Conflicts in learning: A critical analysis of problem based learning in relation to cultivating innovative engineers

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Abstract: Recent studies suggest that conflicts play an important role in educating innovation competency in learner-centered and group-organized curricula. However, there are two opposite views, either constructive or destructive, regarding conflicts' effects on developing innovation competency. Thus it is important to investigate both students and academic staff's perspectives, which could address this issue from practitioners' experience. This paper conducted one case study in problem based learning environment. The research questions were as follows: (1) how learning trajectories were related with conflicts and innovation competency from students' perspective? (2) how learning trajectories were related with conflicts and innovation competency from academic staff's perspectives? (3) how students and academic staff's perspectives were similar and different from the literatures? Besides providing a brief literature review, we collected empirical data by one-year observation and 14 interviews in one engineering master program, Environment Management, at +++ University, Denmark. The empirical findings display diverse views on conflicts in relation to innovation competency from both students and academic staff's statement, which reminded educators to reflect the use and implementation of PBL curriculum. Furthermore, their understandings on conflicts and innovation competency unfold the learning trajectories as the escalating process of conflicts, which could end up either as constructive or destructive on developing innovation competency. Based on the findings, this study revisited the literature and proposed a tentative explanatory model to describe the relationship between conflicts and innovation competency. At the same time, we suggest conducting further research to critically rethink PBL and its effects on cultivating innovation competency.

1.Introduction

To promote economic growth and national competitions, current policies aim to educate innovative engineers, who can contribute both on technology function and business value. Meanwhile, the increasing need of specialized and unique products requires engineers to innovate in relation to cross-disciplinary fields. Traditional engineering education is losing some of its relevance in relation to these new requirements of the engineering knowledge and profession [1]. In many universities, the traditional engineering curricula are increasingly replaced by learner-centered and group-organized approaches, such as problem based learning (PBL). Facing employer demands for innovative engineers, engineering education has tried to connect engineering scientific knowledge with professional practice. New educational models, like problem based learning (PBL) curriculum, are intended to integrate subject knowledge into projects, empower students to direct their learning activities and overcome separation of knowledge and practice. It seems that these new curriculum models have broken down conflicts between social requirement and traditional pedagogy. However, recent studies have found that such

learner-centered and group-organized approaches give rise to a whole new set of conflicts amongst students, while trying to foster innovative engineers [2]. Collective learning and self-directed learning in groups are made up of complex processes in terms of relationship and cooperation. Differences, arguments, debates and conflicts are inevitable in group-organized learning. As a recent research revealed, there are several types of conflicts, which are highly related to innovation competency, in PBL curriculum [3]. Thus, it is important to take "conflicts" as a research subject and investigate their relationship with learning innovation competency. As both "innovation competency" and "conflicts" are used widely in social science research, it is important to point out the use of these two terminologies in this study.

In the field of engineering education, Creativity and innovation research began to blossom in the 1950s [4]. It has been explored in relation to process, product, person and press (the environment) [5-7]. Specifically to engineering innovation competency, the central themes contain both newness and usefulness [8,9]. During the engineering projects, innovation is a process to place new ideas into practice, where innovation competency acts as a fundamental instrument. Along those lines, this study departs from Sawyer's [10] definition of individual innovation competency, which takes it as the emergence of something novel and appropriate, from interactive processes in teams and organizations. Specifically, an innovation process starts from introducing new ideas, goes through processes of communication and collaboration, and ends with new and useful products. It involves a wide range of human abilities and processes such as personal ability (in finding real life problems and formulating research questions), interpersonal ability (by being open and responsive to diverse perspectives and constructing collaborative relationships intentionally), and implementing ability (by implementing their ideas to useful project effectively)[11].

Among literatures on innovation and creativity, conflicts generally refer as tensions, contrasts, contradictions, or oppositions between two propositions. Specifically in learning process, conflicts could be the opposite perspectives, cognitive controversies or personal disagreement. Disagreement and oppositions are the essential elements of conflicts in this study. Thus, conflicts don't have to be violent and chaotic. To be more specific, conflicts in this study, could be cognitive disagreements, which address the different opinions regarding problems, methods and actions; conflicts also can be oral arguments, which manifest during group meetings and daily communications; conflicts might be personal problems, which involves emotions like dislike and anger. Meanwhile, it is also important to point out that, this paper uses "conflicts" instead of "contradictions" or "argument" for the following reasons: (1) 'conflict' reflects both psychological and social views ;(2) 'conflicts' was the term used by students and academic staff in this study.

2. Problem statements

As locating this study on conflicts and innovation competency, we tried to situate our specific research questions based on current literature and insights from fieldwork. Here, a brief literature review, regarding innovation competency and conflicts, and first-hand empirical observations will served as the starting point of this study.

2.1 The opposite voices on conflicts and learning innovation competency

The focus on innovation competency within engineering teams is informed by learning literature and team innovation literature. A multitude of examples in the literature have demonstrated that effectively organized teams can accomplish tasks and facilitate individuals to be innovative. They argued that conflicts have the potentials to offer the spurs to individuals to recognize barriers, errors, and weaknesses in problems and projects. Conflict does not in itself promote an individual's competency or team outcomes. In the view of many learning scientists, conflicts and learning are two sides of one coin. For example, Piaget consider peer interaction to be one of the most critical factors in cognitive development; interactions result in arguments, debates and conflicts; conflicts lend opportunities for students to decenter or consider others' point of view; the less students debate, the less they achieve development [12]. Vygotsky emphasizes the important role of conflicts in learning as well. He examines learning together in order to resolve cognitive conflicts in certain social contexts [13]. The Finnish scholar Engeström has developed his activity theory and proposed expansive learning. He points out that 'contradictions' in learning activity are the source of change and development [14]. These learning perspectives appear to suggest that conflicts provide essential cognitive resources for learning and innovation. While conflicts being the driving force towards innovation, conflicts management were suggested as the factor that made innovation happen eventually. For example, scholars advised that team members have to learn how to deal with conflicts by interacting, sharing and developing cognitive, emotional, and instrumental resources, so that they develop knowledge and skills, contribute in teamwork, and enhance innovation and effectiveness [15].

Besides the positive views on conflicts and innovation competency, there are also many scholars, who take conflicts as the barrier of developing innovation competency. Conflicts become destructive, when team members engage in debates and start to personalize these debates. Human beings are emotional and personal in terms of power struggles and subjective incompatibilities. Opinion debates can create strain and hostility among team members. Thus, some scholars propose that conflicts can transform from constructive to destructive. Within learning theory conflicts are also seen as damaging to decision-making, when it disturbs team members and drive them away from the critical issues of the project. For example, Holzkamp describes how conflicts can end up as a destructive factor in learning. He considers learning as a modality of intentional action and tries to analyze it in terms of an interrelation between societal possibilities to act (depending on the historical conditions and the subject's situatedness) and individual reasons to act (mediated by meanings, which are constructed in response to the subject's vital needs and interests) [16]. Accordingly, he argues, learning mostly takes place in order to avert negative effects such as bad grades. He implies that students would rather take fewer risks and stay safe, when students are confronted with conflicts. In this way, students would try to cope with challenges and conflicts more strategically, in order to invest a minimum of effort. In these contexts, rather than seeking autonomy and innovation, the achievement of good grades becomes students' priority objective. Thus, from his perspective, it seems that education, although it provides a wealth of possibilities to learn, often fails to generate innovation and creativity.

Some researchers try to identify different types of conflicts and investigate their impact on innovation separately. Two typical kinds of conflicts are found---task conflicts and relationship conflicts. Many researchers consider task conflicts as constructive on developing innovation competency, while relationship conflicts are seen as destructive [17,18]. In general, there is little knowledge on the impact of conflicts in the educational context, such as PBL. These type-oriented analyses suggested that different conflicts end up with certain outcomes, either innovation or disasters, within group-organized learning. The prescription for resolving conflicts seems simple – teams should stimulate task conflicts while avoiding relationship conflicts. However, that there is no systematic account and investigation on how conflicts related to innovation competency during learning process.

As stated above, a wealth of literature has demonstrated both constructive and destructive effects of conflicts on learning innovation competency in team-organized learning. There is, however, little research on describing and understanding on conflicts in relation with learning process. To address this knowledge gap, we examine conflicts and innovation competency in students' learning trajectories. To do so, we took +++ University as the research site and aimed to investigate the above problem in real curriculum practice.

2.2 Field work and the focus of this study

+++ University's curricula are based on problem-centered, real-life projects of educational and research relevance. With its strong emphasis on active learning and team-organized learning, problem and project based learning (PBL) incorporates many factors providing powerful facilitation in terms of innovation competency [19, 20]. This paper conducted the fieldwork in one master engineering programme at +++ University, Environment Management (EM). This Master of Science Programme was selected for the following reasons: innovation competency is one of the key skills that the EM programme is intended to cultivate among students; it is a typical engineering programme with a well-rehearsed PBL curriculum and finally curriculum practice in the EM programme was fully accessible to the researchers of this study.

In order to obtain insight into project procedures and group work, this study began its empirical work with selective observations and informal interviews. Coming to group learning processes, we observed that conflicts were unavoidable. Students also brought up the topic of difference/arguments/conflicts during informal interviews. Academic staff correspondingly talked about tensions/conflicts in relation to students' learning. It turned out that both students and academic staff saw conflicts as a vital factor during students' project work, and they mentioned several different conflicts in PBL curricula. However, they hold very different opinions regarding conflicts and their effects on learning. Unlike on the literature, these different opinions were building up on the same group-learning experience, which made this study become more interesting. During the same time, these team-based experiences offered us sufficient chance to observe that conflicts arose from clashes of contradictory ideas, interests, motivations, work styles, needs, and wants. And the on-site observation updated our recognitions on the emerging of innovative ideas, conflicts, learning outcomes, etc. Informal conversations helped us to understand both

students and academic staff's views on the conflicts and learning. Both observations and informal conversations made the final interview highly relate with the events in their daily learning activities. These first-hand data from the fieldwork narrowed our attention to the following research questions:

(1) how learning trajectories were related with conflicts and innovation competency from students' perspective?

(2) how learning trajectories were related with conflicts and innovation competency from academic staff's perspectives?

(3) how students and academic staff's perspectives were similar and different from the literatures?

3. Case Study

3.1 The Case context: EM program in +++ University

In 1974 +++ University was established and has been characterized by designing the problem and project based learning curriculum. It differentiates itself from the older and more traditional Danish universities due to its pedagogical structure, which is based on problem-centered, real-life projects of educational and research relevance. This model is internationally known and recognized as "The +++ Experiment" or "The +++ Model". The Master of Science Programme in Environmental Management (EM) at +++ University (Denmark) mixes both Danish and international students and is taught in English. The programme aims to cultivate professional environmental engineers or leaders who can solve sustainability-related problems in private or public organizations. The curriculum for this program is organized into four semesters in two years. Each academic year, there are approximately 35 students (Danish 50% and foreign 50%). The work on a project report and in courses (related to the theme) covers approximately 80% of each semester and is equivalent to 24 ECTS (European Credit Transfer System). The rest of the semester is made up of fundamental courses or other compulsory courses. Project work is formulated within the framework of the given themes and is related to the overall educational objectives, which can be broad, open themes or a subject-related limited themes. Students are allowed to formulate their project proposal themselves. Students are expected to attend the courses and apply the knowledge gained in them in their project work. The output of the courses is assessed along with the project work at the end of the semester.

3.2 Data Collection Methods

Formal interviews refer as on semi-structured interviews with 4 academic staff and 10students, which serve as the primary data source. These ten students belonged to two groups (5 students per group). Four academic staff supervised these two groups (2 supervisors per group). Each semi-structured interview lasts for a total time of 1.0 to 1.5 hours. And the structure of the interview was determined in relation to the research questions, and followed some basic shape of academic staff and students. Besides the formal interviews, informal interviews and selective observations serve as the additional

data for further understanding on the primary data (Check details on Table 1). Informal interviews are largely unstructured, where questions are prompted by the flow of the conversation. These types of interviews were held as we spent time in the classroom and team room and wanted to understand how the students made sense of their own experiences as they related to innovation competency. Students and academic staff were asked questions related to the projects they were currently working on as well as their attitudes and thoughts PBL curriculum they were enrolled. Selective observation generates detailed information about the practice of curriculum in three cases, helps on understanding the process based on combining data from interviews, informal talks, and so on. These observations were non-participant observations. As a non-participant observer, we spend time in the field with the participants to generate data, but does not extensively interact or interfere with the participants or the behaviors under observation. The observations capture the interactions between the students and academic staff. After one semester's observation on EM program, this study has identified certain patterns of practice in PBL curriculum. Detailed descriptions of the observations were recorded as field notes. And they contained both "emic data" (describing what is seen or heard) and "etic data" (describing the researcher's thoughts or ideas about the description). However, here we

Primary Data	Interviewees of formal interivews		
Semi-structured Interviews	*Group 1*	*Individual interivew*	Students (5 in total): *A, B, C, D, E;* Academic staff (2 in total): *K, L*
	Group 2	*Individual interivew*	Students (5 in total): *F, G, H, I, J;* Academic staff (2 in total): *M, N*
Additional Data	Check list for observation		
Selective Observation	Observation occasions checklist □Group formualtion □Group meeting □Supervison meeting □Mid-term evaluation □Final examination	Chekclist for seeing and hearing □Conflicts (what) □Facilitation (who) □Facilitation (How) □Facilitation Outcome (project progress)	Researcher's relfection □ What's new today? □ Students' change on behaviors □ Communication pattern □ Rethink my interpretation
Additional Data	Informal conversations		

Table 1 Data Collection Process

3.3 Data analyzing

This study employed semi-structured interviews consisting of open-ended questions. The interviews were designed to collect descriptive data in the interviewees' own words and develop insights about the interviewees' conceptualization. The majority of questions were under the interview guidelines (see in the attachment) determined prior to the interview. Word order was modified on site and additional relevant questions were posed depending on the interviewer's perception of the flow of the interview. For example, some of the data reported in this paper came from responses to interview prompts such as "what do you mean by arguments". Meanwhile, interviewees' own words will be used to explain their conceptualizations instead of using the technical academic concepts from the literature.

Each interview can also be followed by an evaluation which considers questions such as: 1) what new information (concepts, reasoning etc.) did the interview provide? 2) Does any of this new information open new conceptualizations in the answering of the overall research question? 3) How can this new information be tested/broadened in later interviews? And 4) How does the new information fit into information from previous interviews?

The interviews were transcribed following a transcription style sheet to maintain the same conventions. The transcriptions were thematically analyzed in two cycles: first, identifying the text that used explicit concepts and second, coding the identified text and classifying and organizing the ideas into a framework that can describe how interviewees used the concepts.

4. Findings

In seeking to grasp the learning processes, this study investigates individual student's learning experience regarding conflicts and innovation according interviewing students. Regarding academic staff, although their understandings were based on their supervision experiences within groups, we asked them to address conflicts in relation to individual students' learning.

4.1 Students' perspective

Constructive learning trajectory: Student C&F&E&G

The majority of the interviewees describe their learning trajectories as a constructive process when confronting conflicts. They were able to be aware of conflicts existing during learning process. Instead of being afraid of conflicts, they showed their positive attitude towards conflicts and learning.

" Of course, there are different opinions in the beginning. There are five members in our group. And we come from different countries, with different expertise. I am actually happy to see the difference and argument. I could be wrong in some way. It's interesting to see others' perspective of our project."

Regarding innovation competency, students used self-reflection as the way to transform conflicts into innovative ideas.

"Generally, I would like to start reflecting my own proposal. It's not like I am not confident on my self. It's just a way to seek more information and rethink our project. There might be some weak or incomplete part in my proposal. As they didn't agree, that means there must be something I need to improve."

However, students didn't have clear thoughts on the productive results of conflicts on innovative ideas. They generally illustrated that they gained a deeper understanding of their project and a broader knowledge in a conflicting situation.

"I feel like I know more about our project after understanding others' ideas. It's like I had one set of knowledge and perspectives. And they provided four more sets of knowledge. After I really understood their ideas, I got five sets of knowledge. Then no matter how we conducted our project, it's not his or my idea anymore. It's us. And the idea is some kind of new because we were able to combine different perspectives into a new form of knowledge."
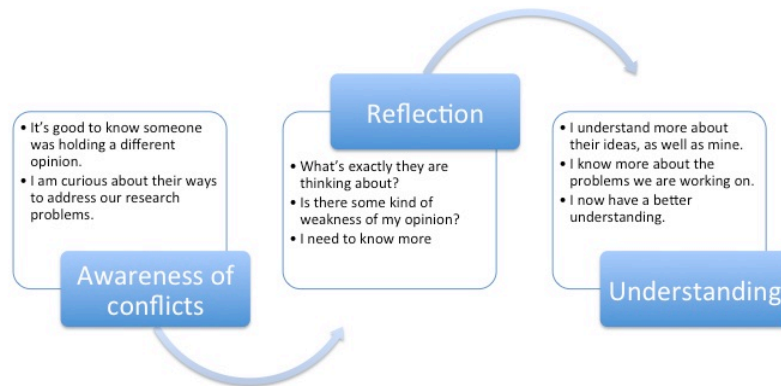
Figure 1. Constructive learning trajectories regarding conflicts and innovation competency

Destructive learning trajectory: Student A&I

However, some students were quite unhappy about their learning experiences in problem based learning, not to mention innovation competency. They complained about their peer learners in groups and academic staff's facilitation. During the interview, they seemed quite emotional and depressive about the conflicts happening in their groups. These conflicts often started from different opinions on doing projects. But these students couldn't accept these differences.

"I couldn't understand why he keep disagreeing with me. If he can provide a better idea, it's fine. But the only thing he did was rejecting others' idea. He was just afraid of losing control. It's true he was the one proposing the first idea of this project and attracting us to be a group. But he had to understand it's everybody's project afterwards".

Instead of focusing on project topics, students easily generate negative emotions when they cannot take others' disagreement very well. They felt insulted, unsure and frustrated. And these negative emotions lead to dislike towards the opponents.

"I just feel so disappointed of this whole arguing situation. We were not working. He was wasting our time. He cannot listen to others. Things won't work out like this when he just ignores others' opinion.

Once there were negative emotions toward group members, their relationship became unstable. They paid more attention on others' flaw on personality and working style. Instead of fixing problems, they just wanted to stop the connections.

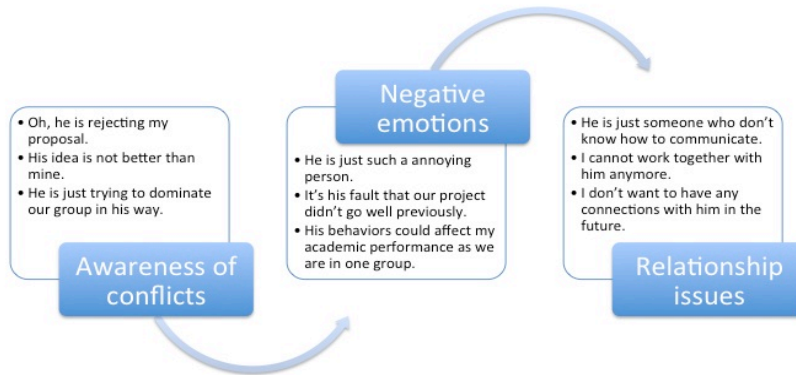*"He is not suitable for this kind of group work. At least, I cannot work with him anymore."*

Figure 2. Destructive learning trajectories regarding conflicts and innovation competency

Mixed learning trajectory: Student B&D&H&J

Many students didn't have one directly constructive or destructive experience with conflicts and learning towards innovation competency. They didn't expect to come across conflicts in problem based learning. And they weren't able to control their emotions at the first place.

"I was looking forward to problem based learning. The idea of student-directed learning is just so attracting. But when we started working in a group, the arguments and tensions surprised me. Personally, I don't like to fight with people, especially when everyone is right to some extend."

When group work became slow because of some students arguing from different perspectives, group members simply didn't like the troublemakers, who cannot step back or convince everybody.

"We could have done much better if they were not arguing everyday."

In order to finish their projects on time, students tried to rethink conflicts and figure them out. The time-pressure made them consider the conflicting points and possible solutions. To make this happen, students tried to coordinate conflicting ideas by mutual understanding.

" When I realize we cannot argue anymore, I just wanted to do something to stop this. What could I do? I reconsidered what exactly we were arguing for and how these conflicting points related to our projects. Suddenly, I saw the overlapping parts of opponents. And I had to admit I never saw this previously."
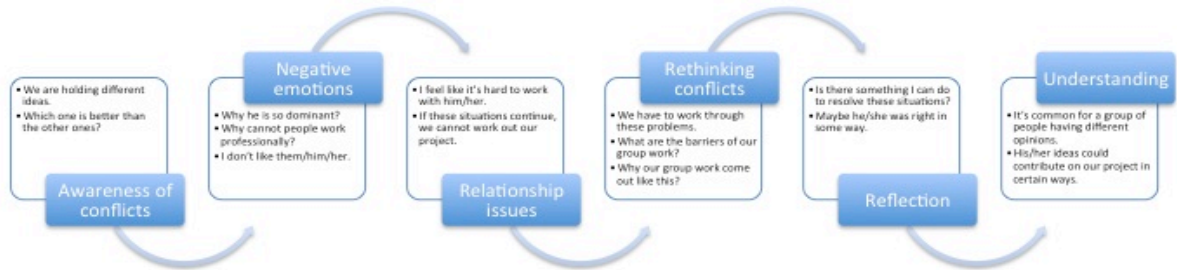
4.4

Figure 3. Mixed learning trajectories regarding conflicts and innovation competency

4.2 Academic staff's perspective

Comparing students' statement based on experience, academic staff seemed like to explain the relationship between conflicts and innovation from the pedagogical view of learning. On one hand, they took conflicts as the driving forces for innovation competency in general. For example, as one academic staff explained:

"As working in a group, they couldn't work simply by agreeing. They have to learn to defend and analysis. And that's where they get to know the problem deeper and critically. This is where student learn how to identify the real and valuable problems among complex reality. Differences and arguments could help them to get there. As one of the most important parts of problem based learning, problem formulation could benefit a lot from conflicting ideas."

And specifically, they pointed out that conflicts serve as the constructive factor in a long run. Like one academic staff elaborated as below:

"The first-semester students might feel like they failed their projects because of conflicts during group work. But this is where they learn how to work as a team. And this is exactly what could happen in the workplace. They will survive, grow and eventually benefit from these unhappy problems. "

On the other hand, they pointed out relationship conflicts could mainly caused by different personalities and group's composition. These conflicts were taken as unavoidable and unchangeable based on some of their opinions. And they elegantly avoided describing learning together with these kinds of problems.

"I noticed the problems you mentioned. But I think that's their personality. And they should work professionally instead of being personal. "

Addressing the constructive process, academic staff all pointed out the importance of team management.

"It's very important for them to develop team-management system, which could help them to work effectively. Furthermore, the management is crucial on building a community where they can express ideas without any fears, where they can risk in an effective way. "

5. Conclusions to the research questions

Regarding to research question "how conflicts are related to innovation competency from students' perspective", different learning trajectories were described based on students' individual learning experience (as described in figure 1-3). Several students were able to benefit from conflicts in problem based learning. Among these students, some of them had problem based learning experience before. Some were forced to deal with conflicts positively and actively, as they want to make things work out. Some comprised at first place, then encouraged participating in argument as they started to feel safe to do so. And obviously, they learned these strategies of transforming conflicts into innovation from hidden curriculum of problem based learning. They mentioned that they not only thought about their project, but also consider how to behave in a group, how to be popular among group members and academic staff, what make a project good, what factors affect their final grade. However, instead of reflecting and using these conflicts, some students were mainly pre-occupied with personal conflicts arising among group members. Ultimately, they perceived the whole problematic is interpersonal problems. At the same time, these students feel frustrated to do project in a team. They hoped that they could get more direct supervision from academic staff. Students were not well informed about the challenging conflicts in problem based learning. They didn't realize that they would confront diverse conflicts during their leaning. And they were not well prepared to deal with these conflicts, not to mention using these conflicts as the trigger for innovation. Some of them even confused about the efficiency of PBL on educating innovation competency, even learning. These confuse were mainly referred to students conflicts could took too much time and end up with mediocre satisfactory learning outcomes.

Regarding research question " how conflicts are related to innovation competency from academic staff perspective", academic staff took conflicts as constructive factors in learning innovation competency. However, they might mainly refer conflicts as the academic discussions during supervision meeting. Because they experience with students were based on group meeting, when students were behave more professionally.

Regarding the third research question "how academic staff and students' perspective are similar and different from academic staff's perspective", this study reveals several very interesting results. What are the students' learning trajectories when confronting conflicts? It's much more complicated than simply constructive or destructive. Comparing between practitioners, academic staff shared more common views than students. Comparing literature, students and academic staff related conflicts and innovation competency in the learning process (as described in Table 2). They described these elements in the process of problem formulation and conducting projects. More importantly, they pointed out one new dimension to do research in this field. As the academic staff mentioned "personality" and students talked about "self-reflection", it is important to emphasize the "self" as an agent in group-organized learning. Last but not least, conflicts could escalate as either opportunities or disasters for developing innovation competency based on students' experience. It could be very interesting to look up learning as an escalating way regarding conflicts and innovation competency.

Table 2. The comparisons among academic staff, students and literature

	Students	Academic staff	Literature
Constructive		×	×
Destructive	×		×
Depends on Escalation	×		
Depends on personality		×	
Depends on Management	× self & team	× team	× team
Depends on types			×

Based on findings, conflicts profoundly affect leaners' relationship and activities in problem based leaning. These affect could be used as opportunities of cultivating innovation competency. These finding remind us that educators and students couldn't simply take conflicts as destructive or constructive in problem based learning. Comprising and avoiding conflicts could not make problem based learning without conflicts. Instead managing conflicts and using conflicts could result in innovation as well as developing innovation competency among students. In light of these findings, we may come to understand the issue of conflicts in cultivating innovation competency in a better way. Meanwhile, it could help us to reflect the facilitation process in PBL learning environment.

6. Further discussion

By paying attention to a previously underexplored construct in problem based learning, this research has uncovered the relationship between conflicts and innovation competency both theoretically and practically. First, we add to the problem based learning literature by offering new insights on the importance of conflicts. Previous researches have widely identified many variables that serve as triggers or barriers to innovative performance in PBL environment. For example, problem space, practice orientation, interdisciplinary, and facilitation. Here, this study identified an important new factor, namely conflicts. Unlike the focus of group creativity in problem based learning, we paid attention on individual experience: the learning trajectory that individuals have when they facing conflicts. We showed that individuals' reflection played an important role on transforming conflicts into learning opportunities. Second, we contribute to innovation research on cognitive theory to understand the relationship between conflicts and innovation competency. Our finding support that conflicts could deepen understanding, broad knowledge and trigger innovation. Meanwhile, conflicts could play a negative role on innovation and learning, when students take conflicts personally and lose emotional control. Finally, this research could enhance educators and scholars to rethink the effectiveness of problem based learning. Although this paper could not prove either the positive or negative impact of PBL curriculum on educating innovation competency, we presented the great potential of unsatisfactory learning experience as results of conflicts. Thus the practice of PBL curriculum should put conflicts into consideration. Both academic staff and students need to understand escalation process of conflicts. In this way, they could use conflicts instead of being messed up with conflicts. It's also worth to mention that this study is limited as the use of case study, which may limit the external validity of our findings. It is necessary for

scholars to gain more knowledge regarding both constructive and destructive process of conflicts and innovation competency.

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