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The Aalborg University PO-PBL Model from a Socio-cultural Learning Perspective

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ABSTRACT

Since the 1970's, Aalborg University has been developing a new pedagogical model in higher education: The Project Oriented – Problem Based Learning (PO-PBL). In particular, the Faculty of Engineering and Science has developed a pedagogical proposal that introduces students to a different type of learning. One of the theoretical frameworks underpinning the understanding of learning is the socio-cultural perspective. This paper aims at exploring and analyzing the PO-PBL model from this theoretical perspective. In addition, this reading may also open a new viewpoint in science teaching for other universities.

Keywords: Project Orientation-Problem Based Learning (PO-PBL), socio-cultural perspectives on science, science education at university level.

INTRODUCTION

The term "innovative university" seems redundant. A university is obviously an innovative institution in knowledge production. Nonetheless, universities also perpetuate academic traditions, particularly as far as teaching is concerned. Founded on the research-based university model introduced in 1809 by Humboldt in Berlin; it can be described as providing

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education to professional elites in which academics are researchers who engage in the production of new knowledge, with a high specialization of subjects and disciplines (Bowden & Marton, 1998). In the last decades, the consolidation of a globalized knowledge society has been related to the expansion of higher education. Universities are expected to equip a growing number of people with competences, knowledge and even research capabilities to perform different jobs in both public and private organizations. The challenge for universities is closing the gap between innovative knowledge production and innovative teaching and learning processes.

In response to such challenges, during the last four decades Aalborg University (AAU) has been conducting an educational revolution that opens university level education to a broader target of students, using the Project Organized – Problem Based Learning model (known as the Aalborg PBL model but here referred to as the PO-PBL model to highlight its special characteristics).

The PO-PBL curriculum works with disciplinary content and competences; examples of competences include learning to learn, group work, define and delimit complex problems, use different resources and theories to propose a solution, and critical thinking. In this sense, it is important for higher education pedagogy to improve its understanding of the learning process in this university, because its practice has shown an effective way of introducing and implementing an education suited to current social and economic demands (Kolmos & Holgaard, 2010).

In different documents and academic writings there are general descriptions of AAU's pedagogical practices and a number of learning theoretical concepts that are useful to consider in relation to the PO-PBL approach. However, these writings do not represent a full or unified theorization of PO-PBL as university pedagogy. Of course, there are many descriptions in Danish of the PO-PBL model, its principles and practices, but these descriptions are far from providing a comprehensive philosophy and theory for university pedagogy. Moreover, few of these descriptions have been translated into other languages making it difficult to adapt the model to other contexts. In addition, most of the existing conceptualizations of the model are based on individual-centered theories of learning (Laursen, in Kolmos, A, Fink, F. K., & Krogh, L., 2004, L; Laursen, in Kjær-Rasmussen, L. K., & Jensen, A. A., 2013) which fall short in grasping the potential for learning of the group-based organization of project work and its problem orientation. Therefore, to develop a theoretical framework for the current model, we find it necessary to introduce a socio-cultural perspective of learning to understand the basic elements of PO-PBL. As we will show, this theory provides a background to explain the benefits of key practices used in the Aalborg model.

For this reason, our purpose is to analyze the PO-PBL Aalborg University model implemented in its Faculty of Engineering and Science from a socio-cultural perspective of learning. Then, from this analysis, we intend to generate an alternative view of this model that may be more useful for other universities. To achieve our purpose, this document is structured in four sections. First, we introduce and describe the Project Oriented - Problem Based Learning (PO-PBL) model as a general pedagogic practice in higher education at AAU. In the second section, we present a socio-cultural perspective of learning in the context of university pedagogy. Then, in section three, we use this theoretical perspective to generate an alternative view of the PO-PBL Aalborg model of the Faculty of Engineering and Science. Finally, we discuss different possibilities to make these university educational practices available to other universities, so that more people can build more and probably better competences.

THE PO-PBL AALBORG MODEL: A NEW UNIVERSITY CURRICULUM

Currently, it is clear that higher education is fundamental for present and future generations. The challenge to educate people to be creative, adaptive and with the ability to work in interdisciplinary teams is huge because these competences are new requirements for professional fields. Therefore, the curricula that have traditionally focused on the acquisitions of disciplinary content urgently need to be reviewed. Some institutions have made progress in this sense and currently have educational approaches that can address this challenge.

In Denmark, the context of youth and cultural movements of 1968 in Europe was important for the creation of higher education institutions that challenged the traditional, elitist patterns of academic authority through the concentration of knowledge in the hands of the "professors". Their pedagogical proposal led to a de-centering of the disciplinary knowledge through the construction of innovative curricula and student-centered ways of teaching in many professional fields. This was how the fourth and fifth Danish universities were founded: Roskilde University (1973) and Aalborg University (1974); both developed the Project Organized – Problem Based Learning model as a strategy to carry out a revolution in higher education (Vithal, Christiansen, & Skovsmose, 1995).

Aalborg University established its PO-PBL model simultaneously in its three faculties —The Humanities, Social Sciences, and Engineering and Natural Sciences— covering all their fields of study. Then, since 2010, the new Faculty of Medicine also adopted and adjusted the model to its programs. Vithal, Christiansen and Skovsmose (1995, p. 200) present a concise description of the Aalborg University model:

> All students work in project groups which function as work units. The groups normally consist of four to five students from a specific study programme. A supervisor is assigned to each project group. Each semester, the students prepare a project report, whose topic is within a given framework. Project topics may be suggested either by students or by teachers. The project work generally takes 50% of

> the study time and another 50% is devoted to courses. Some of the courses are related to the topics of the semester and others serve as direct support to the project work. At the end of each semester, the project is presented in a written report, which is evaluated orally by the supervisor of the group and an internal or external examiner.

In this project, the students have to choose a general subject to work on from range of proposals provided by the group of supervisors; these subjects reflect the principal issues considered in the semester curriculum. The learning process begins when the students formulate a problem on this subject, and continues with the process in which they try to solve it (Kolmos et al., 2004; Ravn, 2008; Vithal et al., 1995). This long-term process (usually for a semester) working with self-defined problems gives the opportunity for students to integrate concrete experiences and empirical research with the theoretical elements of their study. In this way, the students are expected to attain a deeper comprehension of the mandatory topics of the curriculum and to gain experience on some selected and complex problems. This experience is the ground for learning to re-contextualize forms of knowing and acting in fields that are new or related to their subject in a more proficient manner (Ravn & Valero, 2010).

However, the university started developing on the basis of a number of theoretical principles, which have found their way to a pragmatic development (Kolmos, Fink, & Krogh, 2004). In 2010, Barge suggests that the diverse practices generated in the different fields of study have common elements that place them under the umbrella of a general model (Barge, 2010). However, the understanding of these theoretical principles may vary in each department, and these differences will change aspects of the programmes.

For example, Vithal, Christiansen and Skovsmose (1995) present and discuss four core principles on the PO-PBL model: the problem-orientation, the interdisciplinarity, the participant-directed studies, and the exemplarity principle. Kolmos, Fink and Krogh (2004) consider that other principles are learning by doing, learning using own experience, working with others, strong relation between theory and practice, interdisciplinarity and exemplarity. It is not our purpose here to discuss which are the proper principles to describe the model, but rather we intend to enlighten the meaning of these principles using a socio-cultural perspective of learning to analyze the PO-PBL model, in particular in relation to the Faculty of Science and Engineering. For this purpose, we chose the view of Vithal, Christiansen and Skovsmose's on the PO-PBL for our analytical exercise. Further on, we will present their conceptualization of the PO-PBL principles, but first we introduce our specific perspective from the socio-cultural view.

THE SOCIO-CULTURAL PERSPECTIVE OF LEARNING

The socio-cultural perspective of learning is a broad conceptual field that addresses human learning: It is “a cluster of theories that share a premise that learners and social organizations exist in recursive relation to one another” (Beach, 1999, p. 104). A common origin for many of these theories is Vygotsky’s cultural-historical psychology (1978, 1986) about the origins of human thinking being inseparable from social and cultural praxis. This perspective of learning suggests that knowledge is a process resulting from negotiation of meaning, coming from the social activity of individuals, and encompassed by a cultural framework (Radford, 1997, 2008). In this sense, disciplinary knowledge is historically generated during the course of the disciplinary activity of individuals, and fixed patterns of reflexive human activity mediated by artifacts: objects, instruments, sign systems, etc. (Radford, 2008), in institutional settings. For higher education this implies that the knowledge and forms of knowing developed by university staff in their research, historically and in the present, constitute the practice within which individual meaning is negotiated in relation to the other participants in the practice and with the help of its artifacts.

In consequence, learning occurs as a social process —praxis cogitans— through which students become progressively conversant with cultural forms of thinking, being and reflecting mediated by language, interaction, signs and artifacts (Radford, 2008), and the connection between knowing and being is fundamental. In this sense, it is the elaboration that the student does of a reflection; this reflection is defined as a communal and active relationship with the student’s cultural-historical reality (Radford 2008). This implies that learning is not considered an individual and isolated enterprise; it is distributed and transformed among members of the community with diverse expertise and through their action within it (Lave & Wenger, 1991; Wenger, 1998). Also, in a specific activity, the participants’ roles could be complementary or with some leading and others supporting or actively observing, and may involve disagreements about who is responsible for what aspects of the endeavor (Rogoff, 1994) .

In particular, Leach and Scott (2003) argue that adopting a socio-cultural perspective on science education implies viewing science, science education, and research on science education as human social activities conducted within institutional and cultural frameworks. Radford (2008) shows that it means seeing the scientific study of the world itself as inseparable from the social organization of the scientists’ activities. These ideas involve rethinking the ways of learning and teaching science at all educational levels, particularly at the university level.

As universities and professional work environments have very different cultures, activities, discourse and affordances, there is naturally some disconnection between the knowledge, skills and attitudes developed in traditional university courses and the work of different professions (Sutherland & Markauskaite, 2012). On one hand, Northedge (2002) argues that academic communities constitute a special case in that they are spatially and temporally dispersed, with core practices enacted largely in writing textual 'fora' such as journals. On the other hand, the way members of the profession interact and the way they use language, tools and sign systems is particular for each career. Closing this gap and preparing new graduates for a transition into the work place are important challenges for professional education. Part of this preparation involves the development of a professional identity: understanding themselves as professionals and their interactions within this professional world (Dahlgren, Hult, Dahlgren, Segerstad, & Johansson, 2006; Sutherland & Markauskaite, 2012). In this sense, the insights and skills required for learners to become members of these communities are as much social and cultural, as intellectual and content-oriented.

From this sociocultural perspective, authentic learning experiences allow students to begin to engage with some of the routines, rituals and conventions of their profession, so that as part of their education they also acquire some of the values, skills and knowledge associated with their professional practice (Sutherland, Scanlon, & Sperring, 2005). An important development of this vision has been carried out in teacher education programs because there is a high demand on bridging studies at the university with the preparation for exercising the teaching profession (Sutherland et al., 2005; Sutherland & Markauskaite, 2012).

At Aalborg University, in the last decade, some inspirations from the socio-cultural learning approaches, especially Wenger's concept of *community of practice* (Lave & Wenger, 1991; Wenger, 1998), have been used to describe specific processes in the PO-PBL model. For Wenger (1998), the term community of practice comes from the idea of learning as social participation, and it refers to the process of social learning that occurs when people who have a shared practice collaborate over an extended period to share ideas, values, beliefs, languages, and ways of doing things. Learning involves travelling along a trajectory from the periphery to the center of this community and becoming a full member with legitimate participation in it. For example, Du (2006) analyzes how both male and female students develop their engineering identities in the process of studying engineering in a PO-PBL learning environment. In the field of human-centered informatics Dirckinck-Holmfeld and collaborators (2004) interpret the design of a master's program through PO-PBL pedagogy using the concept of communities of practice. These theoretical tools provide insights for designing learning communities, and cultivating them (Dirckinck-Holmfeld et al., 2004). Coto and Dirckinck-Holmfeld (2008) used these ideas in a research project to facilitate communities of practice among university staff as part of their pedagogical professional development, addressing the introduction of information and communication technology (ICT) and PO-PBL approaches into teaching and learning at the university level (Coto Chotto, 2010).

However, in our perspective, the possibilities for interpreting and re-signifying education practices at Aalborg University from the perspectives offered by the socio-cultural approach can be extended. In the following section, we will present a broader analysis from the socio-cultural learning perspective of key elements in the PO-PBL model as it is used at the Faculty of Engineering and Science.

LOOKING AT THE PO-PBL MODEL WITH SOCIO-CULTURAL LENSES

As we previously presented, there are many different descriptions of the learning principles under the PO-PBL model, but here we will use three theoretical dimensions from the socio-cultural theory to analyze it: the problem in a project as a real context for *praxis cogitans*; interactional processes and mediation as ways of learning; thinking, reflecting and becoming as a continuous progressive re-contextualizing of knowledge and competence. Although these dimensions are not separated from each other, for analytical purposes we will work on each of them separately. Our analytical strategy combines discussions on each principle and illustrations of their operation in particular cases of a group of students and their PO-PBL practice.

The Problem in a Project as a real context for praxis cogitans

The second principle for Vithal, Christiansen and Skovsmose (1995) is the *interdisciplinarity*. This concept is derived for the problem-oriented studies because the most interesting problems usually require drawing from different disciplines. Additionally, interdisciplinarity promotes an integration of ways of thinking, doing and being in different disciplines, which are isolated in the traditional approach to university teaching. This integration fosters a deeper understanding of these practices, an additional ability to move in various disciplines and offers different perspectives within the disciplines.

Vithal, Christiansen and Skovsmose (1995) argue that the idea of problem-oriented work in the PO-PBL model is the most important element of project work as stated by one of the key figures in the Danish development of the model, Knud Illeris

> *The central feature of problem-centered instruction is that it does not originate in the subjects themselves - which have been developed through tradition, the basis of which is far in the past and dependent upon societal conditions which long since have vanished - but in currently relevant problems which are addressed using knowledge, methods, and theories from different disciplines to the extent they are relevant to the problems. (Illeris, 1974, p. 81, Vithal, Christiansen and Skovsmose's translation).*

This idea is completely in line with the socio-cultural perspective, because a problem only exists in a social-historical context and it expresses contrasts or conflicts in a specific culture or view of the world. For example, Leach and Scott (2003) show that the development of scientific knowledge (which involves the resolution of problems and the generation of new ones) is not only constrained by empirical data, but also socially validated by the scientific community. When the students choose to study real phenomena of their own interest, and make all final decisions according to the resources and materials to be used to develop the study, they are in a similar position to that of the scientists (Roth, 1995).

In the Aalborg PO-PBL the project and the problem are inseparable. Vithal, Christiansen and Skovsmose express that the problem-oriented pedagogy of the PO-PBL begins with the students formulating a problem. However, it is often not possible to formulate a research problem early in the project. Instead, the original problem must be refined through continuous studies until it is a functional part of the research process, and an important part of the project work fulfils this purpose. Thus, in the Danish version of the PO-PBL model the problem and its solution develop as two aspects of the same process, and in the end, when the problem has been accurately formulated, it is because it has been solved (Olsen, 1993, translated from Danish by Vithal, Cristiansen and Skovsmose).

In opposition to a traditional science or engineering class that works on relatively well-defined problems and where the students construct specific solution strategies, students in the PO-PBL model are motivated to think more about the questions than about the answers (Kolmos, 2004). It is important because recognizing emergent problems in rich problem-solving contexts is a crucial skill in scientific inquiring (Roth, 1995).

Furthermore, the learning process is organized around the project. The project is a complex effort in groups: students should be organized to define a *problem* and try to find a solution within the specific purposes of the semester. This involves making decisions in groups for different areas of the project that must be completed at a deadline determined in advance; this includes collecting information, meeting with the supervisor, defining procedures, writing the report, etc.

Another very important part of the project is that it must be developed within a particular social context and considering ethics. The students are not only learning to pass evaluations and progress in their careers, but to be active members of the society and participate in work environments outside the university.

From a socio-cultural perspective, the Aalborg duality of problem-project reflects the activity in scientific and engineering environments. In many cases, the boundaries between science and engineering are unclear, so what happens in science might as well be used in engineering and what happens in engineering could inspire the development of science. For scientists, science progresses by means of research projects. Usually, they are long-term projects and involve small projects on one area of science specialization and few people –normally Master's and PhD students- working in them. Roth (1995) shows that to actually learn science, students should experience some aspects common to scientific activities such as:

identifying problems and solutions and testing these solutions; designing their own procedures and data analyses; formulating new questions; and experiencing the social nature of scientific work.

Mills and Treagust (2003) summarize that the term "project" is universally used in engineering practice as a "unit of work", usually defined on the basis of the client, and almost every task undertaken in the professional practice by an engineer will be in relation to a project. Projects may vary on time scales and complexity, but all will relate in some way to the fundamental theories and techniques of an engineer's discipline specialization. Successful completion of projects in practice requires the integration of all areas of an engineer's undergraduate training.

In consequence, the problems in the PO-PBL projects can be conceived as an actual social practice, consistent with key elements in the scientific or engineering activity, and an opportunity to learn these disciplines in their complexity. Here, activity refers to processes or events that are part of a socially defined division of labour (Leont'ev, 1978; Radford & Roth, 2011; Radford, 2008; Roth & Lee, 2004; Roth & Radford, 2010); i.e. researching to build scientific knowledge, studying to get a degree. Each of these activities involves different rules, tools and social interactions. Activities are general level events: they are carried out by means of concrete goal-directed actions. The object of an activity can only be attained through actions aimed at specific goals. Activity and actions stand in a mutually constitutive relation: Actions presuppose and draw their sense from the activity that they concretely develop; but activity exists only because of the concrete actions. As a result of this dialectic, the same action has a very different sense when a different activity is being carried out. A good example is the sense of mathematical equations and the associated mathematical actions, which may substantially vary between scientists and engineers or technicians (Brown, Collins, & Duguid, 1989; Roth, 2009).

In the PO-PBL Aalborg vision, in each semester – starting in the first year – the students develop an in-depth study of a few core disciplinary contents through their specific project-problems and have time to think and reflect about how to do it in their profession. Vithal, Christiansen and Skovsmose (1995) identify this principle as *exemplarity*, originated in Oskar Negt's writings (1964); he suggests that it is possible to understand basic structural and political features of society by concentrating on specific social events, which comprise an entry point to a general understanding. In the PO-PBL model, this argument is used to organise the curriculum in relation to authentic problems. These problems have the potential to provide an exemplary understanding of the general problem and by researching them the students will have a deeper theoretical insight. In this sense, a long list of concepts of disciplinary content is not the core of the curriculum. Instead, the curriculum explicitly aims at developing more complex learning objectives; moreover, it supports the relation between the theory and its disciplinary practice.

To illustrate this, we will tell the story of a project developed in 2011 for a seventh semester group of Biomedical Engineering students. The aim of this semester was to collect physiological data and setup an experiment; the written report had two parts: an article and a worksheet report. This group chose to work on a project based on the “Brain Computer Interface (BCI)” technology, and they intended to generate their own data analysis protocol. BCI is a growing research field because the electrical activity generated by ensembles of cortical neurons can be employed directly to control a robotic manipulator (Lebedev & Nicolelis, 2006). The experiments were hard to do because they require safety standards to be performed on human subjects. In a first stage, the group collected different experimental protocols that could be carried out in the university laboratory. They chose a protocol in which a soft magnetic field stimulates some brain areas and generates electrical activity that may be evident in muscular movements. Simultaneously, by working in their project they also learned about cortical neurons, magnetic fields and their interaction with neurons, and ethical aspects on this kind of experiments.

In a second phase, the students learned how to follow the protocols and sought external volunteer subjects to develop the experiments. The measurements were quite risky because the range of response is small and it is difficult to make a difference between the electrical signals generated by the nerves or by the external field. Thus, the volunteers had to attend six or seven sessions: the first three were to get used to the protocol and the rest to actually take measurements. In addition, the students studied different types of analyses to consider if they could produce divergent results, and developed their own protocol. Next, the group analyzed the data using two protocols: their own and one from their literature review. Finally, they wrote down the documents related to problem-project and project report. The article had the usual structure of a scientific paper (20 pages), but the worksheet report included a discussion about the choice of the data analysis protocol, and a deep reflexion on ethical considerations in the conduction of the experiments (70-80 pages).

This experience shows different achievements; first, the students were able to conduct actual scientific activities; second, the core of learning got the students involved on this activity beyond simply covering disciplinary contents or specific kinds of protocols. In this sense, the problem in the project can be seen as an authentic learning experience where the students begun to engage in some of the routines, activities, discussions and conventions of their profession.

Next, we will focus on how language, artifacts and interaction mediate learning.

Interactional Processes and Mediation as forms of learning

As we presented earlier on, the PO-PBL model is a student-centered view of teaching. It implies a different relationship between teachers and students. In the project, most of the learning processes take place in groups or teams where students continuously discuss, negotiate and learn from each other in their project work processes. At the same time, the teachers play the role of supervisors and in the Danish context their function is to facilitate the learning process (Kolmos, Du, Holgaard, & Jensen, 2008). This role is complex because the teachers are not the "project leaders" that direct the students; they better resemble a more knowledgeable person that aids a less experienced novice in the integration of professional knowledge and actions. It suggests a more balanced power relationship between teachers and students and a more open-minded teacher that helps the students to cope with insecurity and guides them in start-up and closing processes more than being the expert that teaches the disciplinary content.

Vithal, Christiansen and Skovsmose (1995) show that *participant-directed* studies were born as a reaction against the power of the professors. Therefore, it does not mean that the students are alone or in absolute control; the supervisors are also participants and their experience is fundamental for the process. Furthermore, the group work encourages discussions that are helpful for problem clarification, analysis, synthesis and critical evaluation of the work; it also encompasses the meta-learning process and psychological support that students can provide to each other.

In addition, the projects are developed in appropriate spaces: every group has a room with all they need in order to create a good working environment, access to laboratories where experiments can be carried out if it is necessary, the library and on-line resources.
According to the socio-cultural theory, learning is mediated by interaction, language and artifacts. Both types of interactions – students/students and students/teacher – have a central role in the learning process; nevertheless, the use of laboratories, books, articles, etc. constitutes an interaction with the artifacts in these disciplines or professions that are not divorced from the interactions between people. To develop this idea we can use the example in the previous section, presenting a meeting between the supervisor and the group in the laboratory. The regular place for meetings was the group room, but considering the goal of the semester, a meeting in the laboratory was the opportunity for a more contextualized disciplinary contact with the supervisor.

The students had studied the techniques of data collection and this particular meeting was intended to check the ability of the group to perform the experiments correctly and safely; if that was accomplished, the group was ready to continue with the experiments on external volunteers. The meeting took place as role-play where the supervisor acted as a "new volunteer" for a set of experiments and the students were the "experts" that explained and introduced the volunteer into this practice. They worked in couples that were switched during the experience, but the whole group was keeping up with all the proceedings. A student began to tell the volunteer that they would be explaining what they were doing and what she could feel, and that they would ask a lot of questions to make sure she would be fine. And, if she had any questions or felt uncomfortable in any way, she should tell them.

Next, a couple placed some electrodes on specific parts of the body (fig 1a) and then turned on the machine that generated the magnetic field (fig 1b). The students described the procedure all the time and the supervisor took different roles: first, as the subject of experiments, and therefore did not comment on the experimental work; she asked more about her body's reactions and sensations. Secondly, as the knowledgeable advisor who gave suggestions on what could be improved. For example, she commented on the pressure applied on the head, which was too hard and the students needed to keep asking about it to guarantee that the volunteer was comfortable. Third, as the examiner, who checked the knowledge of the students by asking them what they would do in case the subject fainted. Meanwhile, the other couple verified on the computer that the system was collecting data properly.

At one point one electrode was not in the right place; one of the students working with the computer noticed it and made an intervention. He adopted the position of the volunteer and told his partner where the electrode should be placed (fig 2a, 2b). The supervisor asked what would happen if an electrode was not well located, and the student that made the intervention answered that the system would not be able to collect the actual muscular response and explained why this would be detrimental to the experiment. Then, the students went back to their original task. On this dynamic, the students developed a complete set of actions, and the supervisor was able to switch between the described positions depending on the moment. There were short suggestions naturally interwoven in the process, for instance, with an open formulation: "have you thought about …" to reflect with them about a particular knowledge; "when you do this, do you then…" - an example of supervision aimed at stressing that they are observant in relation to the subject in the experiment.

Figure Pictures of the group work session in the lab. **1a.** The entire group with the supervisor as a new volunteer for the experiment. **1b.** The students perform the planned experimental protocol. **2a-2b.** The learning process is mediated by language: oral and body expressions of the activity that is learned.

In this example, the learners become effective participants in this engineering practice through the use of a specialized discourse, artifacts and procedures. We want to note how the interaction with the lab equipment (artifacts and tools) is constant and can often be considered as tacit. However, the activity will be impossible to do outside these concrete conditions. Much of the conversation happens around the expected use of these engineering tools.

From the socio-cultural theory, students fully appropriate the way a discourse works only through using it to produce meaning of their own (Lemke, 1990). To become a speaker of a discourse is to acquire a new identity as a member of that community and it is critical for the learning process. The teacher is a speaker of the specialized discourse and through tasks and written documents guides the students in the practices of the discourse. To achieve this, Northedge (2002) argues that the first step is that the teacher must be able to go outside the specialized discourse and engage in a dialogue with the students within the terms of a familiar discourse. Then, having initiated a flow of meaning the students will encounter documents, debates, issues and voices that help them develop a sense of the character of the discourse community: how they speak and argue; their core purposes and values; their preoccupations. Finally, through participation they begin to see the force of the theoretical analysis embedded in the discourse. In our example, great part of the supervisor's role was discursive, encouraging new discussions, meanings and reflections about the scientific knowledge and its production with the aim of helping students to appropriate these practices.

However, for Vygotsky (1986) knowledge is collaboratively constructed between individuals on the Zone of Proximal Development (ZPD)

> *The ZPD is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers* (Vygotsky, 1986, p.86).

This definition has been traditionally accepted in educational approaches focused on children, under the assumption that it is only the learner who learns.

Moving further, Roth (1995) understands the ZPD as a construction zone for sharing knowledge or meaning. From this shared construction zone, knowledge can be appropriated by individuals and included in their personal repertories; this process includes both aspects: the situation –culture, its artifacts, tools and language- and the individual. Roth and Radford (2010) expound that ZPD is an interactional achievement that allows all participants to become teachers and learners. From their analysis, each word in the ZPD is the product of social interaction and is mated with a social evaluation. This evaluative role of each utterance is the reason why the teacher can know that the student has or has not understood, and the student can know that he has or has not provided the appropriate response. Who is in the know and who learns is a product *interactionally* and contingently achieved as participants engage with each other. This symmetric space for interaction introduces the idea of *shared understanding* as a social-knowledge that results from this collaboration (Roth & Radford, 2010; Roth, 1995). In addition, far from being a sole opportunity for the student to learn (e.g., subject matter), the *zone of proximal development* is also an opportunity for the teacher to learn too (e.g., reconfigure knowledge in the new setting of the students' project, subject matter pedagogy or subject matter outside the key expertise area but brought into the project by the students). Our example can be read from these same ideas and this perspective opens the possibility to a completely different view on the university teachers' activity and learning not only due to their relevance in the development of the students' voice as we previously suggested, but also because of their own participation as members of the pedagogical community.

Thinking, reflecting and becoming as continuous progressive recontextualizing

Many of the educational researchers who developed the PO-PBL model consider that reflection is fundamental to introduce and highlight the quality, depth and relevance of what is learned (Kolmos et al., 2004). In addition, this reflection has been interpreted as a core part for the students to develop the skill of applying knowledge to new situations. We want to carefully analyze this idea.

Roth (2009) introduces the idea that Schön's notion of reflection-in-action and reflection-on-action can be integrated into a socio-cultural perspective of learning. For Roth, during activity, reflection-in-action is designed to facilitate the interactions in the ZPD: both students and teacher as reflective-practitioners engage together in practical action and talk. As we previously discussed, this dialogue introduces the student to the culture of which both are members. Moreover, Radford (2008) expounds that the reflexive nature of thinking means that the individual's thinking is neither the simple assimilation of an external reality nor a construction. The idea that thinking is a re-flection implies a dialectical movement between a historically and culturally constituted reality and an individual who refracts it (as well as modifies it) according to his/her own subjective interpretations, actions and feelings. In this sense thinking and reflecting are forms of participation in a specific culture.

From this perspective the subjects in the activity systems not only produce outcomes but also produce and reproduce themselves (Roth, 2009). Learning is not just about getting to know; learning is also about becoming someone (Radford, 2008). As a consequence, a PO-PBL student who participates in long-term scientific or engineering projects learns the rules, tools and social interactions, and gradually gains experience in what it means to be a scientist or an engineer with specialized ways of thinking and reflecting that are accepted as valid by other community members. In other words, students are becoming more expert, and legitimate participants of the practices of their professors and lecturers. They are gaining a sense of professional identity while being students as they acquire and participate in the forms of knowing of their professors.

As Roth (2009) shows, it is important to be aware that activity systems offer resources to those who explore and implement the possibilities of these resources in different ways. It implies that although students work in the same project-context, the practices of each group differ, and each individual implements the available possibilities in different but equally legitimate ways. Ravn (2008) exemplifies this in a concrete practice in a second semester project when he presents different group projects developed to show how these contribute to close the gap between formalism and application for a given scenario involving mathematics. For our purpose, we will present two of these projects:

> The first group studied the spread of bird flu in a concrete context in Denmark, which cannot be interpreted in mathematical terms without information from other scientific perspectives as for example biomedical aspects about the flu: its level of contagion, forms of treatment and their effectiveness. Students not only learned the mathematical content in solving a differential equation, but also how different constants in the mathematical equations critically affect the results in a complex application setting and reliability topics regarding the mathematical content.

> A second group studied a new technique of DNA-micro arrays for classification of certain illnesses. The students did some biological research to clarify the concept of a gene, visited the hospital where they had started to use the technique, and established a background for working with mathematical content such as different types of measures and cluster analyses. The students found that using different segments to measure or different types of cluster analyses produced divergent results on the same dataset. They learned that they must choose among several methodological options, depending on the problem to be solved.

In both cases the students had the opportunity to reflect upon the validity of a mathematical model and their connection with the context and empirical data. Thus, they learned mathematical theory in a real framework, and the practices in a concrete context helped them to see the complexity of doing mathematics and making decisions about appropriate theories or methodologies. For many engineering students this level of depth in the mathematical theory may not seem necessary. Rather than being able to apply the theory, they become competent in generating a *suitable knowledge assemblage* where mathematical language and tools, together with the tools from the other fields involved, provided ways of operating concretely in the contexts of their projects to respond to the problem guiding their investigation. The creation of suitable knowledge assemblages is a central competence as an engineer. In our perspective, these competences that students develop on the PO-PBL model are expressions of valid participation in concrete communities outside of the university.

For the Danish teachers it is clear that the competences gained, for example in relation to *suitable knowledge assemblage*, reach different levels in different semesters. However, upon graduation, it is expected that all students can use their experience to solve new problems outside the university. This can be interpreted as a transfer, and it is related to the idea of applying knowledge to new situations. Beach (1999) presents transfer as a problematic concept from a socio-cultural perspective of learning because transfer suggests that people carry knowledge and skills from one task or situation to another without the context, and assumes that the tasks across which transfer occurs remain unchanged during transference. These ideas about transfer do not consider that transformation across time and social situations is not a function of the individual or the situation, but rather of their relation. In this sense, generalization defined as continuity and transformation of knowledge, skill and identity across various forms of social organization, involves multiple interrelated processes rather than a single general procedure (Beach, 1999; Lobato, 2006). Van Oers (1998) provides a wonderful description of how generalization can be obtained by the embedding of context in other contexts:

> *This is called an activity of continuous progressive recontextualizing. The development toward more abstract forms of activities is one of the results of continuous progressive recontextualizing. On the basis of our observations, we have reason to assume that it is certainly not typically characterized by decontextualization*

> *or disembeddedness. Rather, the important thing was the possibility for the actors to create a new sign-based context related to their previous activities that made their new activity meaningful (p.141)*

We can observe the same process in the PO-PBL students: they engage in successive projects throughout their undergraduate studies with different disciplinary tasks and contexts. Part of the new semester is establishing a new group, and this implies negotiating the meaning of not only the new disciplinary content, but also of some competences as working in a group or managing a project. In the next project, each student has the possibility to recontextualize his/her previous activities and identities to engage in a completely new project and experience. In the long-term, the students learn to do a continuous progressive recontextualizing of their participation and become a full member with autonomous participation of this community. We can say that this flexibility in the participation is a powerful competence that will help new graduates an easy transition into the work environment.

CONCLUDING REMARKS

Let us conclude by revising our vision of learning. The underlying position is that higher competences are constituted in the routines, rituals, conventions and discourses exchanged with communities of specialists, and the purpose of studying a profession is to acquire mastery in these specialists' practice and competences that allow being a member of this community.

Looking at the PO-PBL Aalborg model from this perspective allows the integration of many of its principles and its theorization as a university practice. For example, the variability in the PO-PBL model is only one of the natural characteristics of these activity systems that explore and implement the possibilities of the resources in different ways. In this sense, the diversity of concrete practices offers a wider scope of possibilities to other institutions that may be interested in this model.

By analyzing the PO-PBL model in the faculty of sciences and engineering with a socio-cultural approach, we identified that working on their projects the students participate in practices that are closer to those of scientists and engineers by thinking about concrete and contextualized problems to which they intend to find a possible solution. In this way, the gap between the theory, tools and language, and their knowledge and participation in routines and ways of interaction of their discipline is smaller than in other university approaches.

What is most interesting in universities as institutions is that thinking of the ZDP as a space of symmetrical interaction between teachers and students that participate in these projects that are also new for teachers, they can learn not only pedagogical aspects but also about contextualization of their discipline or inter-disciplinary connections. This enables teachers to use their own competences not only in their research groups but also in their teaching time, which is a unique proposal in this field.

In this sense, there is an entire research line that deserves exploration, which could start by refining the theorization that we propose and continue with other dimensions like studies on how the participants interact in their groups during projects or the development of the role of teacher-supervisor in this model.

Finally, for other universities this analysis intended to identify the why's –beyond the how's – the PO-PBL model may be a source of inspiration for more enriching and innovative pedagogical proposals for both students and teachers. However, we are consequent with our position that there is no easy transference of the experience developed in Aalborg University to other institutions, but it is possible to re-contextualize the main ideas to look for possible practices that respond to the challenges and needs of these new contexts.

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