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A Problem and Project-Based Learning (PBL) Approach to Motivate Group Creativity in Engineering Education*

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In this paper, we explore how engineering students are motivated to develop group creativity in a Problem and Project-Based Learning (PBL) environment. Theoretically, we take a social cultural approach to group creativity and emphasize the influences of a learning environment on student motivation in group creativity development. Empirically, a case study was carried out on a student satellite project in the Department of Electronic System at Aalborg University in Denmark, by using qualitative methods including interviews and observation. The findings show that student motivation is stimulated in multiple ways in a PBL environment, such as formal and informal group discussions, regular supervisor meetings and sharing leadership. Furthermore, factors such as common goals, support of peers and openness stimulate motivation. However, the students think that a time schedule is a barrier to group creativity. Thus, the supervisors are encouraged to be more aware of the complex relationships between student, teacher and task and the student response.

Keywords: group creativity; motivation; problem and project-based learning; engineering education

1. Introduction

Significant changes of society have brought new understandings of engineering [1]. For example, engineering has been defined as being 'naturally a cooperative enterprise, done by teams of people with different backgrounds, abilities, and responsibilities. The skills associated with successful teamwork—listening, understanding others' viewpoints, leading without dominating, delegating and accepting responsibility, and dealing with the interpersonal conflicts that inevitably arise—may be more vital to the success of a project than technical expertise' [2]. Future engineers are expected to be competent in teamwork and engineering education has to pay more attention to group creativity.

Group creativity is generally considered to involve the generation of novel and useful ideas in teamwork, which has gained widespread acceptance [3]. During the past years, researchers working on frameworks of social–cultural theories have emphasized the shaping roles of environment on creativity [4], especially on group-level creativity [3, 5–6]. In the educational context, inspired by the social–cultural approach to creativity and learning, recent studies indicate some essential conditions stimulating motivation of creativity that should be provided by the learning environment [7–8].

Among the strategies discussed, Problem and Project-Based Learning (PBL) has been increasingly recognized as one instructional model that may develop creativity [9–11]. Discussions have examined the impact of PBL on various components of creativity, such as teamwork, problem-solving skills and critical thinking [11]. However, little attention has been paid to environmental influences on motivation of group creativity. We focus on a research question in this paper: how engineering students are motivated to develop group creativity in a PBL environment?

Many studies have suggested that qualitative case studies are well-established and frequently used methods of research for exploring creative collaboration situations [12]. Research methods such as interviews and observation have been used broadly, since they are suggested as useful ways to examine phenomena in a natural context and reveal diverse perspectives [13]. This drives us to use a mixture of methods of interviews and observation to carry out a case study on a student satellite project in the Department of Electronic System at Aalborg University in Denmark. So this research contributes to both theory and practice in fostering creative engineers in the PBL environment.

2. Group creativity, motivation and PBL environment in engineering education

2.1 A Social–cultural perspective to creativity and group creativity

Given the most widely acceptable definition of creativity, the literature has emphasized two common characteristics of creativity: newness or uniqueness and value or utility [4, 14–15]. We can simply see creativity as involving the generation of novel and useful ideas [7]. Recently, with new insights into the nature of creativity, social approaches have been proposed to provide power-

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ful evidence of the shaping role of the context in which creativity takes place [14]. As pointed out by Sternberg [4], the development of scientific thinking about creativity has followed a particular trajectory: going from an early emphasis upon isolated individuals and their internal traits and capabilities, followed by a developing a focus on the interaction between individuals and the environment.

This trend has called for the increasing studies on group creativity [3, 16], which is generally considered to involve the generation of novel and useful ideas in teamwork [3]. It can occur through interactions among friends or colleagues or in more structured groups such as scientific research laboratories and research and development teams [3]. However, we cannot think the group's creativity is a simple sum of the creative talents of the individual members [16]. Existing discussions have regarded group creativity as a collaborative process beyond the individual by focusing on interpersonal interactions [3, 16], that demonstrate collaboration involves an intricate blending of skills, temperaments, effort and sometimes personalities to realize a shared vision of something new and useful [12]; or as emerging through dialogue and 'being in relationship' that is seen as the dynamic interaction based on studies of constructivism [7].

Although the new ideas origin from inspired minds, we think creativity or group creativity basically is a social–cultural conception. This point underpins the researchers need to understand the social–cultural values and practices of the particular setting that might foster creativity.

2.2 Group Creativity in learning process and learning environment

Since the 1990s, research in education has focused more on the creativity of all learners, rather than just the gifted and talented [17]. This is due to awareness that everyone can be creative and everyone's creativity can be encouraged through an educational interference [18]. From the social–cultural perspective, there are an increasing number of studies suggesting that learning and creativity go hand in hand [7]. As Eteläpelto and Lahti [6] describe it, in successful collaborative settings, participants build on each other's ideas in order to reach an understanding that was not available to any of the participants initially. They must also enter into critical and constructive negotiation of each other's suggestions; well-grounded arguments and counter-arguments need to be shared and critically evaluated through collective discussion. These conditions are similar to those needed for collaboration in creative endeavours. However, those conditions indicate that

(1) the learning process is acquired to offer enough opportunities for ideas exchange and knowledge construction;
(2) learners are expected to have strong motivation to deeply engage in the learning process that is stimulated by the learning environment.

The two points will be discussed in the following section.

2.2.1 Group creativity and knowledge in the learning process

As mentioned, social approaches suggest that learning is regarded as collaborative meaning—making acquisition of knowledge a construction rather than knowledge acquisition [19–20]. So the learner is seen as transforming as well as being transformed when participating in communities of practice; knowledge is not a fixed and stable commodity, but rather co-constructed by people in interaction [6]—an observation that drives this paper to discuss group creativity in a learning process by focusing on knowledge conversations.

Most discussions bridge learning processes and creativity by imparting knowledge [7–8, 21]. According to Craft [7], we can see creativity as, effectively, offering students opportunities to shape new knowledge, for 'when we learn something new, we are making new connections between ideas and making sense of them for ourselves and we are constructing knowledge; in this sense we could perhaps describe what we are doing as being creative' [*ibid* 7, p. 52]. Furthermore, studies on innovative knowledge communities [22] have emphasized learning as new knowledge acquired by a creative process using collaborative efforts. However, new knowledge creation cannot occur without some understanding of what already exists, and without opportunities to connect with it and take it to a new place [7]. So learning needs the discussions involving tacit knowledge and explicit knowledge in social practice. As Wenger [19, p. 47] describes, 'social practice' includes 'both the explicit and the tacit . . . our communities of practice are places where we develop, negotiate, and share them'. Accordingly, the level of collective knowledge certainly increases, but that of individual knowledge and expertise diminishes, at least relatively [22].

In one word, creativity and learning can be triggered by each other when groups of people are exploring new meanings. Furthermore, the previous work indicates two points we should focus on:

(1) a concept needs to be built, which encompasses knowledge conversations both between explicit and tacit levels and between individual and collective levels;
(2) learning happens in social practice, where can

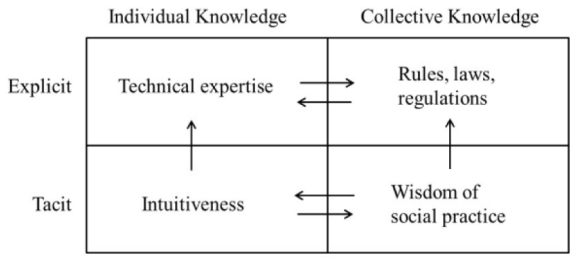

Fig. 1. Baumard's model of four types of knowledge.

offer the context of the knowledge conversations.

The two points lead us to discuss an influential model developed by Baumard [23] (Figure 1).

As shown in Fig. 1, there are four types of knowledge in Baumard's model. First, the knowledge that is explicit and individual, techniques that allow us to counter nets and traps. Second, the collective and profound knowledge of a terrain, environment, rules and laws we achieve. Third, a body of knowledge that is tacit and collective, which is of the unspoken, of the invisible structure of a practice. Fourth and last, a body of knowledge that is tacit and individual. Tacit expertise is complemented by 'hard' technical knowledge—a sort of inimitable technical skills. These four forms of knowledge are indissociable.

Baumard's model is quoted here because it does make sense in collaborative group settings and aligns with the two points that we generalize above. Furthermore, the fundamental hypothesis in Baumard's model is that knowledge contains two basic types of explicit and tacit expertise within the groups or organizations, while the complex mix process is demonstrated by the conversions between the two types, in a back and forth exchange between individual and collective levels [8]. Relating this model to the common idea that creativity and learning go hand in hand, we develop Baumard's model by showing 'where or how group creativity happens' in the learning process, which could be a 'spiral' growing from the junction of the four types of knowledge (Figure 2).

In the developed model in Fig. 2, group creativity

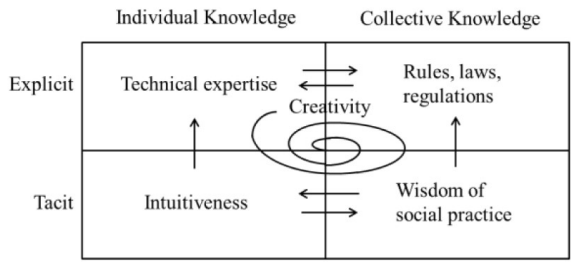

Fig. 2. Creativity and learning in groups.

in the learning process is dynamic but not linear. It contains uninterrupted knowledge conversations between different knowledge types. So the students need a learning environment that provides conditions of both individual reflection and common engagement to support interactions between individual creativity and group creativity. For the participants in the groups, it should be a reflective and iterative learning process. Thus, time must be allowed for the creative process that includes collecting a wealth of information and understanding surrounding a given problem, to incubate the idea or relax and 'back burner' the problem so that the student can have unconscious thought dedicated to discovery of a solution, a working solution or solutions, and finally to test discovered solutions.

Therefore, the concept of back burnering an idea is essential when we discuss the process of individual reflection and common engagement in group learning settings. The 'spiral' of creativity roots in and grows from such a process, as shown in Fig. 2. However, this brings us some further considerations, such as how this 'spiral' can be started, how it can be developed continuously and how it can keep the dynamic. These considerations are relating to the drivers of learner creativity in groups. We focus on group creativity and motivation in learning environment in the following section.

2.2.2 Group creativity and motivation in learning environment

The literature shows that motivation is an influential factor within the driving force which causes learners to achieve goals [14]. It can be stimulated intrinsically and extrinsically [24]. Intrinsic motivation refers to being driven by an interest or enjoyment in the task itself, and existing within the individual rather than relying on any external pressure, whereas extrinsic motivation results from individuals perceiving an instrumental connection between behaviour and receipt of extrinsic rewards [24–25]. Contrary to early works which stressed that extrinsic motivation cannot improve creativity, recent studies show that when the rewards for creativity are salient and instructions are clear, rewards increase creativity [25]. In fact, the interaction between the two types of motivation can stimulate creativity to an optimal level [24, 26].

Recent studies also suggest that collaboration may widen the scope of intrinsic and extrinsic motivation [12]. As Amabile [14] suggests, intrinsic motivation is fragile: if both extrinsic and intrinsic motivation are present in a situation, people tend to attribute their engagement to extrinsic sources [12]. Another person being present can seem to affect his or her balance of intrinsic and extrinsic motivation and a person's behaviour will tend towards confor-

mity [27]. As a result, not only is intrinsic motivation widened in collaboration, but intrinsic and extrinsic motivators can cooperate rather than compete with each other. Accordingly, Moran and John-Steiner [12] proposed that the collaboration itself generates its own kind of motivation—connective motivation. Because collaboration can both stabilize and maximize the energies that partners bring to their projects and creative enthusiasm for the work and for each other, it can also moderate the inherent difficulties that can occur when working together.

In this paper, we are focusing on environmental influences on learners' motivation in group creativity development rather than the differences between intrinsic, extrinsic and connective motivation. In the social–cultural framework, we understand the motivation as learners respond to the learning environment; it determines whether the learners can engage in learning activities, and it is stimulated by the interaction between learners and the learning environment. As we discussed above, in order to develop group creativity in a learning environment, individuals should be given enough time to reflect and engage in the learning process, which requires the appropriate management to involve individuals in the group process. The learning environment should encourage the creative performance of individuals through their intrinsic interests in tasks and positive influences of teachers or other group members. These points and the existing literature lead us to review the following aspects that influence motivation in group creativity development:

(1) characteristics of the task,
(2) the teacher's strategies,
(3) group influences,
(4) management of learning process.

The four aspects help to structure the following theoretical work in this section.

The characteristics of the task have been discussed in respect of intrinsic motivation [26]. As Amabile [14] suggests, the individuals who undertake a task for its own sake are intrinsically motivated; they perceive themselves as engaging in an activity primarily because of their own interest in it. Thus, intrinsically motivated individuals are more likely to expend energy exploring the problem and find creative solutions [24]. So open-ended questions and solving real-life problems have been emphasized as the characteristics of a task that can stimulate creativity [28]. As suggested by Tan [11], problems can take various forms, such as failure to perform, situations in need of immediate attention or improvement, a need to find better or new ways to do things, unexplained phenomena or observations, gaps in information and knowledge, or a need for new designs or innovations. So a problem triggers engagement in terms of emotional motivation and deep thinking.

Teachers' strategies have been emphasized as the main influence on student motivation [18]. As stressed by Dineen [29], the pedagogical model that emerges from the holistic view of creativity does not appear to be discipline–dependent. Rather, it is based on a commitment to an 'emancipatory and transformative' education. The teacher–student relationship is believed to be at the heart of this endeavour. For example, when researchers manipulated the learning environment so that students felt it is more accepting of risky behaviour, students' creativity increased. Students were more excited about the potential to excel and less worried by the possibility of failure. However, when the environment reinforces the penalties for failure, students become more prevention focused and, therefore, less creative in their work [25]. So the studies suggest that educators should encourage creativity by explicitly rewarding it, by teaching students to see common things in a new light, and by inviting them to look beyond one correct answer [7, 25].

The influences of group function on creative ideas have been discussed much, such as group size, membership change and group diversity [3]. The relationships between members have been viewed as the key. For example, Hennessey and Amabile [30] mentioned that setting up competitive situations is a way to kill creativity, because it encourages the performer to win and beat others, not to enjoy the intrinsic rewards of the activity. According to Milliken *et al.* [31], conflict can be created if there is a lack of understanding, coupled with differences of opinion and possible subgroup identification. Meanwhile, Levine *et al.* [32] emphasized that if the newcomer's ability can meet with group requirements, group motivation is improved. Wageman [33] therefore suggested that a group task requiring high task interdependence makes salient a collective sense of responsibility, increasing the need for collaboration and mutual adjustments among group members.

On management of the learning process, some studies emphasize the ownership of students—the learning process is controlled by students not governed by teachers, because students will be more creative when they are internally motivated and when they feel some ownership of or control over a learning process [7]. However, a framework, which identifies two important determinants of group performance is essential:

(a) the resources that group members bring to the group,
(b) the processes involved in the way these

resources are combined to produce group–level outcomes [34].

Thus, there should be a balance between divergent and convergent activities in order to efficiently produce creativity [26]. Moreover, the balance can be influenced by a variety of factors, such as time pressure, leadership style, individual task amount and group norms [26].

To summarize, although the review indicates some appropriate conditions, a systemic influence to stimulate student motivation should be provided by the learning environment, including aspects such as the characteristics of the task, the teachers' strategies, the group influences and management of the learning process. It also indicates that we should take a system view in analysis of how a learning environment can meet the requirements of stimulating motivation in group creativity development. On these points, we focus on a Problem and Project-Based Learning (PBL) environment in this paper.

2.3 PBL as an environment motivating group creativity in engineering education

Recently, studies have recognized PBL as an instructional model that may foster creative engineers [10]. Learning in a PBL environment centres on complex, real-world problems that do not have a single correct answer; students work in collaborative groups to identify what they need to learn in order to solve a problem; the teacher acts to facilitate rather than to provide knowledge directly [35]. Theoretically, a social–constructivism approach to learning has been discussed broadly as the roots of PBL, which calls for learning by doing, hands-on problems solving and construction of interactive understanding. So learning is a search for meaning rather than just memorizing the 'right' answers and repeating someone else's meaning.

In this paper, we regard PBL as an environment that stimulates motivation of group creativity. Because existing literature [9–11] shows that PBL can offer opportunities to learn through practice, to have individual reflection and common engagement in the learning process, and to meet the requirements of stimulating motivation in a systemic way. There are at least three aspects of PBL that satisfy these conditions [36]:

- Problem orientation and project work: the point of departure in open and real life problems.
- Group learning context: the process of group collaboration in searching for the solutions.
- The shift from teaching to facilitation: the idea of facilitating student directed learning rather than teaching.

To present open problems for students is to provide an opportunity for creative thinking. As stressed by Policastro and Gardner [37], creators can be distinguished as much by their ability to find and pose new problems as by the capacity to solve problems. In the problem-solving processes, some skills relating to creativity can be improved, such as critical thinking, divergent thinking and imagination [37–38]. As Dolmans *et al.* [9] emphasized, PBL has effects on cognition and motivation that lead to creative performance. Furthermore, solving real-life problems or interdisciplinary projects requires a deep engagement [39], because much of the new thinking at the 'high creativity' level does involve the merging of ideas from two or more disciplines [7]. On this point, evidence has shown that PBL helps students construct an extensive and flexible knowledge base that makes positive contributions to the development of domain knowledge [11].

Furthermore, students are encouraged to work in groups due to the complexity of problem-solving or project work. This brings special insights from use of the social environment to support creativity in the problem-solving process [40]. For example, Gerhardt and Gerhardt [41] focus on creativity and group dynamic; in a PBL environment based on the synergy of a team, the group rules, there is clarity of mission, superior decision making and improved team structure. Accordingly, they recommend some methods for inspiring creativity, for example, the six hats method. Poikela *et al.* [42] argue that PBL can support creativity because it can provide a collaborative knowledge building and self-directed learning environment. Porath and Jordan [40] indicate that PBL could be viewed as a way to build communities of reflective practitioners in the problem solving process which triggers creative ideas.

In addition, facilitation by supervisors is critical to making PBL function well. As many studies [35] emphasize, teachers should hold on to the philosophy of student-directed education. However, challenges have been discussed in the shift from teacher-led to student-centred education [43]. As Dolmans *et al.* [9] discuss, PBL may lead to some ritual behaviour that brings barriers to creativity. For example, one situation is that students make few connections between new information and their own knowledge base; as a consequence, there is little activation of related networks of prior knowledge. Accordingly, suggestions have been proposed for facilitators to overcome the barriers; for example, Gerhardt and Gerhardt [41] emphasize attention to group structure, group management and conflict resolution, as well as knowledge of common group-related difficulties that can help the facilitators.

Briefly, aspects such as problem orientation and

project work, the group learning context and the shift from teaching to facilitation can be thought as resources of group creativity, because these aspects stimulate student motivation in a systemic way. These points drive this paper to explore a link between group creativity and PBL. Accordingly, we focus on the research question of how engineering students are motivated to develop group creativity in a PBL environment.

3. A case study: the student satellite project (AAUSAT3) at Aalborg University

3.1 Background

For more than 30 years, Aalborg University (AAU), Denmark has educated scientists and engineers by using a Problem and Project-Based Learning approach. AAUSAT3 is the third student satellite from Aalborg University. It was started in autumn 2007 and was launched late 2010. The mission of this satellite project was to carry out and operate the Automatic Identification System (AIS) payloads, which was proposed by The Danish Maritime Safety Administration, aiming to be used by ships to communicate between each other.

AAUSAT3 has a joint venture with several departments at Aalborg University, which includes the Department of Electronic Systems, the Department of Mechanical Engineering, the Department of Computer Science and the Department of Energy Technology. Students from 1st to 10th semester were encouraged to participate in the project work according to the different rate of tasks. AAUSAT3 has the following educational objectives:

- Showing that students are able to develop working satellites.
- Developing the system engineering skills of the students—as a complement to the existing education, while giving them experience in project management.
- Showing that AIS may be able to replace the LRIT (Long Range Identification and Tracking) system, as a cheaper and more effective system.

In this paper, we focus on AAUSAT3 as a research context. First, Aalborg University, Denmark has been discussed broadly as an influential PBL model in engineering education [39]. Second, due to the characteristics of solving real-life problems and interdisciplinarity, AAUSAT3 is expected to provide a rich empirical data resource through research methods. Thereby, this case study is expected to develop some new findings as a contribution to relative research.

3.2 Research methods

We employ a qualitative case study in this paper. Recent studies indicate the case studies can help to bring the hidden mental processes and well-known creative collaborations into the public realm through actions, dialogues, use of tools and works in progress [12]. As suggested by Jeffrey and Craft [44], the methodology for investigating creativity in education has shifted from positivist, large-scale studies aiming to measure creativity, towards ethnographic, qualitative approaches to research focusing on the actual site of operations and practice.

Moreover, the research question addressed by this paper are well-suited to a qualitative case study according to Yin [45]. In this paper, there are three conditions under which a case study makes a particularly valuable contribution. Table 1 summarizes those conditions and maps them to the conditions.

In this case study, observations and interviews were employed, since they have been suggested as useful ways to examine phenomena in a natural context and reveal diverse perspectives [13]. As pointed out by Anderson-Leviti [46], we required a dual perspective: understanding the insider's points of view to grasp the logic of their actions, yet being able to step back to take an outsider's distanced perspective that shows what insiders would otherwise take for granted. In previous work [47], the mix of the two methods has been used broadly in engineering education research.

3.3 Data collection and analysis

The empirical work was carried out from May 2008 to December 2009 and covered two semesters. During this period, there were 14 participants who were observed, including two student groups in 6th

Table 1. Qualitative case study conditions as applied to this study

Case Study Condition	Research Study
The research addresses 'why' or 'how' questions	How are engineering students motivated to develop group creativity in a PBL environment?
The researcher has no control over behaviour	As an exploratory study of an ongoing phenomenon, this study did not attempt to influence participants' behaviour; rather, it sought to explore existing practices in light of current theories.
The focus is on a contemporary phenomenon in real time	Group creativity and learning activities in PBL environment in engineering education occur in real time in the context of ongoing project work.

semester, three student groups in 7th semester, one student group in 9th semester and two supervisors in AAUSAT3. The collaborative process in searching for project solutions and the situations of group creativity generation were focused in the observation. So the empirical data from observation was collected from:

- Notes and recordings of 18 group meetings;
- Notes and recordings of 5 project meetings;
- Notes and recordings of 8 discussions on project work among group members;
- 15 days' observation diaries on project work;
- Pictures of daily learning activities.

In general, the researchers in this paper did not pay any active role in participants' meetings, discussions and their daily learning activities. So the participants were instructed to 'do as they usually do' by researchers of this paper. Accordingly, data were generated from content analysis of the points made by students and supervisors from the data source. Pictures taken during observations may help us to see what we did not see at first and will be used as evidence to support points generated from the data analysis.

In order to identify participants' perceptions on motivation of group creativity in AAUSAT3, a total of 10 interviews were carried out with 12 students and 2 supervisors, which included 2 group interviews and 8 individual interviews. The 14 interviewees were marked from A to N when the data were collected (Table 2).

In the interviews, according to the research question 'how are engineering students motivated to develop group creativity in a PBL environment?', we first focused on where student motivation came from; second we focused on the influences of PBL environment on motivation. According to the theoretical work, the two focuses are related to:

(1) the task itself,
(2) group influences on creative ideas,
(3) management of learning process,
(4) teachers' strategies.

These considerations led to the following key themes in the interviews with students:

- Motivation of participation in project work AAUSAT3.
- Management of individual learning process and group work in AAUSAT3.
- Generation of group creativity in searching for solutions of project work.
- Roles of supervisors on the group work and creative ideas.
- Factors influencing motivation of group creativity.

Moreover, we carried out interviews with the supervisors by focusing on the key themes of:

- Facilitation on students' motivation of group creativity development.
- Challenges or difficulties in encouragement of creative ideas in PBL environment.

The interviews were organized by open-ended questions that allowed for in-depth follow-up. Each interview was about 30 minutes. As with the observations, the interviews were analysed and coded according to key themes. And data from the interviews were generated from conversation analysis based on the transcription.

On the analysis methods used with the data from interviews and observations, many studies have provided the references [13]. Here we adopted research findings of Koro-Ljunberg and Douglas [49], which shows the most common methods of data analysis in qualitative research and the usage of data from interviews and observations (Table 3).

As mentioned, an 'insider-outsider' paradigm in empirical work is essential. Inspired by Table 3, we think interviews represent a critical mechanism when using primary data to confirm or contradict the observational findings. So in the data analysis, we seek the logical and rationality of insider (participant's) perspectives and behaviours. We also try to make sense of behaviours by looking at the larger context of outsider (researcher's) perspective by comparison. So the comparison forces the researchers to calibrate the insiders' and outsiders' perspective and helps to recognize variation or even conflict among actors [46]. Therefore, the collection and

Table 2. Data collected from interviews at AAUSAT3

Interviewees				**Interviews**	
	Semester	**Number**	**Mark of Interviewee**	**Type of interview**	**Number**
Student group	6th	2	A, B, C	group interview	1
			D, E, F, G	individual interview	4
	7th	1	H, I, J	group interview	1
	9th	1	K, L	individual interview	2
Supervisor	6th,7th	1	M	individual interview	1
	9th	1	N	individual interview	1

Table 3 Data analysis methods of interviews and observations

	Observations	Individual Interviews	Group Interviews
Main Purposes	To witness and collect data in actual empirical/real life settings	To gain individual participant's perspective	To create socially constructed knowledge and to find a group perspective
	To use as secondary data	*To use as primary data*	*To use as primary data*
Analysis Methods	content analysis	conversation analysis	conversation analysis
Whose Perspective	Researcher's	Participant's	Participant's

analysis of data lead to the findings and discussions of the case study.

4. Findings and discussions

The data analysis focuses on the research question of how the engineering students are motivated to develop group creativity in a PBL environment. According to the theoretical work based on empirical data in this paper, we organize the findings and discussions as

(1) students' motivation of participation in AAUSAT3,
(2) influences of AAUSAT3 on motivating group creativity.

Furthermore, in the second part, we first explore which ways and factors in AAUSAT3 influence motivation that lead to a later discussion on how AAUSAT3 influences motivation of group creativity development.

4.1 Students' motivation of participation in AAUSAT3

From the interviews with the students, we obtain four different reasons for their participation in AAUSAT3:

(1) being interested in making a real-life satellite,
(2) expecting to acquire more knowledge through AAUSAT3,
(3) preparing students for the future workplace,
(4) being introduced by peers.

The first reason, 'being interested in making a real-life satellite', was thought to be the most basic reason by students. Though AAUSAT3 was a long-term task, each student felt excited at the opportunity to participate in parts of the project. As what the students said in the interviews:

- 'Practice is the most important. We prefer to join in the interesting tasks'. Interviewee B
- 'It sounds great if I can work on a satellite. It is a complex system and it is beyond one product of electronics'. Interviewee D
- 'We do the satellite, because it has more fun than the other projects'. Interviewee L

Moreover, some students thought they could benefit from learning in AAUSAT3. However, the interviews show that there were mainly two focuses based on the students' expression of this point:

(1) students of 6^{th} and 7^{th} semesters focused on learning more knowledge, since they were acquired to study fields such as electronics, mechanics, space, physics, ocean, and energy, whereas
(2) students of 9^{th} semester focused on preparing for the future workplace, because they would graduate sooner and they had more employment pressure than younger students.

Although 'learning more knowledge' was also preparing for future work, students of 6^{th} and 7^{th} semesters did not express this point explicitly in the interviews:

- 'In this project, in order to make the competence system works, we needed to get a little wider, do a few more tasks, and we could get the deep studies of every task through this project.' Interviewee C (6^{th} semester)
- 'I think it is a good thing because probably when we get out into the real life and have to get a job, we will probably be a part of a task to solve some specific problems, and I guess it is like that in this satellite project.' Interviewee K (9^{th} semester)

In addition, interviews found that some students knew each other already before they participated in AAUSAT3, because they had experience of working together in previous semesters. So when one of them found the interests of AAUSAT3, the others whom he was familiar with were introduced to the groups. It is a process in which students develop the network by themselves:

- 'In the fourth semester, we (interviewee B and C) worked in a group together. So when we need one more person, I thought C was excellent and he was easy to get along with, then we had this guy (C).' Interviewee B

So the reasons for participation show that students' motivation could be intrinsic, extrinsic and connective. Since the basic reason is interest in the project itself, motivation is intrinsic. Other reasons are

related to extrinsic and connective motivation, such as the pressure of employment and the network with peers. As mentioned, AAUSAT3 focuses on solving real-life and interdisciplinary problems, which stimulates a depth of learning by intrinsic task motivation and bridges abilities of students and qualified engineers by extrinsic and connective motivation. However, the influences of AAUSAT3 on the different types of motivation, learning process and group creativity should be considered, which leads us to the following data analysis.

4.2 Influences of AAUSAT3 on motivation of group creativity

Relating to the empirical data of the influences of AAUSAT3 on students' motivation, we obtain two main findings:

(1) the multiple ways of motivating students to engage in the daily learning activities, which come from aspects of management of learning process, generation of group creativity and the roles of supervisors;
(2) the series of influencing factors on motivation of group creativity in AAUSAT3 from the students' perspective, which includes both stimuli and barriers.

These two findings lead to a discussion on the systemic environmental influences of AAUSAT3 on the student motivation of group creativity.

4.2.1 Influencing ways and factors of AAUSAT3 on motivation of group creativity

First, the observation and interviews found multiple ways of motivating group creativity in the daily learning activities of AAUSAT3, such as peer-arranged process of group building, making group norms, sharing leadership, group meetings and asking help from supervisors (Table 4). These ways are collected from aspects of management of the learning process, generation of group creativity and roles of supervisors according to guidelines for empirical work.

Second, from the interviews with students, a series of factors that stimulate motivation of group creativity in AAUSAT3 have been found, which include group common goals, equal amount of individual task, good relationship of members, clarity of member tasks, support of peers, diversity of member backgrounds. However, time schedule is thought to be the barrier to group creativity by the students. Furthermore, the empirical work also indicates the multiple ways and influencing factors that interact with each other and can be viewed as a whole when they play roles on motivation, as discussed in the following.

4.2.2 Systemic influences of AAUSAT3 on motivation of group creativity

As shown in Table 4, the students were involved in the management of learning from the stage of group building. As what the students introduced in the interviews, project proposals were announced on the website (http://www.aausat3.space.aau.dk) at the beginning of every semester. Students who were interested in this project gathered to discuss the possibility of group establishment, which can be described as a 'peer-arranged' process. The students initiated meetings and decided how to participate by themselves. So AAUSAT3 is conducive to building a community, where a group of people work together with a common set of goals or interests. And the learning community provides the support network necessary for learning to occur [40]. Peter-

Table 4. Ways of motivating group creativity in AAUSAT3

Aspects	Ways of motivating group creativity
Management of learning process	• Peer–arranged process of group building • Follow the principle of group diversity in process of group building • Make group norms by students themselves • Initiate group meetings, supervisor meeting by students themselves • Make milestones and assign task through group meetings • Mark the group progress and individual task on the blackboard • Online management of project document • Share leadership in project management
Generation of group creativity	• Formal discussion in group meetings • Informal group discussions and debates • Collaboration with students across different semesters • Guided by supervisors in supervisor meetings • Collecting ideas from previous or similar project work introduced in books or internet • Inspired by online document • Test ideas collected from group members through experiments
Roles of supervisor	• Good communication with student groups in both meetings and daily basis • Encouraging collaboration and sharing experience among different groups • Facilitating a deeper learning to move on project work • Dealing with group disagreements

son [49] asserts that when community exists, learning is strengthened; everyone is smarter, more ambitious and productive. Meanwhile, according to the observation, the principle of task-related group diversity was followed in group building process, which matches the data of interviews.

- 'We required a programmer at least. Though there was one guy who was also interested in joining us, he was not good at programming. So we didn't welcome him. Different backgrounds are necessary to the group, as we can have different tasks.' Interviewee A

As Nijstad, Rietzschel and Stroebe [34] suggest, task-related diversity enhances group performance. The right level of diversity seems to be essential to avoid cognitive uniformity and conformity: group members who have different approaches to the same problem are less likely to get stuck in a rut. Also group members should perform the tasks they are good at. People who are given a choice in certain aspects of task engagement will produce more creative work than people for whom the choice is made by someone else [14]. So the ownership of learning should be involved in the management. As the observation shows, members' tasks were not assigned by supervisors in AAUSAT3, instead, it was agreed upon through group discussion. Students had group meeting once a week, where members concluded and shared experiences, planned milestones and assigned tasks. If there were some difficulties in learning, members would have more informal discussions about solutions. So the milestones were kept flexible for modification along the way. In practice, students drew timetables as reminders on the blackboards. Because they thought it was a way to have clarity of member tasks, facilitate effective communication and avoid the overlap of efforts.

The students also introduced their own group norms in the interviews; for example, how many hours they should work together every day. A group coordinator was selected in each student group for cooperating between members and with the other groups. Other members also made different contributions to group management, such as contacting supervisors and sponsors, so everyone was responsible for progress and success. This is how it achieved a shared leadership. As suggested by Wenger [19], shared leadership brings a division of labour in which each participant is relieved from carrying the whole burden. A community needs multiple forms of leadership: thought leaders, networks, people who document the practice, pioneers. These forms of leadership may be concentrated on one or two members of the group or widely distributed; they will potentially change over time, but will harness group innovation ability in practice.

Project meetings were organized once a week in order to support such a complex project and all students and supervisors in the AAUSAT3 were expected to attend. Documentation of the project work includes agenda, problems of each group, possible solutions, decisions, group milestones, tasks assigned in each group, as noted in Tracwiki [50].Because the document was online, groups that joined the project later can easily become familiar with what has been done and how the task was handled.

The project meetings also encouraged collaboration between student groups in different semesters. So the students in AAUSAT3 seemed to work in one big group and at same time belonged to several subgroups. Formal and informal discussions were where group creativity usually happened. Sometimes when group members had disagreements, it led to a deeper discussion even a debate. Learning in AAUSAT3 therefore took place as students participated in shared endeavours with others, with all playing active but often asymmetrical roles in sociocultural activity [51]. Meanwhile, the interviews show that students thought they could benefit from learning in groups and suggested the common group goals, support of peers and equal amount of individual task were important to motivation:

- 'Because we have the same goal, so that it is not like one person is working a lot and the other two are just hanging around. I think it is a good way to motivate oneself, to help each other, and to get something done. If I just worked by myself, I would like to sleep longer or go home earlier, so I would lose a lot.' Interviewee C

As emphasized above, social support groups or networks are vital for creativity to flourish [52]. The interpersonal relationships built within a learning community promote a sense of group loyalty among students, a willingness to help each other, a sense of inclusiveness that respects diversity as well as personal and social growth, high levels of participation, greater quality of discussion and questioning, use of diverse strategies for problem solving, increased risk taking in forming points of view or opinion [40]. Meanwhile, the interview also shows another way of generating creative ideas in student groups in AAUSAT3 as well as the way of solving the satisfactory debate—testing or reflecting on potential ideas by practical experiments. Because only when the idea 'does work' that it shows it can be the solution. If the ideas did not work, the students discussed further until the problem was solved. Group creativity, therefore, was included in the

interactive capacities when students solved and analysed the problems.

As participants in an interdisciplinary project of AAUSAT3, students confront problems that are outside the realm of their competence but that force them to negotiate their competences with each other. According to Wenger [19], competence and experience are in different relationships at the core and at the boundaries of practices. The innovation potential of a system lies in its combination of strong practices and active boundary processes—people who can engage across boundaries, but have enough depth in their own practice that they can recognize when something is really significantly new. Therefore, some students thought the good relationship of members and the group openness were important to move on the group work:

- 'We get along with each other very well. I mean, what we need is not only collecting but also reorganization of what we know. So different ideas and communications are welcomed, otherwise we can't have the combination of the new solutions.' Interviewee B

Asking help from the supervisor is also a way to get new ideas moving in the project work. Usually, the students in AAUSAT3 initiated a supervisor meeting once a week or two weeks. According to the observation in both formal meetings and on a daily basis, the supervisors stimulated the group dynamic by encouraging the sharing of knowledge and dealing with group disagreements. As the students pointed out, supervisors had an 'inspirational' role in groups.

- 'His role is to help us if we need help. He always gives us some suggestions, 'your idea are very good, but if you do that, what will happen?', or "can you prove your idea in practice?" 'Interviewee H

So the supervisors in AAUSAT3 emphasized 'learn through practice'. Moreover, they encouraged an open group atmosphere in what the students did in AAUSAT3. So the students may feel psychological safety in such a friendly environment, which drives members more likely to suggest novel ideas, criticize others' ideas, challenge the status quo, ask naive questions, or admit mistakes because they lack fear of ridicule or more subtle forms of interpersonal rejection [53]. This type of environment provides an opportunity for skill development and helps maintain the intense and sustained motivation or perseverance found in creative individuals. It also produces students who are self-confident in their social roles within a group, who are willing to take risks in the very public social arena of the classroom, and willingly collaborate with others to interpret and develop meaning from challenging problems [40].

However, when students were asked to give more suggestions to supervisors, they replied that some knowledge should be taught directly to some extent:

- 'We acquire supervisor give more details in the feedback of our questions. Sometimes it is waste of time by answering the open questions. And sometimes we are a bit tired of this situation, because we have deadlines.' Interviewee E

Contrary to the students' suggestions, we obtain an opposite point from the interviews with supervisors, because they think 'the best way to teach creativity is to give students enough space to try'. As stressed by Ekvall [54], idea time is a key factory to creative climate. In a creative environment, people have time to formulate and to elaborate upon new ideas. Opportunities exist to bounce around suggestions and possibilities, and to think about how to make things better [55]. So when teachers employ methods such as 'branching out, finding out, or inventing', beneficial effects for students accrue, especially their motivation, attitude toward school and self-image. All of these activities require student–student and student–teacher interactions [56].

However, when the students were supposed to be interacting with each other and had enough time for thinking, sometimes they were concerned about 'losing the ways'. This was due to a dilemma between the high level challenges of project work and pressures of the deadline in AAUSAT3. So the time schedule was viewed as two sides of a coin by the students—it stimulated learning but was a barrier to motivation:

- 'Deadline is a good reminder that we should have the input to the project, such as when we hand in reports and when we fly the cubes. It is like the pressure to drive you. But it tells that we are not able to do everything we want. So we have to give up some possible ideas after we have a useful one.' Interviewee B

This also shows the complexity in the 'student-centred learning' context in fostering creative engineers: students on one hand enjoy the ownership of learning and motivation of group process, whereas on the other hand, they acquire appropriate ways of guiding where the right direction of effort is. The role of the supervisors, beyond creating a risk-free intellectual social environment, is to provide students with age-appropriate problems that challenge their thinking [41]. However, the appropriateness also brings challenges to the supervisors. As they expressed in the interviews:

- 'We are not sitting next to God's right hand or doing everything well. It is a balance of the edge on a knife doing invisible supervision or in other words just guiding the students and letting them not be aware of what we are doing. But we shall also at the same time do team building and from time to time take tough decisions. When we did the AAUSAT-II and tried to get deployable solar panels, nobody could decide and then I had to say 'we are flying these panels- let us go for plan B.' Interviewee M

This indicates the challenges that are due to the complexity of supervision and ambiguity of learning in a team. As Jackson and Sinclair [8] mention, every learning and teaching situation is underpinned by a complex set of conditions relating to the inter-relationship between student, teacher and task. In the case of AAUSAT3, students may not be motivated to try out new ways of working; they may not have adopted appropriate cognitive and metacognitive strategies and may find this difficult without support which impacts on motivation. So the students thought more thinking and doing time was required to try ideas out. Therefore, supervisors working in AAUSAT3 should be more deliberately aware of the complex relationships between student, teacher and task and any possible students' response in order to gain maximum impact.

To summarize, the case study leads to a deeper understanding that PBL as an environment motivates engineering students' group creativity. As a real-life satellite project, AAUSAT3 stimulated motivation intrinsically by its task characteristics; some aspects in students' daily learning activities bring positive influences on their motivation: the management of learning processes facilitates the task-related diversity of group composition, students' ownership and the shared leadership that improves group performance; formal and informal meetings build an open-minded atmosphere that facilitates ideas sharing, the interactive problem solving process and risk taking in all of which the supervisors play 'inspirational' roles. Meanwhile, a series of factors such as common goals, good relationships of members and support of peers are found to interact with each other. In addition, time schedules were pointed out as the barrier to motivation by the students. Accordingly, it is suggested that supervisors be more aware of the complex relationships between student, teacher and the task and student responses.

However, it was found in the group interviews that students tended to offer more positive evaluation on their group work; whereas in the individual interviews, students would like to express more points such as group disagreements and barriers to motivation. Since students in the individual interviews felt more free than in group settings when they answer the questions. This may bring limitations to findings in this case study.

5. Conclusions

In this paper, we explore a link between group creativity and PBL by examining engineering students' motivation. Theoretically, we combine studies on creativity, learning and motivation from a social–cultural approach and emphasize the influences of the learning environment on motivation of group creativity. As the literature demonstrates, the aspects of environmental influences on motivation include the characteristics of the task, the teachers' strategies, the group influences and management of the learning process, which deepens the understanding that PBL can be an environment motivating group creativity. Accordingly, a qualitative case study of AAUSAT3 at Aalborg University, Denmark was carried out in this paper. The empirical work shows that PBL environment has a systemic influence on student motivation in multiple ways, such as formal and informal group discussions, supervisor meetings and sharing leadership. Furthermore, factors such as common goals, peer support and openness also stimulate motivation. However, the student thinking time schedule is a barrier to group creativity. So supervisors should, it is suggested, be more aware of the complex relationships between student, teacher and task and student responses. In addition, limitations are found in this study, since we did not get much negative data for evaluation of group work during group interviews, such as group disagreements and barriers to motivation. Hopefully, this paper will contribute to related studies on fostering creative engineers by using the PBL environment in the future.

References

1. S. D. Sheppard, K. Macatangay, A. Colby and W. M. Sullivan, *Education Engineers, Design for the Future of the Field,* A Wiley, San Francisco, 2008.
2. A. Rugarcia, R. M. Felder, D. R. Woods and J. M. Stice, The future of engineering education I, a vision for a new century. *Chem. Engr. Educ.,* **34**(1), 2000, 16–25.
3. P. B. Paulus (Ed.), *Group Creativity: Innovation through Collaboration*, Oxford University Press, USA, 2003.
4. R. J. Sternberg (Ed.), *Handbook of Creativity,* Cambridge University Press, New York, 1999.
5. M. Grossen, Methods for studying collaborative creativity: an original and adventurous blend, *Thinking Skills and Creativity,* **3**, 2008, 246–249.
6. A. Eteläpelto and J. Lahti, The resources and obstacles of creative collaboration in a long-term learning community, *Thinking Skills and Creativity,* **3**, 2008, 226–240.
7. A. Craft, *Creativity in Schools: Tensions and Dilemmas.* Routledge, New York, 2005.
8. N. Jackson and C. Sinclair, Developing students' creativity, searching for an appropriate pedagogy. In N. Jackson, M. Oliver, M. Shaw, and J. Wisdom (Eds), *Developing Creativity*

in Higher Education, An Imaginative Curriculum, Routledge, London, 2006, pp. 118–141.
9. D. Dolmans, Solving problems with group work in Problem-Based Learning: hold on to the philosophy, *Medical Education,* **35,** 2001, 884–889.
10. H. Awang and I. Ramly, Creative thinking skill approach through Problem-Based Learning: pedagogy and practice in the engineering classroom, *Int. J. Soc. Sci.,* **3**(1), 2008, 18–23.
11. Oon-Seng Tan (Eds), *Problem-based Leaning and Creativity,* Cengage Learning Asia Pte Ltd, Singapore, 2009.
12. S. Moran and V. John-Steiner, How collaboration in creative work impacts identity and motivation, In D. Miell and K. Littleton (Eds), *Collaborative Creativity, Contemporary Perspectives,* Free Association Books, London, 2004, pp. 11–25.
13. K. Punch, *Introduction to Research Methods in Education,* SAGE Publication, London, 2009.
14. T. M. Amabile, *Creativity in Context*, Westview Press, Boulder, 1996.
15. M. A. Runco, *Creativity, Theories and Themes: Research, Development, and Practice,* Elsvier Academic Press, London, 2007.
16. K. Sawyer, *Group Genius, the Creative Power of Collaboration*, Basic Books, New York, 2007.
17. A. Craft, Creativity in Schools. In N. Jackson., M. Oliver, M. Shaw, and J. Wisdom (Eds), *Developing Creativity in Higher Education, An Imaginative Curriculum,* Routledge, London, 2006, pp. 19–29.
18. G. B. Esquivel, Teacher behaviors that foster creativity, *Educ. Psych. Rev.,* **7**(2), 1995,185–202.
19. E. Wenger, *Communities of Practice, Learning, Meaning and Identity,* Cambridge University Press, New York, 1998.
20. K. Illeris, *The Three Dimensions of Learning,* Roskilde University Press, Denmark, 2002.
21. M. A. Boden, Creativity and knowledge, In A. Craft, B. Jeffrey, and M. Leibling (Eds), *Creativity in Education*, Continuum International Publishing Group, London, 2001, pp. 95–102.
22. P. Corsi, S. Richir, H. Chiristofol, and H. Samier (Eds), *Innovation Engineering: The Power of Intangible Networks,* ISTE Ltd, London, 2006.
23. P. Baumard, *Tacit Knowledge in Organizations,* SAGE Publications, London, 1999.
24. R. B. Cooper and B. Jayatilaka, Group creativity: the effects of extrinsic, intrinsic and obligation motivations, *Creativity Res. J.*, **18**(2), 2006, 153–172.
25. K. Kazerounian and S. Foley, Barriers to creativity in engineering education: a study of instructors and students perceptions. *J. Mech. Design,* **129**, 2007, 761–768.
26. D. A. Leonard and W. C. Swap, *When Sparks Fly: Igniting Creativity in Groups,* Harvard Business School Press, Boston, 1999.
27. D. K. Simonton, *Greatness: Who Makes History and Why*, Guilford Press, New York, 1994.
28. R. Felder, Creativity in engineering education, *Chem, Eng. Educ.,* **22**(3), 1998, 120–125.
29. R. Dineen, View from the chalk face: lectures' and students' perspectives on the development of creativity in art and design, In N. Jackson, M. Oliver, M. Shaw, and J. Wisdom (Eds), *Developing Creativity in Higher Education, An Imaginative Curriculum,* Routledge, London, 2006 , pp. 109–117.
30. B. A. Hennessey and T. M. Amabile, *Creativity and Learning,* National Education Association of the United States, Washington, 1983.
31. F. J. Milliken, C. A. Bartel, and T. R. Kurtzberg, Diversity and creativity in work groups: a dynamic perspective on the affective and cognitive processes that link diversity and performance, In P. B. Paulus (Eds), *Group Creativity: Innovation through Collaboration,* Oxford University Press, USA, 2003, pp. 32–62.
32. J. M. Levine, Hoon-Seok Choi, and R. L. Moreland, Newcomer innovation in work teams, In P. B. Paulus (Eds), *Group Creativity: Innovation through Collaboration,* Oxford University Press, USA, 2003, pp. 202–224.
33. R. Wageman, Interdependence and group effectiveness, *Admin. Sci. Quarterly,* **40**, 1995, 145–180.
34. B. A. Nijstad, E. F. Rietzschel, and W. Stroebe, Four principles of group creativity, In L. Thompson, and H. S. Choi (Eds), *Creativity and Innovation in Organizational Teams*, Lawrence Erlbaum Associates, London 2006, pp. 161–182.
35. C. Hmelo-Silver, Problem-Based Learning: what and how do students learn? *Educ. Psych. Rev.*, **16**(3), 2004, pp. 235–266.
36. C. Zhou, J. E. Holgaard, A. Kolmos, and J. F. D. Nielsen, Creativity development for engineering students: cases of problem and project based learning, *Proceedings of the Joint International IGIP-SEFI Annual Conference 2010,* European Society for Engineering Education, 2010.
37. E. Policastro and H. Gardner, From case studies to robust generalizations: an approach to the study of creativity, In: R. Sternberg (Ed.), *Handbook of creativity,* Cambridge University Press, New York, 1999, pp. 213–226.
38. R.W. Weisberg, *Creativity: Understanding Innovation in Problem Solving, Science, Invention and Arts.* John Wiley & Sons, Inc, Canada, 2006.
39. J. D. Nielsen, X. Du, and A. Kolmos, Knowledge building approach for learning engineering: a case study of GENSO (student satellite) project, *Proceedings of SEFI 2008, 36th Annual Conference, European Society for Engineering Education,* Sense Publishers, Rotterdam, 2008.
40. M. Porath and E. Jordan, Problem-Based Learning communities: using the social environment to support creativity. In Oon-Seng Tan (Ed.), *Problem-based Leaning and Creativity,* Cengage Learning Asia Pte Ltd, Singapore, 2009, pp. 51–66.
41. C. E. Gerhardt and C. M. Gerhardt, Creativity and group dynamics in a Problem-Based Learning context, In Oon-Seng Tan (Ed.), *Problem-based Leaning and Creativity,* Cengage Learning Asia Pte Ltd, Singapore, 2009, pp. 109–126.
42. S. Poikela, P. Vuoskoski and M. Kärnä, Developing creative learning environment in Problem-based Learning context, In Oon-Seng Tan (Ed.), *Problem-based Leaning and Creativity,* Cengage Learning Asia, Singapore, 2009, pp. 67–86.
43. M. Savin-Baden, *Problem-based Learning in High Education: Untold Stories,* Open University Press, Buckingham, 2000.
44. B. Jeffrey and A. Craft, The universalization of creativity, In A. Craft, B. Jeffrey and M. Leibling (eds.), *Creativity in Education*, Contnuum International Publishing Group, London, 2001, pp. 1–16.
45. R. K. Yin, *Case Study Research: Design and Methods,* Sage Publications, Thousand Oaks, 2003.
46. K. M. Anderson-Levitt, Ethnography, In J. L. Green, G. Camili, and P.B. Elmore (Eds), *Hand Book of Complementary Methods in Education Research,* Lawrence Erlbaum Associates Publishers, London, 2006, pp. 279–295.
47. M. Borrego, E. P. Douglas, and C.T. Amelink, Quantitative, qualitative, and mixed research methods in engineering education, *J.Eng. Educ.,* **98**(1), 2009, 53–65.
48. M. Koro-Ljungberg and E. P. Douglas, State of qualitative research in engineering education: meta-analysis of JEE Articles, 2005–2006, *J. Eng. Educ.* **97**(2), 2008, 163–190.
49. K. Perterson, *Life in a Crowded Place: Making a Learning Community,* Heinemann, Portsmouth, NH, 1992.
50. http://www.aausat3.space.aau.dk/pmwiki.php?n=Site.AAUSAT3TracWiki
51. K. H. Lycke, Inside PBL groups: observation, confirmations and challenges, *Educ. for Health,* **15**(3), 2002, 326–334.
52. M. Csikszentmihalyi, A system perspective on creativity, In J. Henry (Ed.), *Creative Management* (2nd edition), Sage, London, 2001.
53. A. C. Edmondson, and J. P. Mogelof, Explaining psychological safety in innovation teams: organizational culture, team dynamics, or personality? In H. S. Choi and L. L. Thompson (Eds), *Creativity and Innovation in Organizational Teams,* Lawerncec Erlbaum Associates Publishers, London, 2006, pp. 87–108.
54. G. Ekvall, Organizational climate for creativity and innovation, *Eur.J. Work and Org. Psych.* **5**(1), 1996, 105–123.
55. K. W. Mccluskey, *Thoughts about Tone, Educational Leadership, and Building Creative Climates in Our Schools,* The International Center for Innovation in Education, Ulm, Germany, 2008.
56. A. Cropley, *Creativity in Education and Learning: A Guide for Teachers and Educators,* Kogan Page, London, 2003.

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