. The new tutorial session begins with *the review of the information gathered* phase. The group gets through the learning objectives one by one. The students tell each other what they have found out, what insights aroused during reading and in lectures. The hypothesis made and false information presented in the previous session are corrected and completed. The sharing of knowledge should be a discussion and not a lecture. Accounts given with own words and drawings enliven and clarify this discussion. Finally in *the application of new knowledge to the problem* phase the group reverts to the original problem and discuss it once more, now knowing more.

Discussion

PBL, above all, promotes the activation of prior knowledge and its elaboration (Schmidt 1993). Discussing a problem in the small-group setting strongly activates prior knowledge of participants and the effects of prior knowledge activation in turn facilitates the processing of problem-relevant new information (Norman 2000). The influence of the discussion in the tutorial group on the extent to students' decisions on what to study is remarkable and tends to increase over curriculum years (Dolmans 1994). The level of cognitive congruence influence tutorial-group functioning and that on the other hand affect self-study time and intrinsic interest and time spent on self-study influenced level of achievement (Schmidt 1995). Moreover, the prior knowledge is not simply a bag of facts that students have available but can be described as a 'naive theory' that these students entertain with regard to the problem at hand (Schmidt 1989). The systematic discussion and analysis of prior knowledge is essential to this 'theory' and thus emphasizes the role of the model.

In Tampere model there is no scenario as presented in Linköping and Seven jump models. We found it factitious and enervating to pronounce a scenario, for example "a depressed woman". As in Linköping model, in the Tampere model the beginning of a new problem is short and leads straight to the brainstorm without listing the phenomena to be explained as in Seven-jump model. However, our model is more simple and straightforward than the Linköping model. The discussions in our tutorials are very analytical and arranging already during brainstorming, resulting in an early explanation hypothesis of the phenomena. Thus, review and organization of the existing information means organization of the notes on this hypothesis. Of note, this phase is the most difficult, demanding and the most crucial for learning, because it requires thinking, negotiations and decisions with insufficient knowledge. The Linköping phases 2 to 4, i.e. free associations concerning the scenario, systematization the outcome of brainstorm into problem areas, reflection upon and appraisal the knowledge of the group in relation to the problem areas, definition one or more problem issues, did never work unforced in our tutorials and usually lead the tutor to restrict the chain of reasoning.

After profound organization of prior knowledge and birth of an 'explanatory theory', it is easy to formulate the learning needs. This also enables a cognitive process called epistemic curiosity or intrinsic interest that is peculiar to PBL (Schmidt 1993). Formulating the learning needs as questions that have remained unhandled during organization further contributes to this. We also emphasize that it is crucial that all students are clearly aware of the learning issues at the end of the sessions. That is why, it is named as a own phase in the model. As in Linköping model, our phases are represented on circumference, which we think, underlies the fact that learning is a continuous process. Both models also point out the importance of continuous evaluation. In addition evaluation of quality of learning and group work, our model also evaluates the areas of self-study and sources of information more clearly.

However, all the models of PBL in fact aim to the same outcome, although the phases and the stress of phases differ. After all, the main functions of the tutor groups are effective activation of existing knowledge, systematic analysis and processing of knowledge, and collection and sharing of knowledge. The model presents an instrument to assure this. The problems used are crucial in facilitating students to identify relevant learning issues (Dolmans 1993; Mpofu 1997) and these guide the students' studying (Mpofu 1997). The problems affect also the validity and working of the model. In addition, initiation of the tutors to the principles of PBL and the problem handling model is a key to the success of tutorial sessions and learning (Barrows 1988; Moust 1990; Holmberg-Marttila 1998; Virtanen 1999).

The model is a tool that serves learning, not the main issue in tutorials. The high turnover of tutors, the rush and many responsibilities of medical faculty members impose pressure to tutors and student training. This may compromise the problem handling model that students apply and tutors guide in tutorials. Thus, it is important that the model is adapted for the faculty and to the people working and studying there. The fitness of the model mainly determines how well tutorials adhere to the principles of PBL.

The main functions of the tutor groups are systematic analysis with activating, collecting, processing and sharing of knowledge. The Tampere model has served its purpose well. This may be due to the fact that the model has been adapted for the local culture of the faculty. Our own model also reflects the process of implementation of PBL in the community.

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STUDENTS' PERCEPTIONS OF PROBLEM-BASED LEARNING IN AN UNDERGRADUATE MEDICAL PROGRAMME

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Over the last 35 years, innovations and research in medical education have proliferated. Early on, in 1969, McMaster University became the first school in the world to introduce a medical program that utilized Problem-based Learning (PBL) as its main form of curriculum delivery. Since then, the incorporation of PBL has become commonplace (Albanese & Mitchell 1993; Ryan et al. 2004). Through the PBL approach, students are expected to acquire new knowledge by studying around problems and clinical scenarios. Students encounter a new problem and work interactively with one another to solve it while simultaneously identifying learning needs, self-studying, seeking new knowledge relevant to the problem, and summarizing findings for one another.

Introduction

PBL is expected to provide a challenging and motivating approach to learning (Norman & Schmidt 2000). It is intended to improve knowledge retention and help students develop self-directed learning skills that will enable the habits required for continuous learning throughout one's worklife (Dolmans & Schmidt 1996). The fundamental theoretical advantage of PBL is contextual learning (i.e., acquiring material in the context of how it will eventually be used as a way to increase the likelihood that new knowledge will be useful in actual practice) (Albanese 2000).

Despite the apparent advantages, there have been debates in the literature regarding the actual effectiveness of PBL. Colliver (2002) has argued that over the last 20 years, research has failed to provide much evidence for the effectiveness of PBL. Morrison (2004) agrees and states that students in PBL systems do not perform better on certifying exams compared to students participating in the traditional style of medical education.

While the relevance of these claims has been debated, it does appear that the most robust difference between PBL and more conventional curricula appears to be that students get more enjoyment out of the problem-based approach to learning (Morrison 2004; Norman & Schmidt 2000). Albanese (2000) stated that improving the work environment for both students and faculty in a PBL curriculum is a 'worthwhile goal,' even if knowledge and skills are not improved compared to traditional type of learning.

Despite the large amount of debate and the resulting refinements made to how educators view the benefits of PBL, it is still the case that student perceptions are incompletely understood. Students in their preclinical years undertaking PBL have more positive attitudes toward basic sciences than students in traditional learning environments (Kaufman & Mann 1997). Norman and Schmidt (1992) state that PBL enhances students' intrinsic interest. In a study by McGrew et al. (1999), students in a family medicine rotation were asked their perceptions of PBL in the clinical years of medical school. They evaluated educational components of their program in terms of how well their learning was facilitated; the active learning areas, including clinical activity, independent learning, and PBL tutorials rated the highest.

Like most students, those entering McMaster's medical program primarily come from conventional undergraduate programs, where student learning revolves around traditional lectures and evaluation utilizes traditional examinations. The change to PBL often requires an adjustment period during which students become familiar with this new learning style. Students must adjust to small group interactions, learn to prioritize objectives and to assimilate new knowledge in a self-directed manner. An explicit goal is to enable students to become lifelong learners so they will continue to use the skills they develop throughout their worklife.

The current study is an initial attempt to survey student perceptions of PBL-relevant issues that are still discussed in the literature and hotly debated by McMaster's faculty. We have organized these issues into four categories. The first speaks to the value of the tutorial as a forum for learning/information delivery. The second speaks to the issue of who should tutor, clinical experts or basic scientists. The third is evaluation – a common source of debate within PBL communities. Finally, we asked questions about resources and whether or not anatomy and library resources are sufficient for PBL. The paper has been organized as a function of these categories, background information on what happens at McMaster and in the more general community, being presented along with the results. It is hoped that this work will provide a starting point for further understanding student perceptions of their worklife within a PBL environment that will allow medical programmes to (a) satisfy student expectations when they can be met and (b) determine where education around the PBL process might be required to help students understand when and why their expectations cannot be met. It is also hoped that further research into student perceptions provide students new to this learning style with an opportunity to understand what they should expect throughout their studies. Such insight might allow us to help students adjust to the new style of learning with greater efficiency and enable them to carry their lessons forward into their worklife.

General methodology and results

The study was undertaken at McMaster University, in Hamilton, Ontario, Canada. Focus groups with medical students were initially conducted to determine what questions are relevant to student perceptions of PBL. Results from these interviews and the literature were used to create an appropriate survey tool that was tested on a sample of medical students for reliability. First year medical students were surveyed in September, 2002. The survey was then administered to all first- and second-year medical students five weeks later in October, 2002. All participants were in the process of completing their pre-clerkship, learning primarily through problem-based study in tutorials; first year students had just begun their medical studies and second year students were nearing completion of their tenure in the pre-clerkship portion of the programme.

The questions asked of students are listed within each section. In response to each statement students were asked to assign a number on a 7-point scale indicating their agreement with that statement (1=strongly agree, 4 = neutral, 7 = strongly disagree).

Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS). Generalizability theory analyses were used to determine the test-retest of the questionnaire. Mean differences between first- and second-year students on the questionnaire items were examined using Analysis of Variance (ANOVA).

All first and second year students had a survey delivered to their campus mailbox. The response rate was 20.3% (28/138) for first year students and was 18.8% (24/128) for the second-year students. While the response rate is low, it is typical of survey methodologies used within the medical school and we have no information that would lead us to believe that the sample is biased in any way. Overall test-retest reliability for first year students was found to be 0.57. Individual questions for which the test-retest reliability was found to be less than 0.5 were excluded from analysis due to these judgments being deemed insufficiently reliable to allow inferences regarding stable student perceptions.

Information delivery and the use of tutorials

McMaster's three-year undergraduate medical program emphasizes both self-directed and problem-based learning, requiring students to identify their own knowledge gaps and seek out appropriate educational resources to fill in these gaps. The curriculum is designed to expose students to a broad range of health care issues and to prepare them for a career that emphasizes ongoing learning and problem solving.

The primary mode of curriculum delivery is tutorial. The class is divided into groups of approximately six students, with each group having a tutor and possibly a co-tutor. Each group discusses a series of health care problems, each week setting chosen objectives to solve a programme-provided problem. Students must learn to set objectives and choose appropriate resources to meet their learning needs. In addition, these tutorial meetings are sometimes supplemented by large group sessions in which the students themselves (or the unit planners) ask a faculty member to deliver information in a more conventional lecture-based format for the entire class. The first sixteen months of the program are set up in this way. The first unit is a time for students to familiarize themselves with PBL and the self-directed nature of tutorials as students begin to learn how to set objectives and to identify learning resources. The health care problems in this 2-month unit are mainly psychosocial, with a very limited amount of the biological sciences. At the time this research was carried out, unit two focused on cardiovascular, respiratory and renal systems, unit three examined hematologic, gastroenterologic and endocrine systems, and unit four focused on neurologic, locomotor and behavioural systems.

Table 1 illustrates the mean scores for responses received to questions about information delivery. Overall students agreed that tutorials provide an enjoyable and useful format for learning. First year students were more positive about both tutorials and large group sessions relative to second year students.

TABLE 1. Means (and standard deviations) for questions pertaining to information delivery

Question	Year 1	Year 2	p-value
You enjoy tutorials.	2.29 (0.85)	3.12 (3.12)	0.005
You are satisfied with the amount of knowledge you acquire in tutorials.	3.07 (0.86)	3.64 (0.86)	0.02
The adjustment to tutorial-based learning is difficult.	4.11 (1.37)	4.04 (1.72)	0.88
Tutorials allow you to explore issues in enough depth.	3.61 (0.79)	3.84 (1.43)	0.46
The large group sessions complement the learning that is done in the tutorials.	4.43 (1.50)	4.36 (1.47)	0.87
The large group sessions are informative.	3.21 (0.92)	4.08 (1.23)	0.01

Tutors

There has been much debate within the literature pertaining to whether or not tutors in PBL curricula should be experts in the content area as opposed to simply being individuals who simply maintain expertise in facilitating group interactions. Many educators argue in favour of non-expert tutors, suggesting that an expert tutor can endanger the development of students' self-directed learning skills (Silver & Wilkerson 1991). This conclusion was based on a report from a study at Harvard Medical School, showing that expert tutors were more directive, spoke more, were more direct in answering questions and suggested more of the discussion topics than non-expert tutors. Dolmans et al. (2002) has similarly argued that tutors who are experts on the content material use their subject-matter expertise more to direct the discussion in the tutorial group, while tutors who are not experts in the content area use their process-facilitation expertise for group direction. In contrast, Schmidt et al (1993) has shown that students guided by content expert tutors achieve a higher level of understanding compared to students with tutors who are not expert in the area, concluding that maintaining content knowledge is necessary for effective tutoring.

De Grave et al. (1999), examined the profiles of effective tutors in a problem-based learning setting using an instrument called the Tutor Intervention Profile (TIP) and concluded that tutors stressing the learning process were perceived as more effective than expert tutors stressing content. Hay and Katsikitis (2001) caution that more research should be completed and 'caution should be exercised' when using non-expert tutors in problem-based learning settings. We have followed up on Hay's call for more research by assessing student opinion on the issue of using non-physicians as tutors.

At McMaster the tutor has traditionally been expected to guide the group and to facilitate group interactions rather than teaching, but in reality much teaching does take place in some tutorials. Most tutors have a doctor of medicine (MD), but many basic scientists do contribute to the programme in this capacity. In North America, an MD is an undergraduate degree that certifies one to sit the licensing examinations and complete post-graduate residency training. Table 2 illustrates the mean scores for responses received to questions about the use of various types of tutors. Students were neutral regarding whether or not the tutor should play a major participatory role though they view co-tutors somewhat positively. Students were strongly opposed to having non-MD tutors in each unit except the first introductory unit. No differences were observed between first- and second-year students.

TABLE 2. Means (and standard deviations) for questions pertaining to tutors

Question	Year 1	Year 2	p-value
Your tutor should have a major participation role.	4.68 (1.09)	4.04 (1.43)	0.07
You find it useful to have a co-tutor.	3.43 (1.48)	3.25 (1.65)	0.70
A non-M.D. tutor is suitable for unit 1.	4.21 (1.87)	4.39 (1.97)	0.74
A non-M.D. tutor is suitable for unit 2.	6.64 (0.78)	6.00 (1.59)	0.06
A non-M.D. tutor is suitable for unit 3.	6.00 (0.47)	6.1 (1.33)	0.64
A non-M.D. tutor is suitable for unit 4.	6.00 (0.47)	6.1 (1.34)	0.54

Evaluation

Since its inception, one of the primary challenges facing those who wish to adopt a PBL curriculum has been the creation of a psychometrically defensible evaluation system that is consistent with the philosophical tenets of problem-based learning (Newble & Jaeger 1983). Typically, some form of tutorial evaluation is used in an effort to steer learning despite broad recognition of the psychometric limitations of this approach (Eva 2001; Nendaz & Tekian 1999). The same is true at McMaster, where after each tutorial the tutor is expected to lead discussion on how well each student performed, encouraging self-assessment and peer evaluations. In addition, students complete Clinical Reasoning Exercises (i.e., short answer quizzes on which students are expected to demonstrate understanding of unit specific material) at the end of each unit (Neville et al. 1996), Personal Progress Inventories (i.e., 180 multiple choice tests sat by all students in the programme) three times annually (Blake et al. 1996), and Objective Structured Clinical Examinations (Harden & Gleeson 1979) once per year.

Table 3 illustrates the mean scores for responses received to questions about McMaster's evaluation protocol. Despite the poor psychometric qualities associated with end-of-tutorial evaluations, students in both year 1 and 2 believed them to be useful and important components of the evaluation system. They were less positive about use of formal evaluations, but neutral with respect to the quantity of evaluation components. Again, no differences were observed across year.

TABLE 3. Means (and standard deviations) for questions pertaining to evaluation

Question	Year 1	Year 2	p-value
Self-evaluation components of end-of-tutorial evaluations are important.	2.79 (1.0)	3.24 (1.3)	0.16
Self-evaluation components of end-of-tutorial evaluations are useful.	3.11 1.13)	3.17 (1.24)	0.86
Peer evaluation components of end-of-tutorial evaluations are important.	2.54 (0.92)	3.16 (0.92)	0.05
Peer evaluation components of end-of-tutorial evaluations are useful.	2.71 (0.94)	3.17 (1.34)	0.16
You would like formal exams implemented into the program.	5.04 (1.43)	4.96 (2.13)	0.88
You would like to see more evaluation components in the program.	4.21 (1.50)	3.88 (1.92)	0.48

Resources

The final section on resource availability addresses questions that are somewhat McMaster-specific, but are included here in case educators at other institutions encounter similar discussion. One resource issue that is generic is the teaching of anatomy given the limited number of anatomy preceptors available. Like other parts of the curriculum, students in McMaster's medical program use a problem-based approach for learning anatomy. Students are divided into small groups, meeting with an anatomy tutor once a week to discuss a clinical scenario. They discuss anatomy specific to the pathology encountered in the problem, aiming for incorporation of common pathology within a context in which the information can be retained. The problem-based approach, however, makes it impossible to cover the same amount of material that one would be exposed to in didactic teaching. As a result, Older (2004) argues, the replacement of traditional didactic anatomy lectures and cadaver dissections by the problem-based approach is resulting in a reduction in undergraduate anatomy knowledge. A study by Prince et al. (2003), however, counters this argument as PBL training did not result in a decreased amount of anatomical knowledge compared to the traditional style of teaching anatomy.

In addition to anatomy training being a distinct part of the preclinical years, McMaster University has a clinical skills component beginning in, and continuing through, the preclinical program. Students are placed into small groups and meet an MD tutor once a week. They are taught clinical skills, and practice on both hospital and standardized patients in a manner consistent with Lam et al.'s (2002) argument that it is useful to introduce clinical skills training early in medical school; several studies have shown that students who study within a PBL curriculum perform better on clinical exams than do students in conventional curricula (Thomas 1997).

Table 4 illustrates the mean scores for responses received to questions pertaining to resource availability. Overall students disagreed that PBL is appropriate for learning anatomy and disagreed that they receive enough opportunity to practice their clinical skills. Students were satisfied with the resources available at the Health Sciences Library, but that satisfaction appears to decrease with seniority, at least in the preclinical years.

TABLE 4. Means (and standard deviations) for questions pertaining to resource availability

Question	Year 1	Year 2	p-value
You receive enough opportunity to practice your clinical skills.	5.00 (1.33)	5.52 (1.39)	0.40
The PBL style is appropriate for learning anatomy.	5.04 1.34)	4.44 (1.85)	0.18
The library provides resources that complement the PBL McMaster University Undergraduate Medical program	2.96 (1.20)	3.58 (1.14)	0.06

Discussion

This research project investigated students' perceptions of PBL in the McMaster University undergraduate medical school. Using questionnaires distributed to pre-clerkship students in both first and second year, perceptions were assessed in four areas: Information delivery, Tutors, Evaluation, and Resources.

In general, students seem to enjoy the tutorial-based nature of PBL as it is practiced at McMaster, they felt that MDs were the most appropriate tutors for all preclinical training with the exception of the first introductory unit, they viewed tutorial evaluations useful and important, but they did not think the PBL structure was appropriate for learning anatomy or providing enough opportunity to practice their clinical skills.

Some of these views are consistent with the evidence presented in the literature, others are not, as indicated throughout the manuscript. We are well aware that students are not always in the best position (relative to informed educators) to judge which aspects of educational curricula are evidence-based as opposed to driven by faith, but this does not preclude gathering more accurate perceptions of student opinion so that some reconciliation can be attempted when the two forms of information stand in opposition to one another.

This project has provided us an opportunity to begin determining where such reconciliatory efforts must be focused, but more work needs done as the answers provided by this research project are not conclusive in this regard. Limitations include the small sample size and the inclusion of only one program. Still, the responses were fairly uniform across cohort, a replication that increases our confidence in the accuracy of the results, at least in the local context. It should be noted, however, that while researchers and educators alike often talk of PBL as a uniform entity, problem-based learning should be considered anything but; even within McMaster no two tutors practice PBL in an equivalent manner. In fact, Barrows (1986) has gone so far as to outline a taxonomy of PBL. The purpose of this paper is not to identify which form of PBL is ideal, but rather to provide educators with a sense of student perceptions to consider when designing their own version of PBL.

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WHO SAID LEARNING COULDN'T BE ENJOYABLE, PLAYFUL AND FUN?

– the voice of PBL students

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Two teams of lecturers are completing a module on problem-based learning that was part of a staff development Postgraduate Diploma in Learning and Teaching in Higher Education, in a higher education institution in Ireland. The lecturers are problem-based learners for the module. The research question for this paper is 'How do lecturers as problem -based learners talk about their learning?' This research is part of a wider doctoral study that is investigating how two teams talk about four of the key characteristics of PBL, namely the problem, the PBL tutorial, the PBL process and learning.

My research position is from the stance of the constitutional paradigm and within this context my theoretical perspective is interpretivism. My research methodology is action-research. The methods are conceptual analysis based on a thematic approach informed by critical discourse analysis. Two themes of how each team talk about learning are identified and discussed. These themes are interpreted in the light of the illuminative concept of hard fun in the wider context of the play ethic. Play is viewed, not as something separate from work and learning but as a media for both. The argument is that play will be for the 21st century what work was to the last few hundred years of society, our dominant way of thinking, doing, learning and adding value, and that hard fun in problem-based learning is a way of actualising this.

This paper begins with giving the context and background of this research. It then outlines the research strategy utilized. The illuminative concept of learning as hard fun in the context of the play ethic is explored. Employers' perspectives are discussed before concluding comments. The teams have been given the pseudonyms of the Glendalough team and the Skelligs team and the participants have also been given pseudonyms.

Contexts and Background

This paper analyses the dialogue of two problem-based learning teams. Two teams of eight lecturers were completing a module on problem-based learning that was part of a staff development Postgraduate Diploma in Learning and Teaching in Higher Education. These lecturers were problem-based learners for the module. The lectures came from a variety of disciplines that included engineering, business, visual communication, nursing and architecture. They worked on two problems about PBL. Thus both the content and process of the module was problem-based learning. The teams met once a week for fourteen weeks. This research is based on all of the dialogue, of the full set of tutorials for two teams.

Four of the key characteristics of PBL are the problem, the PBL tutorial, the PBL process and learning (Barrows & Tamblyn 1980; Barrows 1988). This paper focuses on one of the key characteristics of PBL: learning. The research question is 'How do lecturers as problem -based learners talk about their learning?'

In Ireland, the Skillbeck report (2002) stressed the importance of developing graduates who are problem-solvers and innovators. Hak and Maguire (2000, 769) identify the need for more studies on what actually happens in PBL tutorials. It is a vital yet under-researched area of PBL and thus they called their paper "Group process: The Black Box of Studies on Problem-based Learning". Murray and Savin-Baden (2000) highlight the scarcity of studies in the area of PBL staff development. This paper analyses how participants talk about their learning in the tutorials of this PBL staff development module.

Research Strategy

This research is situated in the constitutionalist paradigm. Trigwell and Prosser (1996, 2) define the constitutional paradigm as:

> an internal relationship between the individual and the world. The individual and the world are not constituted independently of one another. Individuals and the world are internally related through the individual's awareness of the world. Mind does not exist independently of the world around it. The world is an experienced world.

Within this constitutionalist paradigm, the theoretical perspective is interpretivism. Interpretivism seeks to understand the complex world of lived experience from the perspectives of the participants, and draws on a broad combination from the history of ideas to do so which includes hermeneutics, critiques of scientism and positivism, practical philosophy and discourse analysis.

The chosen research methodology is action-research. This involves the twin processes of the theorizing of PBL practice together with the situated theorizing from this PBL practice (Usher & Bryant 1988). I was a tutor for one team, the PBL module co-ordinator and the programme leader. The methods used are conceptual analysis based on thematic analysis informed by critical discourse analysis.

I videoed and audio-recorded all the PBL tutorials for both teams. The participants went through a process of informed consent. Pseudonyms are used. I analysed the videos exploring how participants talk about their learning. The thematic analysis involves finding patterns and proposing interpretations of the patterns together with accounts of the meanings and ideological significance of these patterns (Cameron 2001).

The thematic analysis was informed by critical discourse analysis, which makes use of systemic linguistics, continental pragmatics and cross-disciplinary trends, "but attempts to go beyond them in providing a synthesis of necessary theoretical concepts and analytical frameworks for doing critical analysis." (Fairclough 2001, 11).

The thematic analysis is the basis for the conceptual analysis. I analysed the emerging themes for both teams. I then gave the first draft of this analysis to the participants and met with them to discuss this at a member check. At the member check I asked them having experienced the staff development modules as students and having read my analysis of the themes, to comment on what I had written. After the member check, I then looked at the themes across both teams and formulated illuminative concepts. These illuminative concepts provide a meta-language that give intellectual light to help in understanding the lived experience of the dialogue of lecturers as students. Conceptual analysis in this paper is about discussing the concept of hard fun that emerges from exploring themes about learning across the two teams.

The illuminative concept of hard fun, in the context of the play ethic

Learning as *hard fun* following Papert (1996) is a concept that encapsulate the idea that emerged from the data, that learning can be fun because it is hard, challenging and stretches participants. The fun in hard fun is a fun with enjoyment, laughter, freedom, creativity and energy.

From my data the idea of learning in PBL as fun emerges. This is a fun that is not superficial and frivolous, rather a fun that is rigorous and challenging. Hard fun following Papert (1996) encapsulates the idea of learning as fun *because* it is hard. Although this concept was developed in relation to children learning about computers, I would argue that it is very relevant to the learning of adults in problem-based learning. The following quotation captures Papert's definition of this concept:

> One of the best formulations of a fundamental principle of learning came from a conversation reported to me by Carol Sperry, the director of a pioneering computers in school project supported by IBM and the Silicon Valley Technology Center at the Gardiner Academy in San Jose, California.

One kindergarten section was waiting to take the place of another section that had just had its first encounter with the computers. A student recognized a friend coming out of the room and asked: "What was it like?" The friend replied: "It was fun." Then paused and added "It was really hard." (Papert 1996, 52–53.)

Papert interprets the relationship between "fun" and "hard". He argues that it is not a case of it being fun in spite of being hard but rather a case of it being fun *because* it is hard. His argument is based on the tone of the conversation heard by the teacher who knew the children, together with the fact that since this experience he has come to "know that the concept of hard fun is widely present in children's thinking." (Papert 1996, 53). I argue that the learning in PBL is an experience of the many dimensions of fun *because* it is hard in many ways.

I illustrate this by giving an extract from the dialogue where I argue the participants are talking about their learning in terms of hard fun. The Skelligs team give a shadow acting presentation that they had prepared for the problem about doing a presentation to heads of school about the PBL process. Ann, a tutor on the module asks them the following question:

Ann: I am wondering at the end of your presentation to the heads of schools, what sort of thoughts do you think you might have left with them in relation to PBL?

Hanora: But I would love to think the thoughts we have left with them is that wow,(*eyes opened wide and head lowered to right hand side)* you know, those students had an opportunity to be creative how does that reflect on your own person and how you develop y and we were actually challenged by doing something scary and we faced it and did it. And working it through, tackling it and breaking it down into units (*hand moves up and down moving across*) and addressing them. And as heads of schools they are wanting to have something unique in comparison to other schools. Maybe that is what they want, they want something unique. Em I would love to leave them with the fact that we were so creative, and the amount of students are, we put it all together without anybody's help, no lecturers.

Maura: It was such an enjoyable experience as well. It was actually fun…

Hanora is saying that learning is "creative" in an experience of being "challenged" through doing something "scary", and doing it themselves. It is creative and has a "wow" factor because it is challenging and "scary", "fun" because it is hard.

Fun as laughter and joking

Fun in learning in PBL has three dimensions: laughter, and joking, freedom and creativity, and playfulness. Fun is laughter and joking. Julie, from the Glendalough team at the member check said that PBL was "fun", "relaxed" and that "you could slag people off". "Slag" is an Irish expression meaning to joke with someone about her/himself in a friendly not a malicious way. In Ireland people only "slag" people they are comfortable with and having fun with. There is much laughter and joking and "craic" (the word Irish people use for an explosive, energetic boisterous type of fun) in the dialogues.

Fun as freedom and creativity

A second dimension of fun is freedom and creativity. The Skellig team talk about assessment of learning in terms of the theme of "terrifying lack of freedom versus enjoyable freedom". They experience freedom, creativity and laughter in presenting their learning through shadow acting, which was is a lot of hard work. They do the entire presentation through shadow acting. This is a genre that was new to some of them. This change in genre is reflective of a change in the way they are interacting with one another in an assessment of learning space. They have four characters behind the screen with a fifth character created with a puppet. There are two narrators. One narrator tells the story of the PBL team as it moves from scene to scene. The second narrator links what was happening to PBL theory. After there presentation there is a discussion about why they decided to take the particular approach to the problem and presentation and the following is an extract from that presentation:

> *Maura:* In terms of our own learning…mm…some of us who had never engaged in that type of learning before, you know, so, or active before, so it was important for the team as well that there were people in the group that had a lot of experience of this kind of presentation. So it stretched the boundaries a wee bit for some of us.
>
> *Hanora:* How many of us have been on a course and we would have had the freedom to do something so creative, so when the idea came up even though some of us were quite nervous about doing it, but we said lets give it a try and see how it works.
>
> *Beatrice:* And Hanora is now running away with the circus *(.laughter)*….

Participants talk about the freedom and creativity that is part of their learning experience in PBL. Freedom is a prerequisite of creativity and both are essential elements in fun. The participants in the Skelligs team contrast their experience of assessment of learning in PBL as enjoyable freedom compared with some previous experiences of assessment of learning that are characterised in terms of being terrifying and lacking in freedom:

Ann: O.K, I am interested in the problem you talked about PBL being in the strategic plan as it were stuck with no.. .(inaudible) I am wondering at the end of your presentation to the heads of schools, what sort of thoughts do you think you might have left with them in relation to PBL?

Hanora: I think as well for the heads of schools to see that education can have such freedom. I said this before, I just think, I have not seen it before,…..we had great freedom here to move furniture *(laughter)* and you know set up props, and do something completely different that challenged us , which we wouldn't have had, well particularly in my background, maybe people with a media background , we wouldn't have had this lovely creativity.[….]

Maura: It was such an enjoyable experience as well. How many times do you have the opportunity to be assessed and actually enjoy it, without being terrified….(*laughing)……*

Ann: You mean you were not terrified? *(laughter)*

Hanora: The screen helped, you know if you don't like acting or anything like that, you are totally hidden away, there was an element of protection and security as well.

The participants have freedom in both dimension; in terms of an inner existential freedom, and in terms of an outward expression of freedom as choices between alternatives (Roger & Freiberg 1994).

At the member check, Betty made links between this theme and Stake's (2002) keynote. This keynote was entitled "The Unbearable Lightness of Education". She explained that this was an analogy with "The Unbearable Lightness of Being." She said: "Do we want our students to be heavy with the curriculum we have set or light with their own curriculum, own agenda. This links with words like freedom and enjoyment." She then spoke about how Stake talked about the lightness of how his granddaughter who was three learned. I joined in the conversation to make the link with this and "Poem from a three-year old" (Kennelly 1990). I talked about how in this poem the three year old is learning through asking a series of questions.

Can we bring some of the lightness, fun, curiosity, questioning and sense of playfulness of the three year old back into learning in higher education through problem-based learning?

Fun as playfulness

A third dimension of fun is playfulness. My understanding of hard fun is in its context of the play ethic to which it belongs. Play in terms of the play ethic can is viewed, not as something separate from work and learning but as a media for both. Kane (2004a) argues that play will be for the 21st century what work was to the last few hundred years of society, our dominant way of thinking, doing, learning and adding value. Play can be a fruitful approach to different types of work including science, education and media. Kane (2004b: 38) refers to Freyerabend to introduce the general applicability of his theory of play and to illustrate the role of play in science.

Kane (2004b) explains that play is about engagement and that the Indo-European root behind the old English *plegian* is found in Celtic, German, Slavic *dtegh* meaning to engage oneself. Hard fun fits very well into the modern rhetorics of play which Sutton-Smith (1999) views as; play as frivolity, play as progress, play as imagination and play as selfhood. The idea of play as "selfhood" both asserts that we are only fully human when at play and that through play we can develop a more integrated self. Central to the play ethic is a way of thinking which tries to close a huge gap in modern living, the gap between who we are and what we do (Kane 2004b).The concept of hard fun has two complementary parts fun and hard.

The hardness of hard fun

The hardness of the learning has three dimensions: the hard level of difficulty associated with the problem, the high level of activity demanded by the nature of the learning and the transformative nature of learning in terms of attitudinal change.

Hard level of difficulty associated with the problem

The Glendalough team talk of their learning in terms of "I used to believe" versus "and then I learnt some more". The Glendalough team summarises their learning about problem-based learning in a poem. The poem is part of a presentation that they gave at the end of the module. The presentation was the result of their working on a problem called "The Enthusiastic Lecturers". This problem was about them being asked to help with a workshop on problem-based learning for heads of school by giving a presentation on the PBL process and teamwork. The learning they talk about is hard in terms of the difficulty level of meeting the challenge of the problem. The opposite of this hard, difficult problem they experience would have been an easy problem. The Glendalough team talk about the high difficulty level associated with way they decided to address the problem:

> *Kate:* And sometimes the harder thing to do probably distils the essence a bit better. It was extremely difficult to come up with that poem. What it actually did for us, distil the essence of what the PBL experience was like for us.

High level of activity demanded by the nature of the learning

A second dimension of the hardness of the learning is the high level of activity demanded by the nature of learning in PBL. One way of differentiating hard and soft is in terms of whether the people themselves are doing the action or whether they are passively observing others doing the action. A striking characteristic of how hard the learning in PBL is that the students themselves do the action and the work. They define the problem, review the facts, brainstorm ideas, seek out resources and information, reason through the problem, complete other work they decide to do, make their own decisions on which directions to take or not take and finally present their learning.

Hanora talks of the hard work doing the work on the problem and presentation themselves: "Em I would love to leave them with the fact that we were so creative, and the amount of students, we put it all together without anybody's help, no lecturers."

It could be regarded as a "softer" option for the student to passively receive transmitted knowledge in lectures.

Transformative nature of the learning

A third dimension of the hardness of the learning in PBL is the transformative nature of the learning. The following extracts of the poem they present shows how the learning is hard because of the transformative nature of the learning that is about change in beliefs and attitudes. The leaning is not just at the levels of knowledge and skills acquisition.

> *Mary:* In conclusion out team has come up with a communal poem and you will find a copy in your information packs. This poem attempts to give you a flavour of how some of our beliefs have been challenged and changed in the course of this process. The source of the poem began with two lines borrowed from a poem by Pat Ingolsby entitled Then I Learnt Some More. The poem is taken from a book called How Was It For You Doctor. Group members took pen and paper in hand and wrote one or more verses beginning with" I used to believe" and ending with "and then I learnt some more". I will call upon Sue to begin.

Sue: I used to believe … that I was the lead, and that the students need was to follow … and then I learnt some more. (*Tears up written verse and sits down*).

Noel: I used to believe … that my teaching style gave cause to smile … and I enjoyed my delivery style … and then I learnt some more … I used to believe that students learned according to my notes … would give me cause to gloat … and then I learnt some more.(*Tears up written verses and sits down*)

Julie: I used to believe with all my might and height *(laughter*) [she is … short!] … I could shelter students from the mess of real life … and then I learnt some more. *(laughter*) … (*Tears up written verse and sits down*)

Fairclough (1992) views changes in genre and changes in social practice as having a dialectical relationship as he uses the term genre referring to a relatively stable set of conventions that is associated with a socially ratified way of acting and interacting

The change to a new way of learning through PBL, with the associated changes in the participants beliefs about different aspects of learning and teaching are manifested through changing to a new genre, the genre of a poem.

What about poetry? Some of the participants described writing a poem as "extremely difficult" and "new". However, perhaps all of us inherently have the ability to express ourselves poetically but are not in the habit of using this ability. In *The Poetics of Mind: Figurative Thought, Language and Understanding* Gibbs (1999) using evidence from recent research in the cognitive sciences argues for that thinking is deeply poetic. Poetry is often used as it was in this case to capture emotional and attitudinal change. The participants describe how their beliefs and attitudes about many aspects of learning and teaching have changed with a major causal factor being experiencing problem-based learning as PBL students in a staff development module.

Trigwell and Prosser (1996, 80) stress that academic development that focuses on teaching strategies "is unlikely to be successful without an ongoing focus on the intentions that are associated with the strategy" (emphasis my own).

We can see the participants through their poem engaging in ideological critique through questioning their beliefs, This de-mythologising of their learning and teaching situations has involved them in questioning both their teaching strategies and intentions. There is some movement from teacher focus to student focus. They are also deeply questioning their underlying attitudes. In the poem there is some movement away from the intention of the transmission of information. This demythologising of reality has the potential to lead to transformative social action. The learning is hard as it is working at the transformative level of beliefs, values, attitudes and ideologies. The participants are experiencing attitudinal change which I would argue is the hardest but most important type of learning. When beliefs, values and attitudes that have been held for years are challenged, turned upside down or replaced by new ones it can be experienced at once as both hard in terms of hard work and fun in the sense of a liberating freedom of having new attitudes and beliefs that serve us and others better.

I represent the concept of hard fun in the context of the play ethic in terms of the yin-yang symbol of two complementary halves forming a whole:

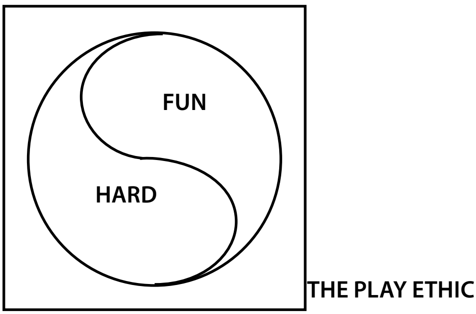

FIGURE 1. Learning as *Hard Fun* in the context of the Play Ethic

Employers' perspectives

Problem-based learning is about building bridges between education and work and it is very interesting to look at employers' perspectives. Kate said at the member check discussion that she used PBL with a group of third year undergraduates and a postgraduate group. She explained that she is well set up in terms of infrastructure with syndicate rooms in the library, laptops and a website to support the course. She gives the masters group one big problem at the very start of the module. This is how she describes it: "They break into groups and work on the problem. I am not good at getting them to reflect. I am directive and not good at staying out and letting them be confused. I am absolutely fascinated by the way they are doing it. Yesterday one of the girls produced a cardboard box with a face painted on it and said let's use this to get a handle on Mary on whom the problem is based."

She said she brought in some people from industry including someone from the biggest sales and marketing agency in Ireland and that they were fascinated at observing a tutorial and "gob smacked" at the high standard of the end product produced. I was fascinated with how they were playing with the problem visually.

Frank who had piloted PBL with aeronautic engineering technicians and was doing research at the time of the member check he had this to say: "We are close to employers. It's very obvious we cannot continue the way we are going … PBL is a very clear solution to some of the problems we are trying to grapple with. I got them to do it in a difficult module and it was very successful… I had an interview with the head of the Aviation Authority this morning. The first thing he said was that this new curriculum cannot be done in the time teacher has face-to -face. You are going to have to get these people in some shape or fashion to do it themselves. I was nodding my head and making sure the recorder was working well (*laughter*). If I had written the speech for the man! (*laughter*). I said as it just so happens I have piloted PBL."

Frank saw PBL as a solution to two major problems he had namely; implementing a new curriculum and a high failure rate at the international exams for this course. More of the same approach that was being used would not address these two crucial issues. Frank's head of department had attended PBL two-day staff development workshop for heads of departments and schools and was supportive to him in piloting PBL. I see that Frank's students have to do a lot of hard work themselves but a PBL approach means that possibility that this hard work can also be hard fun.

Conclusion

The following figure summarises my view of the learning in PBL as hard fun (see Figure 2).

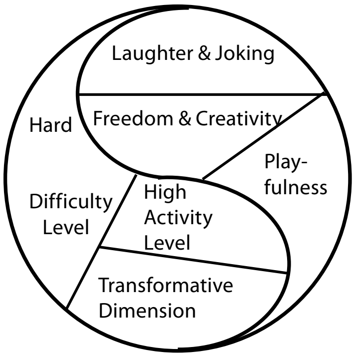

FIGURE 2. The dimensions of Fun and Hardness in the illuminative concept of Hard Fun

I argue that learning in PBL is an experience of hard fun. It is fun *because* it is hard. The illuminative concept of learning as *hard fun* in the context *of the play ethic* has enabled me to integrate my analysis of the learning experienced by these two teams of problem-based learning students. Some academics and students can be sceptical about the notion of fun in learning. They consider that learning in higher education is serious hard work. I am not talking about a superficial or gimmicky fun or entertainment. I am talking about hard fun. Fun without hardness is frivolity. Hardness without fun is drudgery.

Learning in PBL demands both the fun of playing with ideas and the hardness of refining and reworking ideas. Both complementary parts are needed for learning. The argument is that play will be for the 21st century what work was to the last few hundred years of society, our dominant way of thinking, doing, learning and adding value, and that hard fun in problem-based learning is a way of actualising this. The words of the voices of these problem-based learners are saying that learning can be enjoyable, playful and fun.

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LEARNING AT WORK AS A TUTOR
– the processes of producing, creating and sharing knowledge in a work community

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The research carried out in the area of problem-based learning has focused mostly on the point of view of the learner and the learning outcomes. The changes in teachership and within the whole organization have been given less attention. In this article, I will go further and analyse the challenges of tutors' work and the complexity of producing, creating and sharing knowledge necessary for continuous professional development within the frame of problem-based learning. Firstly, I will describe briefly the special nature of tutor work. Secondly, I will analyse tutors' work and the work community utilizing the process model of learning at work (Järvinen & Poikela, E. 2001). The aim is to open the individual, social and organizational processes in which knowledge is created within the frame of problem-based learning and pedagogy. In doing so, I will use Blackler's (1995) description of the typology of knowledge inside an organization when describing the knowledge environment in which a tutor works. In addition to problem-based learning, I will also use the term problem-based pedagogy to emphasize the teacher's/tutor's perspective.

Since the mid-1990's, interest in PBL has increased rapidly in the field of Finnish higher education. The first two implementation programmes were begun in the Faculty of Medicine at the University of Tampere and the Department of Physiotherapy Education at the Pirkanmaa Polytechnic, Tampere. These two educational institutes were also the case organizations in my research (1996–2001) focusing on the development of tutors' competence and knowing, and also on the core elements of their work (Poikela, S. 2003).

The authentic quotations used in the article are drawn from data provided by informants that participated in this study.

The tutor's varied duties – facilitator, expert and teacher

One of the most important aims of PBL is to bridge and integrate the contexts of education and work. PBL gathers and integrates not only the different disciplines, but many elements regarded as essential in effective, high quality learning, such as self-directed or autonomous learning, as well as critical and reflective thinking skills. (Boud 1985; Poikela, S. 1998; Silén 2001; von Schilling 2001.) These are essential skills not only for the learner, but for the tutor as well. However, research on learning and PBL has mainly focused on the learner's point of view and on learning outcomes. For example, a meta-analysis by Dochy, Segers, van den Bossche and Gijbels (2003) reports the positive effects of PBL on learning results. This strengthens the earlier well-known meta-analysis of the advantages of PBL (Albanese & Mitchell 1993; Vernon & Blake 1993). However, PBL gives new meaning to the teacher's role. Within the frame of problem-based pedagogy facilitation and guidance of learning have a broad meaning. The nature of a teacher's work changes from acting as a supplier of information and manager of learning to becoming a facilitator, supporter and resource of learning. It also means redefining the teacher's work and the content of the curriculum.

The core of the learning activities consists of meetings in tutorial groups or teams (of approximately 10 students) facilitated by a tutor having the status of a teacher. Tutorials are usually held once or twice a week and all other learning and teaching activities are constructed around these meetings. So, tutorials can be regarded as a dynamo for learning and for the whole curriculum. The role of the tutor is ambiguous and not easy to define since it might consist of many simultaneous roles and tasks that may even feel contradictory at times. As a facilitator, the PBL tutor is a part of a group her/himself and, in that respect, one of the learners too. However, s/he is still in a position of power, for example acting as an evaluator of the learning results. It is important to become familiar with and to recognize the meanings and functions of the tutor's different roles. (Poikela, S. 2003.)

When giving a lecture, the teacher/tutor is an expert and a resource for learning, but in tutorials s/he facilitates learning. The tutor does not operate prominently and, under no circumstances, dominantly in a tutorial. S/ he facilitates and challenges learning mainly by asking questions. Tutoring is probably the most challenging role the teacher can take on. This means that fundamental questions about oneself as a human being and as a teacher need to be carefully addressed. It is essential to evaluate the depth of one's own expertise regarding the substance of tutorials, as well as one's own ideas about PBL and its theoretical background. Being able to identify and guide the phases (or steps) of the problem-solving process is a starting point for acting as a tutor, but the knowledge of PBL should not be limited only to this. Teachers themselves tend to see learning more as a teacher-centred than a learner-centred activity, but this is no longer possible in the context of PBL. The role of tutor may feel strange at the beginning and feelings of uncertainty and inadequacy are usual. Expertise is not determined only by knowledge of the substance but by the ability to get this expertise to work. This is done by asking good questions dealing with substance and by guiding learners to reflect on their learning. (Silén 1996; Poikela, S. 2003.)

PBL changes the culture of learning in many ways. It changes the relation between learner and teacher, the collegial relations between teachers, and impacts on the organization as well. In the broadest sense, all the functions of an organization have to be re-evaluated and re-organized according the principles of problem-based pedagogy and learning. Otherwise, both the teachers/ tutors and the students will end up in state of frustration. Curricular development becomes a collaborative process, continuously evolving, and integrating every single teacher into the process. Ideals and practices have to correspond with one another at the level of action. If the impact of these developments at the meta- and macro-levels of an organization is disregarded, PBL is easily misunderstood as a static construction arising from a doctrine or dogma, rather than as a transforming educational strategy. From the teacher's perspective, PBL demands fundamental reflection on one's own values and work practices. Development as a PBL tutor is not only a matter of managing the techniques of facilitating learning or of designing problems. The core of PBL goes deep into conceptions of knowledge and learning and utilises these conceptions as tools for comprehension.

The processes of learning at work

Development as a PBL tutor is not only a matter of managing the techniques of facilitating learning or of designing problems. The development of teachers' knowing and competence has seldom been analyzed from the point of view of learning at work. However, according to my research data the essential factors proved to be how tutors acquired and processed knowledge indispensable to their professional development and how they learn at work.

In the following, my aim is to analyse how simultaneous learning processes connected to an individual, group and organization cross and intersect each other in the context of work. A tool for examining these elements is the typology of learning at work as social, reflective, cognitive and operational processes (Järvinen & Poikela, E. 2001).

Järvinen and Poikela, E. (2001, see also Poikela, E. 2004) argue that the most essential point in producing learning and knowing is not what happens "in the levels" of an individual, group or organization but rather what happens between these levels. However, it is more fruitful to use expression of the individual, communal and organizational contexts of work and learning involving the processes of learning and action defined by situation, time and place. The processes producing learning and knowing can be described by integrating the dimensions of learning at work in a following way:

1) *Social processes:* Concrete Experience – Sharing Experience – Intuition Formation
2) *Reflective processes:* Reflective Observation – Reflecting Collectively – Intuition Interpretation
3) *Cognitive processes:* Abstract Conceptualization – Networking New Knowledge – Integration of Interpreted Knowledge
4) *Operational processes:* Active Experimentation – Learning by Doing – Knowledge Institutionalization

I also analysed the interactive relations between learning processes and different types of knowledge presented by Blackler (1995). Objective knowledge, which can be divided into encoded and embedded knowledge, is not dependent on an individual. The types of subjective knowledge, either individual or collective, are embrained and embodied knowledge. Encultured knowledge emerges on the basis of other types of knowledge. For this reason it is both objective and subjective in its nature. The process model of learning at work connects this to cognitive processes: abstract conceptualization leads to organizing the conceptual knowledge and this, in turn, leads to the integration of interpreted knowledge. Both explicit and tacit knowledge are needed for utilizing the potential knowledge hidden in the knowledge environment. According Järvinen and Poikela, E. (2001) there are several tacit or only partly conscious functional processes. The interpretation of intuition could start from explicit elements, and this may help to make parts of tacit knowledge explicit as well. (Poikela, E. 2001; Poikela. E. & Poikela, S. 2002.)

The process model of learning at work cites forms of symbolic knowledge as sources of organizational learning. These are integrated and institutionalised as a property of the whole work community. I focused the analysis of data mainly on locating subjective and experiential elements of tutors' knowledge (embrained and embodied). However, encoded and embedded knowledge could also be located in the descriptions of different instructions, resources and infrastructure. If these forms of symbolic knowledge remain static, they may even, in the worst cases, prevent learning. On the other hand, if they are dynamically processed, they create preconditions and circumstances for learning new knowledge as a group (see Järvinen & Poikela, E. 2001).

Social processes – interaction as a source of learning: obtaining, sharing and producing experiences

Experiences were obtained, shared and produced in different ways. When teachers started to act as tutors, the first challenge was how they established contact with the tutorial group. Tutors were worried about their skills of facilitating learning and were even unsure about their own expertise with the substance of tutorials. In the worst cases they felt they could even harm learning if they did not facilitate the group "in the right way". Tutors also speculated on the effects of their non-verbal actions. Many factors appearing in tutors' physical movements and actions became visible with this kind of embodied knowledge. Tutors' uncertainty about their new role also affected the group which made the students suspicious about their learning too. However, this happened only during the first couple of years with the PBL curriculum. Some tutors assumed that this was because they themselves as tutors had become more convincing, even empowered, as facilitators of learning. At the beginning, they felt they were more "tense and alert". It was only little by little that they started to relax which, in turn, led to an atmosphere of openness and trust in a group. Tutors were able to analyze the group very skilfully, both in terms of the emotions and the moods of its members. For example, they felt they could sense something in the air which they could not exactly specify.

> *"How could I help the students come into the tutorial situation, work there and feel themselves relaxed? And how could I do this for myself, too?"*

Deliberate control of one's own non-verbal actions was one part of embodied knowledge. One of tutors realized she affected the interaction of the group unduly by simply nodding her head much too often. By doing this she took too much power in the group situation. Students started to look at the tutor and talk to her instead of talking directly to each other. This is a good example of how tutors recognized the meaning of tacit and embodied knowledge in their actions. It proved to be hard to give a verbal form to all the elements of subjective knowledge. So, the knowledge was more embodied or involved in actions. Tutors described the ways they could influence the creation of a “strong and good” atmosphere in tutorials. Still, they found it hard to say aloud how their own actions could create such an atmosphere. This was also linked to the joy of learning when, at its best, the tutorial was described as a collective flow-experience enjoyed by all participants.

Even during the early stages of PBL curriculum medical tutors started to mentor each other. However, it was not organized or planned in the first place and one of the tutors described it more as “talking over a cup of coffee”. It was soon apparent that the freshman tutors could not be left alone, and the more experienced tutors started to establish a tutor training system. In this way more experienced tutors were able to guide the novice tutors. The tutor training formed a very important forum for obtaining, sharing and producing knowledge. Not all the teachers were very happy that they had to change their traditional style of teaching. For this reason, the tutor training sessions also served as forums for handling and processing active resistance to change. One of the tutors described the atmosphere of the sessions with the metaphor “a continuing battle”. Tutors said that changing medical education was hard, even more difficult than “moving a cemetery”. It was important that a part of the tutors acted as active agents for change in curriculum reform and that they were patient enough to train new novice tutors over several years. Some of the teachers were reluctant to participate in tutor training but active resistance changed to acceptance little by little. The tutor training and its development provided the most important forums for sharing common encultured knowledge.

Another important common forum both in medicine and physiotherapy was the curricular work which was a continuing process. Working hard alone, isolated from colleagues, was no longer possible because curriculum work forced all the teachers to consider shared practices and procedures. Everybody had to argue and justify their opinions. At the same time, the opinions and thoughts of colleagues became more familiar than ever before.

> *"It happens in meetings, we sit down and talk things over and then we agree what everyone needs to do next. If you share your thoughts during the meetings then your own ideas get noticed more."*

More formal modes of cooperation were developed in medicine because there were so many teacher involved. Acting together, curriculum-planning groups produced collectively shared knowledge. At the start, the members of the groups hardly knew each other and they did not know much about each other's areas of expertise. This sometimes led to misunderstandings and difficult situations. Earlier teachers' own private areas had been protected too well and opportunities for collegial cooperation had been underestimated. Tutors, acting as trainers, had an idea that every novice tutor should have an older colleague observing and commenting on how the first tutorials were going. Some teachers did not want this because they felt it was tantamount to inspect their private area of work. Little by little, most of the teachers started to understand the advantages of cooperation. Tutors describe the present situation as "good and inspiring". The doors of the curriculum planning groups were open and everyone interested could join the groups s/he wanted. The atmosphere of the groups was much more open and relaxed than in the early years.

Reflective processess – assessment and evaluation as a source of learning: reflection, feedback, assessment and evaluation

Subjective knowledge is processed through reflection. Reflection can be understood as the smallest unit of assessment in learning and producing new knowledge. Its aim is to produce new knowledge for learning and developing (Poikela, E. 2004). The data richly revealed the elements of embrained and embodied knowledge described by tutors. This knowledge had been generated through observation and assessment over many years. At the start, tutors felt that the new kinds of practices and their role as a facilitator were very difficult and they missed their former secure role as an expert on the substance of their subjects. This was connected with worries about ensuring that learners learned everything necessary – a typical desire for a teacher trying to explain everything in as much detail as possible.

> *"I feel that all the theories about acting as a tutor prevent my spontaneous action. Somebody said teachers need to find their own way of becoming a tutor and to work continuously with their own role. Maybe I am right at the beginning and I need to accept that I am apprentice to a tutor."*

These doubts about being a tutor were reversed over the years. Tutors started to feel that acting as a tutor was more meaningful than giving an expert lecture, for example. Developing as a tutor meant passing through different stages. The primary concern at the beginning was being able to guide the cycle of problem-solving appropriately. Tutors felt this took most of their energy and they had difficulties in making challenging questions or making comments about the group dynamics. So, this meant that encoded knowledge, which in this case was the cyclical model of problem-solving, supported the creation of embrained knowledge. The model, as such, was not static because tutors said it helped them to go through the problem-solving process smoothly and to guide the group more effectively even after several years. The model had the status of established practice and institutionalized knowledge, but it was submitted to a process of continuous reflection both individual and collective.

All tutors examined at a fundamental level the change from their former teacher's role to that of facilitator of learning. On the one hand, they sensed they were finding their own ways of being tutors only little by little. On the other, they acted with increasing fluency and felt more comfortable in their new roles. The duties of facilitator and expert meshed more satisfactorily and the changes in approach forced by the new situation were not felt to be as problematic as before. At the beginning, the tutors worried most about how they could help the learners in the best possible way. The development of tutors' skills can be regarded as learning through the interaction between experimenting and changing experiences. However, experimenting was not enough; a continuous analysis of one's own work was needed. It was essential to try to do better all the time. This guaranteed the creation of new intuitions as a base for learning at work. For example, tutors noticed that it was not enough "to know" the processes of group dynamics, but it was also important to influence and facilitate these processes in practical situations. At first, tutors felt helpless in the situation. This meant that symbolic embrained knowledge had not yet been produced as knowing and competence. So, the lessons about tutoring and acting as a tutor were not in balance. When more experience was gained the phenomenon of group dynamics was found to be more interesting. Tutors also started to analyse their actions in more detail as "builders of the learning environment" and "supporters of the joy of learning".

> *"Well, the spirit or atmosphere has a strong effect. Sometimes it happens that everyone seems to be in a similar mood and they joke and have a good time. Still the learning issues are dealt with and there is real progress."..."I think we have been able to organize the first year well and it is functioning effectively. It gives students a sense that we, as teachers, believe in this way of studying. I see it like that. I sure hope it is like that and it is dependent on us."*

However, despite this experience there still were situations when tutors felt their knowledge and skills were insufficient. Helping the group to synthetise and construct the new knowledge was one area that was particularly in need of development. The key words in acting as a tutor could be characterised as courage, trust and patience. Courage was needed not to intervene in the action of the group too early. Tutors needed to wait and observe and to trust that the group was capable of rational work by itself. Tutors learnt to consider more closely when interventions were needed and what their purpose was. It was realized that in the worst case a tutor could even sabotage the learning if s/he made an unnecessary intervention. Tutors learnt to focus their interventions and noted the importance of framing good questions. Observing tutorials facilitated by fellow tutors was found to be an effective way of also developing one's own facilitating skills. After years of experience, some of the tutors saw their role more as that of a pedagogue than an expert on substance. So, the development of knowing and competence was enabled through the processes of assessment and reflection.

Many tutors used writing as a tool for personal reflection. Notes and journals were important for assessing both one's own actions and the functioning of the group. Collective reflection was possible in tutor training and in other common meetings. The experiences gained through training other tutors were also significant. The systematic observation of tutorials was even described as the most influential learning experience at work. Tutors saw the importance of giving and getting feedback both in tutorials and as part of collective action with colleagues. However, both the tutors and students needed to practice systematic feedback. Reflection needed focus and the realization of what elements were essential.

A broader evaluation was possible with the continuous development and outlining of the curriculum undertaken every year. The PBL curriculum was not "carved in stone" for several years at a time like the traditional curriculum. If shortcomings were noted, they were dealt with and corrected at once. The development of the curriculum on this new basis was noted nationally and both organizations received public commendation in the form of awards for the quality of teaching.

***Cognitive processes** – creating and processing knowledge as a source of learning: creating, processing and documenting knowledge*

The cyclical model of PBL that structures tutorial work and learning is a representation of symbolic knowledge. During the early phase of the project, the model offered detailed direction for the actions of tutors and students. Following it gave tutors a sense of "doing things right" and they gained a sense of support and encouragement for their work. Tutor guides and course manuals had a similar role, aiming to guarantee that all the tutors followed the same collective rules. The tutor guides were especially important in medicine because not all the tutors reflected on their work together in collective meetings on a regular basis. Tutors described this as "decent methodological management" and felt that carefully following the same procedure was needed at the start. Designing these shared instructions together was also a good indication of collective learning.

Also, cultural knowledge was created by using metaphors and parables. This can even be described as a collective state of mind inside an organization, involving interaction and knowledge created and shared together. The social appearance of cultural knowledge was easier to locate and express than the values or the tacit collective knowledge of an organization. The creation of cultural knowledge can be compared to organizational learning which starts from the creation of an intuition. This intuition is linked to the tacit or preconscious action processes of an organization. The intuition is modified by shared language and by collective interpretation which, in turn, integrates it into the former knowledge of the organization and institutionalises it as a part of the organization's collective action. According to the data, the challenge was how collective knowledge and competence could be passed on to "the tutors of the next generation".

The management openly supported the curriculum change in both organizations. Resources, as such, were not much increased but principal and emotional support was a very important factor in the success of the change process in both cases. However, the process of curriculum change was carried out in different ways. The tutors of physiotherapy guided their unit towards the problem-based curriculum a step at a time by integrating a new part of the study programme "with PBL" every year over a five-year period. Their unit was small and the change mainly affected the work of about ten teachers. Tutors felt that the management gave quiet assurance and support to the change. Tutors regarded the atmosphere of their unit as excellent and, after some fights at the beginning, their cooperation had proceeded fairly smoothly. In medicine, the change influenced dozens of teachers simultaneously. The change was personalized with a strong faculty dean putting his full authority into guiding the change process. The differences in these change processes were linked to the ways the elements of cultural knowledge appeared in tutors' expressions. For example, how implicit knowledge proceeded to explicit knowledge was expressed with metaphors.

> *"In earlier days, the teacher was sitting alone in a fully loaded boat almost sinking, and the poor teacher was trying to row with the last energy s/he had. After PBL, the tutor is sitting in a boat with a group and guiding while others are rowing and eagerly looking ahead."*

Collective cooperation and learning did not mean that everyone was in agreement all the time. However, objections had to be dealt with and it was understood that everyone's opinions should be taken into account. But it was also the case that some had to give up and accept an idea if a colleague could reason and argue her/his opinion better. The best part of cooperation was sharing both the good and the bad experiences. Creating a good general atmosphere required the transformation of attitudes. Everyone had to realize that old habits and procedures needed to be changed because of PBL. There was a lot of cooperation but its intensity and style varied even after years. Being open could be surprisingly difficult.

> *"Some are too critical of themselves and, because of this, they may even hide their own competence."*

The role of development as a facilitator was also indicated in the way tutors were capable of supporting the learners' growth with regard to autonomy, self-directedness and reflection. Also important was the way in which tutors managed to conceptualise their own actions and pass on their "know-how" to colleagues. The tutor her/himself is also a learner in the process of problem-based learning but, at the same time, s/he needs to guide the learning skills of the learners. If the tutor tries to give over-strict orders and instructions with regard to the learning process, it is possible that there will not be enough space for the learners' (students') self-directedness. So, the duty of a tutor is a very complex one. S/he needs to trust the learners' self-directedness, support their construction of knowledge and act as an active resource for learning. At the same time, it is essential to take care of the individual and collective development of expertise in problem-based pedagogy both in terms of substance and new ways of acting inside the organization.

***Operational processes** – action as a source of learning: acting, cooperating and forming routines*

The application of problem-based pedagogy and the curriculum associated with it started to proceed more smoothly after more experience had been gained. The other side of the coin for "managing the method" was the threat of actions becoming too routine which, in turn, would not guarantee learning quality. This could be avoided by continuous assessment and reflection regarding the action processes. For example, the first part of tutor training in medicine followed a procedure tutors called "a cook book exercise". The aim was to gain personal experience of being a member of a tutorial group. The second part of tutor training deepened knowing and competence using an observation exercise followed by a process of collective reflection. The observation exercise was developed so that an observation form helped to direct attention towards essential features of group dynamics and tutors' actions.

Important questions were raised when tutors considered whether a tutor always needed to be the expert on the substance of tutorials. Almost all tutors of medicine were practitioners of medicine themselves. Most of the tutors in physiotherapy were also physiotherapists, but this was not emphasized as a qualification as much as it was in medicine. In both organizations the work of the curriculum planning groups was carefully organized and involved participants in different roles. All the teachers of physiotherapy were evidently involved with PBL as tutors, expert lecturers and examiners because of their small number (about ten).

Sometimes old procedures in medicine conflicted with new ones. It had been mainly the professors who had earlier acted as examiners. After curriculum reform they still had this same role but only some of them actively participated as tutors. For this reason the question of exams and the criteria for evaluation were sometimes in contradiction with the principles of PBL. The former institutionalised roles as teachers and prevented the creation of roles as tutors, facilitators of learning. However, implementing PBL led to tutors gaining new experiences, interpreting them and, in this way, the integrating new knowledge which, little by little, became institutionalised.

Fundamental organizational changes were faced by physiotherapy tutors when the former Institute for Health Care became part of the Polytechnic. The situation was challenging for individuals, the work community and the whole organization. On the one hand, tutors felt the change, which lasted many years, was very stressful. On the other hand, the change was not simply a negative phenomenon because it continually drove the process of curriculum development.

> *"Next autumn we will have a new curriculum once again. So, this must be the normal state. We are doing it all the time and I guess we are used to it. Sometimes this feels like a burden. Now we are going to have a new curriculum and new terms and conditions of employment for teachers. This is the fun we have been busy with. I think we have kept everything together surprisingly well and our gang have managed it pretty well."*

Collective processes could not be stabilised because the processes involved in knowing and action were in a state of continuous movement and testing. The organizational changes established a strict framework for the use of teaching resources. There were 35 teaching hours for one study week at the beginning of the PBL curriculum and this was reduced to 18-20 hours for one study week. Tutors' shared the opinion that without PBL they could not use that time effectively. Unfortunately, this meant that tutors had less time for their meetings together because they aimed to maximize the hours they were using for contact lessons. Changes in the terms and conditions of employment caused problems with resources. The compulsory teaching duties were no longer based simply on counting the amount of contact lessons but on all the duties of a teacher. Tutors felt positive about this change because they expected it to offer a better framework for cooperation and development work.

> *"We had a lot of cooperation even before, but now we do it even more. I think it is one really good point in all of this."*

Conclusions – "Acting as a tutor is like continuous learning at work."

I have analyzed the formation of tutors' professional knowing and competence from the point of view of processes of learning at work. The change affecting individuals, the work community and the whole organization was crystallized in the successful reformation of curriculum. It was not a matter of the skills of the individual teacher or even of effective cooperation among some of the teachers, but a matter of fundamental development producing new pedagogical knowing and competence. The development work institutionalized in the form of a new curriculum touches everyone. If it is not continuous and elastic there is a danger that PBL becomes characterised as a static doctrine or dogma which could, in time, be replaced with another fashionable reform. This kind of misapprehension is not unknown in Finland either. However, rather than being only a method, problem-based pedagogy is a strategy or even a philosophy requiring deep reflection on the personal values and practices of its practitioners (see also Chen 2000; Silén 2000).

Every tutor needs to face changes in their teachership. It may be a fundamental change process resulting in personal growth and development which can be described as social and individual empowerment (Poikela, S. 2003; Savin-Baden 2000). This kind of transformative change takes time and needs support in order to be fulfilled. It was possible with the help of tutor training and the supportive network of colleagues. At first, teachers were worried about their own role both as facilitator and expert and especially about their tutoring skills as a facilitator of a tutorial group. However, different elements of teachership started to fit together in more creative way with the help of tutors' own reflection and the collective learning process. So, it was possible to move from a culture of working alone to a culture of shared work and genuine trust. The curriculum, which was constructed together, became a tool to reform the whole culture of an educational organization.

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