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Interplay between Individual Creativity and Group Creativity in Problem and Project-Based Learning (PBL) Environment in Engineering Education*

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Recent studies regard Problem and Project Based Learning (PBL) as providing a learning environment which fosters both individual and group creativity. This paper focuses on the question: In a PBL environment, how do students perceive the interplay between individual and group creativity? Empirically, qualitative interviews were carried out with 53 students (12 groups) in Computer Science, Electronic Systems, Architecture and Design, and Medialogy at Aalborg University, Denmark. The data analysis shows that there are three aspects to the influences of a PBL environment on the interplay between individual and group creativity: (1) the project as "an extra member" in student groups; (2) tacit modes of collaboration in student groups; and (3) students have both domain-general and domain-specific understandings of creativity. These findings suggest the need for improved approaches to develop creativity in the PBL environment.

Keywords: interplay; individual creativity; group creativity; Problem and Project-Based Learning (PBL)

1. Introduction

Creativity in general is the ability to come up with new ideas that are surprising yet intelligible, and also valuable in some way [1]. Because developing new ideas is a key component of the success of large and small businesses [2], the issue of creativity has become increasingly popular in research in many fields of the social sciences. Social and cognitive psychologists, sociologists, and marketing and management experts are addressing this issue from different perspectives and levels of analysis in an attempt to find specific answers concerning antecedents and moderating factors [3]. For example, research in sociology has focused on more macro issues concerning the influence of the environment on creativity [4]. More recently, creativity has been viewed in terms of a dialogue, a social and communicative transaction between individuals who, in some sense, share a mutual goal [5].

The increasing interest in creativity research has driven a series of educational approaches for fostering creative students [6]. Problem and Project Based Learning (PBL)** takes such an approach. At least three principles of PBL are conducive to a creative learning environment: (1) problem orientation and project work, (2) the group learning context, and (3) the shift from teaching to facilitation [7]. PBL provides a community of practice which supports both individual creativity and group creativity. Accordingly, efforts have been made from diverse perspectives to explore how PBL stimulates creative thinking skills [8]. However, special attention should be paid to the interplay between individual creativity and group creativity. Studies on this issue could provide powerful insights in terms of providing a more effective PBL environment because the teaching support needed to develop creativity in groups differs from that needed to develop creative individuals.

Accordingly, this paper aims to explore the question: In a PBL environment, how do students perceive the interplay between individual creativity and group creativity? Thus, the focus of the study is the students' perspective, explored through an empirical study in which 53 students (12 groups) at Aalborg University in Denmark were interviewed. Aalborg University has a tradition of PBL going back more than 30 years. The interviewees came from Computer Science (3 groups), Electronic Systems (3 groups), Architecture and Design (3 groups), and Medialogy (3 groups), and were from the 3rd semester (6 groups), 5th semester (4 groups), 7th semester (1 group), and 9th semester (1 group). Analysis of the empirical data led to the findings discussed in this paper which related to three aspects of the influences of the PBL environment on the interplay between individual and group creativity:

** Whilst Problem and Project-Based Learning can be regarded as two distinct approaches, for example in the extent to which a problem is predefined by an instructor. They have much in common and this paper therefore follows de Graaff and Kolmos (2007) and Du (2011) in using PBL as an umbrella term for both.

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(1) the project as "an extra group member", (2) tacit modes of collaboration in student groups; and (3) domain-general and domain-specific understandings of creativity. The findings have implications for how to improve PBL as a more effective strategy for developing creativity in the future.

2. Interplay between individual creativity and group creativity

2.1 Generic model of group creativity

Group creativity is the creation, development, evaluation, and promotion of novel ideas in groups. This can occur informally in interactions between friends or colleagues, or in more structured groups such as scientific research laboratories and research and development teams [9]. According to Nijstad and Paulus [10], three aspects are important for group creativity: group members, group processes, and group context. Group members bring resources to the group and these resources determine the group's creative potential or what the group is able to accomplish. The contributions of group members need to be combined in some way to yield a group response. The ways in which individual members' contributions are combined constitute the relevant group processes. Finally, the context largely determines which group processes will occur and how individual contributions are combined. Eventually, this determines the quality and creativity of the group response. Thus, according to this framework, the resources of individual group members determine the potential creativity of the group. However, group processes, or the way in which individual contributions are combined, determine whether the group actually achieves its potential. Group processes, in turn, are influenced by the social climate and the environment (Fig. 1).

The generic model in Fig. 1 demonstrates a dynamic process of how individuals are engaged in group activities, how individuals engage in reflective learning through the group process, and how group performance is improved through individual contributions. It should be noted that the dynamic process does not always flow in the sequence shown in Fig. 1; however, there is a "back" and "forth" exchange between individual-level input and group-level output, and the exchange continues until all individuals yield to the group response due to a satisfying group outcome. Relating this model to the PBL environment, it indicates that the literature needs to incorporate at least three aspects in order to focus on the interplay between individual and group creativity: (1) the influence of individual factors on group creativity, (2) group-level creative synergy, and (3) bridging individual creativity and group creativity in the PBL environment.

2.2 Influence of individual factors on group creativity

The basic resources of a group reside in its members. Group members bring knowledge, skills and abil-

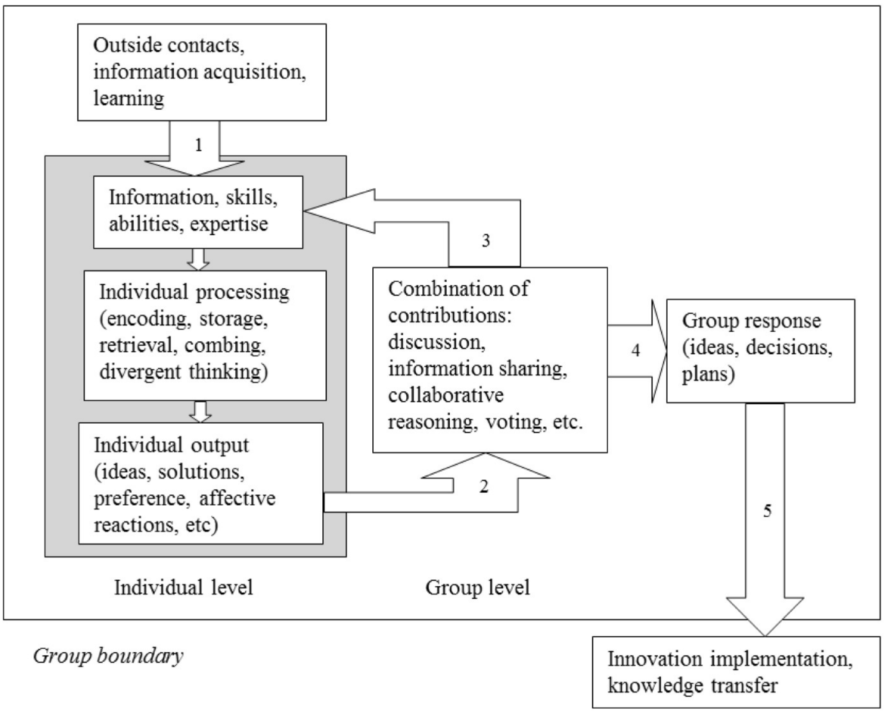

Fig. 1. A generic model of group creativity [10].

ities to the group without which the group task cannot be accomplished and group creativity would not be possible [10]. According to the literature, individual factors, such as knowledge, domain, motivation, and attitudes towards creativity development, play an important role in the contribution of individual creativity to group creativity.

Knowledge. From a cognitive psychology perspective, creativity can be understood as comprising three types: (1) *combinational creativity* produces new ideas by combining (associating) old ideas in unfamiliar ways; (2) *exploratory creativity* can happen once the person has learnt (some of) the relevant rules; and (3) *transformational creativity* involves a significant alteration in one or more of the rules of current conceptual space. All types of creativity are grounded in previous knowledge. Therefore, the need to break out of the boundaries set by knowledge for creative thinking is emphasized. Boden [1] points out that creativity and knowledge are not opposed to each other, even though an overemphasis on current knowledge can sometimes smother creativity; however, creativity thinking cannot happen unless the thinker already possesses knowledge of a rich and/or well-structured kind. As Weisberg [11] proposed, high creativity builds on knowledge—what he calls the "foundation" view. In addition, the role of tacit knowledge has also been stressed in group innovation [12].

Domain. Domain provides a knowledge context within which to be creative [13]. Unlike the domain-general view of creativity that regards creativity as a general skill or trait or characteristic that can be applied to a wide variety of situations, the domain-specific view of creativity is that different kinds of creative ability are required in different domains [14]. For example, Kaufman and Baer [15] discuss how people think, work, and act creatively in diverse domains which include arts, computer science, mathematics, and engineering, etc. Furthermore, the significance of experts in a given field of knowledge which recognizes work as creative is recognized [16]. For something to be creative at this level means a departure from what is generally accepted to be conventional knowledge or approaches within the field; this means that both creator and judges must know what is conventionally accepted in order to know whether something new is creative [13].

Motivation. The creation of novelty requires not only appropriate thinking and personality, but also the desire or at least the readiness to diverge, take risks, defy conventional opinion, or expose oneself to the possibility of being wrong—in other words, appropriate motivation [17]. Two types of motivation are predominantly addressed in the creativity literature [18]. Extrinsic motivation results from individuals perceiving an instrumental connection between their behavior and their receipt of extrinsic rewards, such as money and praise. In contrast, intrinsic motivation arises from positive reactions to the qualities of the task itself; intrinsically motivated individuals engage in a task primarily out of their own interest in it [19]. In a group context, Moran and John-Steiner [20] propose that collaboration itself generates its own kind of motivation, namely connective motivation. They argue that both intrinsic and extrinsic motivation focus on the outcome of the partnership (the energy behind reaching a goal or creating a product); whereas connected motivation emphasizes the partnership process itself.

Attitude. The individual's attitude toward creativity is very important, especially his or her creative self-efficacy. Belief in one's own ability to create, defined broadly, forms the psychological foundation of creative achievement [21]. Thus, creative attitudes are intimately tied to a creative personality and they include traits that predispose one to think creatively and be creatively productive [21]. Teachers, managers, parents, and others who are attempting to foster creative self-efficacy in others should model a can-do, enthusiastic attitude when confronted with problems and tasks that require creative solutions. Davis [22] suggested 15 categories of positive traits related to creative attitudes including: awareness of creativity, originality, independence, risk-taking, energy, curiosity, sense of humor, attraction to complexity, capacity for fantasy, being artistic, open-mindedness, needing alone time, intuition, emotion, and ethics.

The literature also indicates other factors, such as identity [20], leadership [23], and cultural background [24], etc. However, the factors interact with each other and they play a common role in creativity. For example, Moran and John-Steiner [20] point out that identity and motivation are related in a collaborative creative context because they both focus on the connection with another person. Amabile [18] contends that creativity does not occur spontaneously or randomly, but happens when the appropriate combinations of knowledge, skills, and motivation enable an individual to create new ideas.

2.3 Group-level creative synergy

Collaboration not only doubles energy resources by putting together two or more people's efforts towards a shared goal, but also the synergies of collaboration create a further reserve of energy [20]. As Pirola-Merlo and Mann [4] suggest, group creativity could be an aggregate of creativity across individuals and time. Individual creativity can provide the raw material for novel and useful ideas, but group member interactions and group processes play an important role in determining how this raw material is developed into group-level creativity. In this sense, Moran and John-Steiner [20] suggest three characteristics of group-level creative synergy, these being: (1) complementarity, (2) tension, and (3) emergence.

Complementarity. Collaborators are not a homogeneous group, but rather individuals with different perspectives, expertise, conceptualizations, working methods, temperaments, resources, needs, and talents. The interaction of these differences forms the foundation for the dynamics of collaboration to unfold [20]. Therefore, in group composition, a series of fundamental factors of group formation are often conceptualized as representing member diversity on dimensions such as demographic characteristics, personality traits, opinions, tenure in the group, and educational and functional background [25]. As Nijstad and Paulus [10] suggest, in principle, two heads should know more than one, but a group's creative potential first and foremost depends on the degree of diversity in the group. Functional, informational, and cognitive diversity are associated with higher levels of group creativity and innovation. In addition, the relationships among group members, such as whether they are engaged in cooperation or competition, whether they are friendly or not, and the extent to which they have different working habits or thinking styles, etc., are also key to creative collaboration [2].

Tension. The goal of collaboration is not to reach consensus as such agreement does not lead to learning or challenge. The tension between vulnerability and security, doing and getting done, jumping in and stepping back, and collaborators' personal differences should not be eliminated, but rather put to good use as a mechanism for bringing out latent opportunities of the domain. Collaboration is not the absence of tension, but the fruitful cultivation of tension [20]. Group creativity involves both the generation of ideas and the selection of the best ideas to be implemented. Thus, it involves both divergent and convergent processes [10]. In the divergent process, creative groups should generate many ideas from a wide range of categories, a high number of unique ideas, and provide opportunities for elaboration of each other's ideas [26]. In the convergent process, a set of ideas is narrowed to one alternative [27]. Group decisions in judgmental tasks are typically determined by the most popular preferences in the group at the onset of the discussion [28]. Conflict or disagreements among group members often arises over the ownership of ideas [29]. However, during idea selection some criticism is essential, and a constructive debate among group members may lead to a better decision [10].

Emergence. A theory of the development of creativity as emergent is an intermediate position between two potential alternative explanations. First, one could explain the final state of the system by arguing that it is predetermined by the initial state of the system. A second alternative is the empiricist view; empiricism explains development by arguing that the final state of the system is determined by the environment of the organism. Emergentism holds that an explanation of the final state of the system requires an examination of the step-by-step interaction between organism and environment as it passes from stage to stage because the organism changes at each stage. Thus, the environment is not directly imposed or internalized by the organism; rather, development results from a constructive process or organism–environment interaction [30]. The social process of creativity is analogous to collaborative improvisation: in both an improvised dialogue and a scientific discipline, creativity emerges from a complex interactional and social process [30]. Creativity is an emergent property of the group, field, or society, rather than a property of individuals [30]. Collaboration can lead to outcomes that could not be predicted solely from the additive power of people working as a group [29].

The above characteristics deepen understanding of group creativity as a sociocultural conception—group creativity can be regarded as a collaborative activity and it often occurs in interactions between individuals, not minds in isolation. Group creativity needs individual contributions and at the same time affects individual outputs through group processes; the environment exerts an influence on group processes, but groups also affect their environment. However, each group environment is different from one to another, so it is apparent that the specific collaborative context should be taken into account when the issue of the interplay between individual and group creativity is discussed.

2.4 Bridging individual creativity and group creativity in the PBL environment

The PBL approach in education has a long history. In the PBL environment, rather than being taught through lectures, groups of students solve realistic unstructured problems from their field of professional practice. Students are expected to define problems, identify related gaps in their knowledge, collect relevant information, and propose solutions [32]. Diverse models of PBL have been applied in different fields of education such as business management [32], engineering [33], medicine [34], and law [35], inter alia. As discussed in the literature, PBL can be an effective educational strategy for supporting both individual and group creativity since it provides conditions of (1) self-directed learning, (2) collaborative knowledge-building [36], and (3) a community of practice [37].

Self-directed Learning. Among the various aspects of PBL, self-directed learning skills and a well-structured knowledge base are mentioned as two specific benefits [38]. "Self-directed learning" relates to both social and cognitive issues—that is, issues of "self-direction" and "learning", respectively. In education, however, most of the focus has been on self-direction (i.e., self-management of learning tasks) [39]. Thus, it stimulates students to enjoy the ownership of learning, which is the internalization of the learning experience, the development of the competent individual who gains public recognition and enjoys telling others, gaining a real sense of achievement and developing feelings of personal worth [40]. As Craft [41] proposes, the intention of young people to take ownership of ideas, processes, directions, and to engage with motivation in their own creative journey provides assurances that manifestations of their "selves" as individual and unique learners are valued and safe in that personal perspective, and what might at times be seen as idiosyncrasies are acceptable and contribute to the general dynamic culture. In this way they feel creative and able to act independently.

Collaborative Knowledge-Building. As mentioned, PBL involves the use of student problem-solving groups; it is more likely than conventional methods to foster the development of teamwork and other social skills [32]. Hmelo-Silver [42] suggests that educating students to be effective collaborators is one of the goals of PBL. Similarly, Fruchter [43] contends that one focus of the dimensions of teamwork is to give students the opportunity to learn how to participate in and lead multidisciplinary teams. Furthermore, solving real-life problems and working with project work could be sources of creativity [44]. The PBL process begins with students working towards a shared understanding of the problem presented to them; meanwhile, in real-world problem solving, the context tends to be unstructured, and it takes big picture thinking, analytical thinking, as well as generative and divergent thinking to produce effective solutions [45]. As situations and problems are multidimensional, they require more than individual insights to reach the desired goal or to meet the need in question [45].

A Community of Practice. The recent community of practice perspective brings new insights to PBL [34]. This perspective argues that learning occurs naturally through people's participation in the practices of social communities and through their construction of identities in relation to these communities [47]. Wenger [48] emphasizes the role of both social competence and social experiences in establishing communities of practice; essentially, these are aspects of the organizational or classroom culture. Porath and Jordan [37] consider that, in PBL, social aspects of meaning-making that influence creativity should be taken into account. An aspect of this type of environment is a community built on mutual respect among all members. 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, a high level of participation, greater quality of discussion and questioning, the use of diverse strategies for problem solving, and increased risk-taking in forming points of view or opinions.

In summary, the literature review shows that the PBL environment may provide conditions for stimulating both individual and group creativity, and provide the context for interactions between the two levels of creativity. However, although groups have the potential to generate their own synergy, ideally allowing the group to go beyond the capacities of individuals working by themselves [46], for groups to be creative, the group process must be structured in a way that prevents process loss [49]. For teachers in a PBL environment, it is necessary to be clear that the support provided should be different when fostering individual creativity as opposed to stimulating the group dynamic. This calls for empirical research investigating student group members' perceptions of the interplay between individual creativity and group creativity in a PBL environment.

3. Methodology

This study employed qualitative interviews to explore the research question: *"How do students perceive the interplay between individual creativity and group creativity in the PBL environment?"* As Kvale and Brinkmann [50] point out, the interview tends to work with words and not with numbers and it aims at nuanced accounts of different aspects of the interviewee's life world. Furthermore, qualitative methods have been increasingly explored in creativity studies [40, 51]. As Craft [41] states, methodology for investigating creativity in education has shifted from large-scale studies aiming to measure creativity, toward ethnographic, qualitative approaches focusing on the actual site of operations and practice, again situating creativity in the specifics of the underlying disciplines, and in the social and cultural values and practices of the particular setting.

Accordingly, interviews were carried out with 12 student groups (53 interviewees) from the 3rd, 5th,

Table 1. Interview data collected from student groups

Education Field	Student Groups	Semester	Group Size	Interviewee Marks
Computer Science	Aa	3rd	2	Aa1–Aa2
	Ab	3rd	4	Ab1–Ab4
	Ac	3rd	5	Ac1–Ac5
Electronic Systems	Ba	9th	4	Ba1–Ba4
	Bb	5th	4	Bb1–Bb4
	Bc	7th	3	Bc1–Bc3
Architecture and Design	Ca	5th	4	Ca1–Ca4
	Cb	5th	4	Cb1–Cb4
	Cc	5th	6	Cc1–Cc6
Medialogy	Da	3rd	5	Da1–Da5
	Db	3rd	6	Db1–Db6
	Dc	3rd	6	Dc1–Dc6

7th and 9th semesters at Aalborg University, Denmark, which has a long tradition of taking a PBL approach. The interviewees came from Computer Science (3 groups), Electronic Systems (3 groups), Architecture and Design (3 groups), and Medialogy (3 groups). The size of the groups ranged from two to six members. All the groups were assigned separate designations and each interviewee was then assigned a separate number within their group. Thus, the capital letters represent different educational fields, the lowercase letters different groups, and the numbers different individuals (Table 1).

The interviewees participated in this research voluntarily. The interviews were semi-structured, allowing in-depth follow-up of initial responses to questions. Many open questions relating to the interplay between individual creativity and group creativity in the PBL environment were asked. The interviews were carried out in students' group rooms, where they study and have group discussions daily. Each interview lasted approximately 45 minutes and was recorded. The interviews were transcribed and the data generated formed the basis for conversation analysis. In line with the focus of this paper, the findings are organized under the following themes:

(1) Ways of developing creative group ideas.
(2) Individual contributions to group creativity development.
  - Relevance of creativity to learning domain knowledge.
  - Attitudes to creativity development.
  - Reasons/motivation for individual contributions to group creativity.
  - Self-evaluation of individual contributions to group creativity.
(3) Group influences on developing individual creativity.
  - Influences of group idea development processes on individual creativity.
  - Influences of group decision-making processes on individual creativity.

As the above themes illustrate, self-evaluation of individual contributions to group creativity was incorporated in the interviews. Thus, group interviews were chosen in this study: the group context provides individuals with an environment for objective self-evaluation in interviews and individuals also have opportunities to evaluate the others' contributions. Combining this with the other interview topics, the group interviews were able to elicit a wide range of perspectives. Focusing on a common topic in the interviews, the students used group discussion to express their points as they would usually do in group meetings in the PBL environment. As suggested by Kvale and Brinkmann [50], the aim of the focus group is not to reach consensus about or solutions to the issues discussed, but to elicit different views concerning an issue. It is characterized by a non-directive style of interviewing, where the interviewer's task is to create a permissive atmosphere for the expression of personal and conflicting viewpoints on the topics discussed.

4. Findings and discussion

4.1 Students' perceptions of the interplay between individual and group creativity

In the interviews, students expressed a wide range of opinions, generating a large amount of data. Their perspectives are summarized in relation to the aforementioned themes (Table 2, 3 and 4).

As the findings show, in a PBL environment, the students considered that the project plays an important role in developing creativity. The project could thus be viewed as an "extra group member" in student groups. It "calls for" group discussion and increases individual motivation. It "reminds" students to stop disagreements because of the time constraints. It "tells" students which ideas could be possible solutions because the idea should make

Table 2. Ways of Developing Creative Ideas

Interview Themes	Students' Perceptions
Ways of developing creative group ideas	• Project problems stimulate group creativity. • Individual new ideas lead group discussion. • Brainstorming and mind mapping. • Individual creativity may need time for reflection, or informal discussion.

Table 3. Individual Contributions to Group Creativity Development

Interview Themes	Sub-Themes	Students' Perceptions
Individual contributions to group creativity	Relevance of creativity to learning domain knowledge	• Students define creativity variously. • In some fields (e.g. Architecture and Design), creativity is viewed as more central than in others (e.g. Electronic System).
	Attitudes to creativity development	• Students in some domains expressed higher levels of confidence in being creative than those in others.
	Reasons/motivation for individual contributions to group creativity	• Two reasons were found: (1) responsibility for individual study, and (2) stimuli from peers in groups. • Most students express the two reasons together, the basic motivation being that they want to move on in project work. • Individual experiences of group work and project work are more important than assessment scores.
	Self-evaluation of individual contributions to group creativity	• Most students tried their best to contribute to group work. • Students think everyone is important in a group and individual work cannot be completed without other members' support.

Table 4. Group Influences on Developing Individual Creativity

Interview Themes	Sub-Themes	Students' Perceptions
Group influences on developing individual creativity	Influences of group idea development processes on individual creativity	• Increasing individual motivation. • Learning through group feedback. • Learning ways of solving problems and sharing ideas with peers. • Learning to change thinking perspectives. • Learning skills of brainstorming.
	Influences of group decision-making processes on individual creativity	• Learning to compromise with peers. • Increasing skills of arguing for individual ideas. • To speed up group decision by "testing ideas in practice". • Group disagreements and time schedule as both drivers and barriers to individual creativity.

sense in practice. However, in order to reduce group disagreements, students like to collaborate with familiar peers with whom they have been working for a long time, because they trust each other and tacit modes of collaboration have been formed. Moreover, the common points on creativity and different attitudes towards creativity between different domains demonstrate both domain-general and domain-specific understandings of creativity. These findings are discussed in the following sections.

4.2 Influences of the PBL Environment on the Interplay between Individual and Group Creativity

As previously mentioned, PBL provides conditions for bridging individual creativity and group creativity. Relating this to the empirical data illustrated above, at least three aspects that demonstrate how the PBL environment influences the interplay between individual creativity and group creativity should be discussed further: (1) the project as an "extra group member", (2) tacit modes of collaboration in student groups, and (3) domain-general and domain-specific understandings of creativity.

4.2.1 Project as an "Extra Group Member"

PBL encourages student groups to work with real-life projects. Project work provides a common approach for group members—that is, they work together to accomplish their purpose. All the students' learning activities center on projects because progressing a project involves both individual learning goals and group goals. Relating this to the empirical findings in this paper, a metaphor is used in which the project is viewed as "an extra group member": the project is a key part of students' learning in PBL and it plays important roles in group collaboration. One of the roles is to stimulate individual contributions to group creativity:

> "When the project started, I wanted to do a better design this semester. This is my goal, my personal goal. But the group helped me when I had problems, so I believe that the whole project is what we have to find together. So (my individual contributions) may be small personal goals, but if someone wants to have a successful project, he has to work together (with the other group members)." (Interviewee Cb3)

The above points indicate that the goal of solving problems increases task motivation. This resonates with Amabile [18], who suggested that task motivation determines an individual's approach to a given task, including one's attitude towards the task and self-perceived motivation for undertaking the task. The task, guiding question or driving question delineates what individuals are to accomplish and embeds the content to be studied [52]. Furthermore, when student groups are working on solving problems, they are engaged in an active search for meaningful information, a proactive immersion in the task, a conscious and subconscious investment of time on the task, and a search for meaning and explanation, along with the adoption of goal and future orientations [8]. As students expressed in the interviews, individuals can gain considerable benefits from the process of developing group ideas, such as learning the skills of brainstorming, learning to change thinking perspectives, and learning to share ideas with peers. At the same time, the group context can have the effect of exposing individual strengths and weakness and group feedback improves individual creativity. As Tan et al. [8] suggest, constantly reflecting on ideas and considering alternatives in a group is a way to ensure that fresh ideas surface. It appears that creativity evolves from students' deep knowledge of a domain and self-knowledge:

> "When we are working together, one of us might have one idea and he shares it with group members. He can see how the other people think about problems; maybe their ideas are helpful to develop his design, to make it better through more details." (Interviewee Cb4)

However, for group creativity to occur, groups must reach consensus on which idea is best. This involves convergent thinking, in which a set of ideas is narrowed to one alternative. The arguments for ideas exist in group decision-making processes. According to Levine and Moreland [29], disagreements have the potential to stimulate consideration of new ideas, which is generally essential for group acceptance. However, in some cases, disagreements become so intense that group members abandon potentially useful lines of thought or give up on problems altogether. In other cases, disagreements elicit emotional reactions that inhibit productive interactions between collaborators. As to what students suggested in the interviews, on the one hand, there are the disagreements that are normal in groups, from which they may deepen understanding of both their own and others' ideas; on the other hand, it takes time to reach satisfying decisions and this may delay project work. Therefore, a second role of the "extra group member" is to remind students to find ways of dealing with disagreements in order to finish work on time. In this situation, a third role is usually played in terms of encouraging the group to reach an agreement—pushing students to test ideas in practice or find other ways of reaching a compromise:

> "If I have a very perfect idea, but the others do not think (the idea is good), I try to approve my idea (in practice), because the idea is for the solution (to solve problems in project work)." (Interviewee Ba3)

Therefore, group creativity is developed from "conversations" between students and the "extra group member". The conversations are "back" and "forth" processes—the "extra group member" "asks" that students to meet task challenges, "calls for" group discussions, and "speeds up" group decisions; the students react in collaborative ways in order to "answer" the "extra group member". The creative group ideas are the result of such "conversations". During such processes, individual motivation is stimulated and the group dynamic is increased, facilitating learning in depth. The interplay between individual creativity and group creativity also happens in such processes where students share learning experiences, motivate each other, and derive benefit from interacting with their peers.

4.2.2 Tacit modes of collaboration in student groups

The interviewees in this paper are not beginners in the PBL environment. They have at least 3 semesters of learning experience of group work. The interviews show that most of the students know each other when the groups are formed—they have collaborative experience from previous project work and some of them are good friends, so they know each other's interests, ways of thinking, and working styles. In order to form an effective group, students like to choose a "complementary" type of collaboration with members from their own different specialties, so they can perform different tasks with the aim of progressing projects. This is why students emphasize the importance of equal membership in groups. From the students' point of view, choosing group members with whom they are familiar is a way of reducing disagreement because they can focus on the project work once the group formed.

> "I think that now we have worked together so long, we know each other. But it is strange at the beginning of the process because we need a lot of time to get to know each other before we can work together and a good

> group environment is necessary. . .then we would like to stick with the group from semester to semester because it can save hours of getting to know each other." (Interviewee Ba4)

Thus, tacit modes of collaboration are formed in the students' long-term learning community. However, "taken-for-granted" collective tacit knowledge is developed communally, over time, in interactions among individuals in the groups in the PBL environment:

> "At the beginning (of the project), we had many disagreements because we liked to discuss everything—we get better and better at managing group work. With time, I learn to move the project on efficiently and move the task on with other group members." (Interviewee Cc3)

This reflects Leonard and Sensiper's [12] point that one form of collective tacit knowledge encompasses the entire production system, allowing individuals to contribute to innovation without explicit communication because they understand at a systemic level how all the individual operations in an organization fit together. Thus, students develop implicit ways of working and learning together. Much work depends on their informal, shared use of inexpressible collaborative experience. As Wenger [48] suggests, in a community of practice, people learn certain ways of engaging with other people, and they develop certain expectations about how to interact, how they treat each other and how to work together. Group members feel bonds of shared accomplishment in the mutual engagement. Furthermore, mutual engagement requires the ability to take part in meaningful activities and interactions in the production of sharable artifacts, in community-building conversations, and in the negotiation of new situations. So group members must actually communicate their ideas to another and learn to support the emotional dynamics of collaboration, especially the importance of belief in a partner's capabilities [34]. Thus, trust between peers seems especially important in terms of mutual engagement in the long-term community:

> "Casper (Interviewee Ba3) is a very good programmer and I am good at the other parts, so we divide the work into two parts. We help each other but meanwhile we think the other one is excellent. Because we only have two people, it is easier to discuss face to face and then assign work, manage time and decide on what has to be done tomorrow." (Interviewee Ba4)

This indicates that trust is generated from "complementary" types of collaboration. As students expressed in the interviews, individual work cannot be completed without the support of other members. Eteläpelto and Lahti [53] contend that, in long-term collaboration, trust includes individuals' emotional safety and people's confidence that they will receive help from each other. Trust consists of respect for another person's different perspectives, an expectation of good will, and confidence in another's ability to continue to fulfillment of the common purpose. Such trust is the foundation for the tacit collaboration in student groups in the PBL environment that allows the development of true sharing, openly negotiated conflict, and a long-term relationship, even when uncertainties and risks are present. As West [54] states, group creativity is intentional, a conscious attempt by group members to initiate the changes that would bring about benefits. The group's ability to form an emotionally secure work environment may contribute to this intentionality, and trust and mutual respect among members will create the sense of safety that is required for this type of mental synergy.

4.2.3 Domain-general and domain-specific understandings of creativity

In this study, four different domains are represented: (1) Electronic Systems, (2) Computer Science, (3) Architecture and Design, and (4) Medialogy. Compared to Electronic Systems and Computer Science, which can be seen as representatives of traditional hardcore engineering disciplines, Architecture and Design and Medialogy are comparatively new engineering disciplines. Whichever domain the students come from, most of them think creativity is very important in developing one's career. Their definitions of creativity are wide-ranging, as can be seen from the following statements:

> "Creativity means changing how people behave. The ideas should be amazing and can lead to many changes." (Interviewee Aa2)
>
> "Creativity may be shown by someone who comes up with different solutions for problems."(Interviewee Db4)
>
> "I think it is that some people are critical and that is a way to be creative." (Interviewee Ca1)
>
> "We are working on control engineering . . . creative work in our field is coming up with new designs, designing a new system to help solve problems."(Interviewee Ba4)

The different conceptualizations of creativity are shaped from students' different creative experiences in projects. For example, some students pointed out that the beginning period of a project needs more creativity than the end period—students need ideas for planning and starting projects at the beginning and they focus on writing project reports at the end of the semester. However, students in Computer Science and Electronic Systems did not think creativity was particularly relevant to their fields and they demonstrated poor understanding of creativity and a lack of confidence in being creative in project work; for example, one student in Computer

Science (Interviewee Ab3) argued that their projects did not need creativity:

> "I don't know (what creativity is). I don't think we need creativity because in my group we usually have to do project work immediately. We have some discussions and make decisions on what we think and which plan would make sense in the project." (Interviewee Ab3)

Other students (Interviewees Ac2 and Ac1) think of creativity as something they can use, similar to some kinds of software or tools relating to computer science studies:

> "I am thinking about the use of creativity. . . I think we did (use creativity). We have a lot of tools to deal with different kinds of questions in programming." (Interviewee Ac2)

> "In the project last semester, we used creativity a lot because the project was about the application of some technology. We did not use it this semester and the project is about managing a system." (Interviewee Ac1)

The Computer Science and Electronic Systems students' views of creativity can be related to the characteristics of their fields. As Thompson and Lordan [55] suggest, to many engineers creativity is a nebulous concept that sits uneasily in the precise quantitative engineering world. Engineering disciplines such as computer science and electronic systems have a strong mathematical component. For example, Saunders and Thagard [56] contend that computer science resembles engineering in that it is often concerned with building machines and making design decisions about complex interactive systems. It is also often concerned with questions of how to accomplish a technological task rather than with scientific questions of why some natural phenomenon occurs. Thus, from the perspective of students who are from such disciplines, creative products seem more important than creative processes. As Cropley and Cropley [57] suggest, engineering creativity results from creativity with a purpose, namely to create products and perform tasks or solve problems. In other words, students are concerned more with the effectiveness of solutions in problem-solving than the novelty of approaches to solutions. This tendency leads to a poor understanding or a misunderstanding concerning what creativity means in their field of study. Although most students think creativity is very important, they do not think creativity is particularly relevant to them. However, when individuals are motivated to engage in group discussions for problem-solving, and when groups make decisions in order to progress project work, creativity is embedded in such processes. The students themselves may be unaware of their creative behaviors because, in their eyes, creativity is a trait possessed by great inventors or artists and engineering is far from creative work.

In contrast, students in Architecture and Design and Medialogy consider creativity highly relevant to their fields; they express a clear understanding of creativity in their projects:

> "We always prepare for the task we are working on with new thinking. We always ask each other: 'How do you see (this idea)?', but each of us thinks, 'Oh, that is my opinion, I think the idea could be excellent'." (Interviewee Ca4)

> "I think we were pretty much creative during the beginning of the project work. We came up with a lot of basic ideas and we labeled ideas on the table. We read them and decide which one was the best. That was the main creative process." (Interviewee Da5)

Although multiple ways of developing group creativity have been found in the interviews, such as using techniques of brainstorming or mind mapping, students in Architecture and Design stressed that sometimes individual creativity needs time for reflection on ideas, or they need informal discussions or a break to draw inspiration for a new design. As Sawyer et al. [58] suggest, the emergence of creativity is unpredictable and cannot be discerned analytically before it emerges. For students in Architecture and Design, the relaxed atmosphere stimulates the possibility of the emergence of creativity. Thus, the experience of students in Computer Science and Electronic Systems differs from that of those in Architecture and Design and Medialogy as the latter are engineering disciplines with an embedded ideology of combining technology with creativity. For example, as characterized by Holgaard et al. [59], medialogists work with animations, computer games, sound and film, graphics and interactive environments. The aim of medialogy is to foster students who are able to combine technology and creativity to provide new processes and tools for art, design and entertainment. The educational purpose is to meet the demands of the modern media industry and the experience of media. Thus, the core of medialogy lies in the design process and therefore creativity is regarded as a key skill to mastery in the profession. Accordingly, students are encouraged to develop as many new ideas as possible during the design process in order to deepen understanding of creativity and increase awareness of being creative in group work. This also leads to motivation in terms of being creative engineers in their future careers:

> "I could say it is very important to have a very strong wish and very strong concept (to be creative). (If you have them), then your creativity can follow the concept and (new) vision. If your creativity is connected with the vision, you are doing something creative. I believe this is a good resource (for a future career)." (Interviewee Cb3)

Thus, differences in understandings of creativity are related to the characteristics of the different domains and students' learning experiences in those domains. This indicates the need for multiple approaches to develop creativity in different disciplines of engineering education in the PBL environment. For example, to develop creativity in computer science or electronic systems, a more explicit way of delivering knowledge related to creativity by aiming to increase the sense of being creative engineers is required. Ways of fostering creativity could be integrated into the curriculum by focusing on topics in which students are interested. As experts in their domains, supervisors in the PBL environment could play a greater role in stimulating creativity in daily supervision work—students should be able to be creative in groups; they should also know what they have done creatively or what they should do that could be creative.

5. Conclusions

This paper explores the interplay between individual creativity and group creativity in the PBL environment. Theoretically, group creativity is a sociocultural concept which indicates the shaping roles of environment on developing creativity. The literature shows at least three types of collaboration should be considered when group creativity is the aim: (1) complementarity, (2) tension, and (3) emergence. However, individual factors such as knowledge, domain, motivation, and attitude influence individual contributions to group creativity. The PBL environment provides individuals with the conditions in which to develop individual creativity and motivation in group work. The theoretical points led to empirical work which was carried out with students at Aalborg University, Denmark, from Computer Science, Electronic Systems, Architecture and Design, and Medialogy. The data from the interviews indicate at least three aspects in relation to the influence of a PBL environment on the interplay between individual creativity and group creativity: (1) the project as "an extra group member", (2) tacit modes of collaboration in student groups, and (3) domain-general and domain-specific understandings of creativity. The discussions deepen understanding of PBL as a learning community which stimulates individual motivation, increases group dynamics, and facilitates long-term collaboration. However, students have multiple ways of defining creativity, different levels of confidence in being creative in projects, and diverse attitudes towards developing creativity in their studies in different domains. The foregoing calls for improved ways of working that relate the characteristics of different educational disciplines to the development of creativity in the PBL environment.

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