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Factors Influencing Group Creativity in Project-organized Teams in Engineering Education in China*

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In China, project-organized learning is regarded as a strategy to foster creative engineers. This study explores the link between project-organized learning and group creativity. We regard group creativity as a socio-cultural concept, influenced by factors from a social and cultural context. Relating this point to project-organized learning in engineering education in China, this paper focuses on which factors influence group creativity development in project-organized teams. Multiple methods including questionnaire and interview were employed. A CCQ (Creative Climate Questionnaire) survey was conducted among 126 members from 25 teams at seven universities. Interviews were carried out with eight team leaders. Research findings show that a series of factors such as task challenge, group diversity, conflict, group size and membership change etc. influence group creativity interactively; however, risk taking is not encouraged in these teams, which could be the potential barrier to creativity. Therefore this paper has contributions to implications for engineering education innovation.

Keywords: group creativity; project-organized team; engineering education; Chinese culture

1. INTRODUCTION

WITH THE RAPID CHANGE of society, engineering practice is increasingly characterized by a highly collaborative and innovative process. The scope, timeframes, and complexity of most projects require the effort of groups of engineers—experts in some aspects of engineering practice working in coordination with other experts [1]. The increasing challenge of engineering work requires future engineers to be competent in teamwork creatively, which leads to group creativity development becoming one important issue in engineering education.

In previous years, some actions aiming to assist excellent future engineers with project work have been taken in some universities in China. Learning in project-organized teams is considered as a promising strategy for postgraduate level education. By this strategy, students have opportunities to participate in projects supported by government or companies. Usually, the project teams consist of supervisors and their students from different levels and diverse backgrounds. However, there are always some new recruits entering teams and graduates who leave at every semester, so a high personnel turnover rate exists in most projects which are at least one-year-long with aims of solving real engineering problems needed in society. The supervisors are professors in universities with responsibilities of leaders in these teams, as well as being experts in some fields of engineering education. For engineering students, learning is organized through practical problems and in collaborations among group members, which may develop skills of creative thinking along with the problem-solving process.

Previous research on group creativity has shown it to be basically a social-cultural concept, influenced by factors from an organizational environment in a given cultural context [2–5]. Relating the previous work to the learning environment, this paper aims to study factors influencing group creativity development in project-organized teams in a Chinese engineering education context. Two research questions will be focused on:

1. which factors will influence group creativity development in project-organized teams?
2. how do these factors influence group creativity development interactively?

Multiple methods including questionnaire and interviews were employed and discussed in this paper. Empirical data are derived partly from a survey on group climate by using CCQ (Creative Climate Questionnaire) [6–8], which was conducted among 126 members from 25 project teams at seven engineering universities in Northeast China. Other data are from interviews carried out with eight team leaders (professors/supervisors) out of the 25 teams

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with focus on their perceptions on students' group creativity. Analysis of the findings suggest that there are a series of factors such as task challenge, group diversity, conflict, group size, group openness, member change, project management, that play influencing roles on group creativity development in engineering project-organized teams, while risk taking is not encouraged among students due to the project management system and Chinese cultural influences. These findings are expected to have implications for innovation implementation in engineering education.

2. THEORETICAL RESEARCH

2.1 Challenges of engineering education and creativity development

There are many studies suggesting that engineering education is facing a growing number of challenges. Rugarcia et al. [9] described seven features that will pose challenges to future engineers:

1. Information: Proliferating;
2. Technological development: Multidisciplinary;
3. Markets: Globalized;
4. The Environment: Endangered;
5. Social Responsibility: Emerging;
6. Corporate Structures: Participatory;
7. Change: Rapid.

Against the background of challenges, "creativity development in engineering education" has been an important issue. For example, Thompson and Lordan [10] reviewed creativity principles applied to engineering design; Cropley and his colleague [11] explored some studies on creativity assessment in engineering undergraduates. Some barriers to creativity in engineering education have been researched from instructors' and students' perceptions by Kazerounian and Foley [12].

Diverse pedagogical practices with the aim of fostering creative engineers have been explored in many engineering educational institutions. Learning through project work is thought to be a promising strategy in different countries, for example, in Denmark, U.K., Australia, Finland, Brazil, Spain, and elsewhere [13]. There is Project-led Education in Portugal [14], Project-centered Learning in the USA [1], and Project-organized Learning in China as introduced in this paper. These strategies have common underlying assumptions that creativity can be stimulated by a suitable environment and using effective exercises in practice. The idea that teamwork is the basic way to organize learning activities by these strategies, brings in a series of research studies on student groups in project work [15–17].

2.2 Social-cultural view of creativity and group creativity

There are many definitions of creativity ranging from the very simple to the highly complex, but most see creativity as involving the generation of novel and useful ideas [3]. Researchers commonly use the metaphor of the "big c", which means something that emerges as historically new within the broader culture. In this paper, we focus on the "little c", which lies at the opposite end of the "big c", referring to creativity in everyday life as people try to solve problems at work and at home or on the road in between [4]. The "little c" could be seen as a way of expanding what we know and what we can do—in which case it could be said to be an aspect of learning. When we learn something new, we make new connections between ideas and make sense of them by constructing knowledge. In this sense we may describe what we are doing as being creative [5].

In recent years, researchers in the USA [2–4], Sweden [6, 7, 18], U.K. [5, 19], Germany [20], Norway [21], and some areas in Asia [22–24] have suggested that creativity is fundamentally a social-cultural concept, though new ideas originate in the mind. For example, Csikzentmihalyi [25] suggested that any creative idea is affected by three main shaping forces: the field, the domain, and the individual. The field is the set of social institutions that selects only those creative products worth preserving. The domain is the knowledge base and culture that will carry the new ideas or forms forward to the next generation; ideas must be accepted by a larger audience before considered creative. The individual is the one who brings about some change in the domain that the field will consider to be creative. Moreover, the development of novel ideas requires a certain degree of knowledge and experience, a willingness to take risks or take unique perspectives, and a style of bringing together diverse or previously unconnected domains. From the various ideas that are generated, the most useful must be selected and then promoted to gain social acceptance [26].

The concept of creativity as a socio-cultural concept therefore involves both the individual and the environment that the individual interacts within. Accordingly, when we focus on creativity at group level, the system view on interactions should be emphasized—"creativity, especially in collaborative new product groups, is not an individual trait, but a product of complex interpersonal interactions with a system" [27]. Furthermore, the interaction is influenced by factors from a social and cultural context. For example, Grossen [28] suggested the characteristics of the task, its social and personal meaning for the subjects, the activity in which the task takes place are all elements which frame and orientate the subjects' interactions. Similarly, Rojas-Drummond et.al. [29] argued that the micro-context of the interaction is related to the other contexts, the institutional context of a school, for example, and, more broadly, the cultural practices at work outside the school.

Relating these considerations to the learning environment, educationalists are increasingly

coming to realize that learning and creativity in groups go hand in hand, especially those working within the approaches that have been labeled socio-constructivist, cultural-historical, or socio-cultural [30]. In these approaches learning is regarded as having a collaborative meaning—making knowledge construction rather than knowledge acquisition. Such conceptions have tended to break down the old dichotomy between learning and creating [31]. Therefore, in successful group learning settings, participants build on each other's ideas in order to reach an understanding that was not available to any of the participants initially. Group members 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 talk. These conditions are similar to those needed for collaboration in creative endeavors [30].

2.3 Factors influencing group creativity development

The socio-cultural approach has brought much attention on environmental factors influencing group creativity development. For example, West [4] focused on interactions in a team context, team process and organizational context; Milliken et.al. [4] explored studies on the relationship between diversity in group composition and creativity in work groups; Simonton [4] analyzed short-term effects and long-term effects from a socio-cultural environment on group-level creativity. There are also many studies emphasizing factors from the group climate [2, 6, 7, 18, 32]. From previous literature, we draw the implication that the impact of any social or cultural factors can be understood by taking the individual-group-context interactions into account, which always applies to any collaboration in creative work. Linking this to the aim of this paper, we decided to review influencing factors from aspects of group composition, group process, group climate, and cultural context. The group composition and group process focus on interactions among individuals within a group, since group composition indicates what the individuals themselves may contribute to the group, and group process means how individuals engage in group work. The group climate and cultural context focus on interactions between group and its environment, as well as individuals and the environment, with the latter taking a broader view than the former.

2.3.1 *Group composition*

Group composition refers to the representation and balance of people in the group [33]. The common approach to group composition involves how the composition on a given attribute affects group performance. These attributes include member ability (e.g. knowledge, skill, task experience), belief system (e.g. value, attitude, culture), member styles (e.g. personality, cognitive and behavioral style), and demographic characteristics (e.g. race, gender, ethnicity). Some of these attributes (e.g. demographic characteristics) are more visible than others (e.g. personality), and, all else being equal, visible attributes have a stronger and more immediate impact on groups than do less visible attributes [4, 16, 17].

The majority of work involving the link between group composition and creativity has dealt with how diversity in member attributes relates to the creativity of groups. Previous work in this research tradition generally supports the notion that diversity is a mixed blessing. For example, Thomposon and Choi [19] pointed out that diversity promotes group creativity through the wide range of ideas, perspectives, and solutions that members bring to the task, but is associated with less desirable outcomes such as low member satisfaction, weak identification with the group, greater emotional conflict, and higher turnover. Similarly, research on how membership changes affect group functioning has also been distinguished by two main perspectives: the disruption perspective and the stimulation perspective [4]. Thus, we can see diversity or membership changes as two sides of a coin.

2.3.2 *Group process*

Group process is described as the way individuals contribute to common goals of the group along with collaborations among members [4, 19]. As West and his colleagues [19] pointed out, the key group processes that enable the team to translate the effects of diversity of knowledge into creativity are clarifying and ensuring commitment to shared objectives, participation, minority influence processes, support for ideas to introduce new ways of doing things, and reflexivity. Researchers also have looked at how group members can work together to improve innovation. Many different process interventions exist and all help the team to improve group creativity. Accordingly, several techniques have been developed to help teams generate many ideas and move from idea generation to choice, for example, the brainstorm technique [34] and the TRIZ [35].

Some studies of the relationship between individual creativity and group creativity along with group process have been explored. Researchers have tackled this issue by focusing on the contributions of individual group members, or on the group processes and broader contextual influences, or by examining the interaction between member contributions and group processes [36]. Project management in group is essential to stimulate a dynamic group process [37]. Amabile [2] suggested that the sense of control over one's own work and ideas, sufficient resources and time, pressure and so on relating to management can influence creativity in groups.

2.3.2 *Group climate*

Climate has been found to play a crucial role in achieving objectives of group work, which indi-

cates the reflections of group members from interaction between the group and the environment [6, 7, 18, 38–43]. As Ismail [32] said: "climate is defined as the recurring patterns of behavior, attitudes, and feelings that characterize life in organization. At the individual level of analysis, the concept is called psychological climate. At this level, the concept of climate refers to individual perceptions of the behavior. When aggregated, the concept is called organizational climate". Thus group climate is perceived and shared perceptions by group members involved in teamwork. It enables members to generate and implement creative ideas more effectively [39].

Ekvall's [6, 7, 18, 41] research is an influential and comprehensive study to measure and understand group climate. From the organizational perspective, he highlighted group climate as "a conglomerate of the attributes, feelings, and behaviors which characterize life in an organization". Relating to other studies, some factors from group climate have been suggested as relevant contributors and inhibitors of creative behavior within groups. For example, those factors including idea support, shared vision and goals, freedom, collaboration, ownership of ideas, commitment to the team, challenges at work and trust in each other are thought to be positive. However, conflict and organizational impediments are seen to have a negative impact [3].

In practice, some instruments aiming to examine the climate factors that influence group creativity have been designed and employed based on theoretical research, such as Creative Climate Questionnaire (CCQ) [6, 7], Team Climate Inventory (TCI) [42], and Team Factors Inventory (TFI) [43]. The validity of these instruments has been discussed and compared in studies [21]. Studies showed that the CCQ developed by Ekvall [6, 7] has been welcomed in many organizational environments. It has the range of factors covering creative climate within a given context, which both stimulate and hamper creativity. For practitioners, it is an appealing questionnaire owing to the fact that it has a well-arranged structure of 10 relevant climate dimensions such as challenge, freedom, idea support, and conflicts, etc. It has previously been applied in research in Europe and Asia, especially in studies involving Swedish, German, and Spanish organizations [21, 32].

2.3.4 *Cultural context*

Culture has been highlighted in reference to its influence on creativity in a growing number of studies. For example, Csikszentmihayli [25] emphasized the role of culture in shaping creativity by carrying the new ideas or forms forward to the next generation. Lubart [44] suggested that culture provides a set of facilitating and inhibiting conditions for creativity that influence the general level of creative activity. As he explained, several beliefs embedded in cultures may work against creativity, such as "fantasy and reflection are a waste of time", "playfulness is for children only", "there is a right answer", and "reason, logic, numbers, utility, and success are good-intuition, emotions, qualitative thinking, and failure are bad". These may affect "perseverance", "tolerance of ambiguity", and "risk taking" in family, education, or a given organizational environment, which have often been identified as important for creativity. For example, Ng and Smith [45] carried out some empirical work aiming to study how beliefs embedded in culture affect teachers' attitude toward learners' creativity development in classrooms, and found that some teachers in Singapore who are socialized into the Confucian tradition tend to get obedient behavior from students and tend to control their activities in the classroom, which are barriers to the development of a creative learning environment. Therefore Claxton and his colleagues [46] argued that to see how creative mentalities might be developed we have to attend to the cultures that operate in schools and classrooms, and to a process of cultivation that is slower than "teaching" or "training", but possibly more effective in the longer run, since "like any other habits, creative habits of mind do not appear overnight".

To summarize, the reviews of previous work on the socio-cultural approach bring a deeper understanding of how group creativity can be influenced by factors from the environment. Moreover, these factors play mutually influencing roles on group creativity rather than separately, which is the "system perspective to creativity study" emphasized [25]. Inspired by these findings, we focus on factors from the learning environment influencing group creativity development in project-organized teams in engineering education in China, by examining aspects of group composition, group process, group climate, and cultural context. Accordingly, the findings are expected to contribute implications for improvement of project-organized learning strategy to stimulate creative engineers in higher education in the future.

3. METHODOLOGY

There are two main methods, questionnaires and interviews, of studying different factors that influence group creativity in previous works. Climate factors are usually examined by questionnaires. Also a few researchers have employed interviews as their major data source in studying other factors [47]. Questionnaires and interviews were employed in our empirical work.

3.1 Samples

Our questionnaire survey was conducted among 126 members in 25 project-organized teams at seven engineering universities in Northeast China. These teams were from 12 fields in education: production, electricity, electronics, material, chemistry, biology, medicine, agriculture, oceano-

Table 1. Samples in questionnaire survey and interviews

Name of University	Fields of engineering	Questionnaire Survey		Interview
		Number of teams	Number of members	Number of Interviewees
Northeastern University	*Electricity*	*2*	*10*	*2*
	Process	*2*	*10*	*1*
	Material	*2*	*10*	*1*
	Environment	*2*	*10*	*0*
Dalian University of Technology	*Material*	*2*	*10*	*1*
	Chemistry	*1*	*5*	*1*
	Ocean	*1*	*6*	*1*
	Production	*2*	*10*	*1*
	Electronic	*1*	*5*	*0*
	Environment	*1*	*5*	*0*
China Medical University	*Biology*	*1*	*5*	*0*
	Medicine	*1*	*5*	*0*
Shenyang Agriculture University	*Biology*	*2*	*10*	*0*
Shenyang Medicine University	*Medicine*	*2*	*10*	*0*
Shenyang Industry University	*Electricity*	*1*	*5*	*0*
	Material	*1*	*5*	*0*
Shenyang Jianzhu University	*Civil*	*1*	*5*	*0*
Total		*25*	*126*	*8*

graphy, environment, process, and civil engineering. Meanwhile, interviews were carried out with eight team leaders (professors/supervisors) out of the 25 teams. They came from six out of 12 fields including chemistry, production, material, oceanography, electricity, and process engineering at two universities (Table1).

3.2 *CCQ and group climate survey*

The aim of the climate survey to the teams is to study which factors influence group creativity relative to the learning process in project work. In this paper, the Creative Climate Questionnaire (CCQ) survey was employed. As previously mentioned, the CCQ was developed by Ekvall [6, 7] in Sweden, aiming to measure environmental conditions that may stimulate or hamper creativity. The Chinese version of this questionnaire was revised by Wu and his colleagues [8] in Taiwan. It includes 10 climate factors and is supposed to measure them with five questions in each factor. Nine of the factors include questions hypothesized to promote creativity. The tenth factor "conflict", is supposed to be negatively related to creativity (Table2) [21].

In the questionnaire, fifty questions were constructed to fit the ten factors. Each question consisted of statements which required respondents to determine the degree to which the statements were true of the organizational creative climate occurring in their groups. A five-point scale was chosen in our work which represents how accurate each statement was from 1 to 5. The "1" represented a degree equivalent to "not at all applicable strongly", the "2"represented "not applicable to some extent", the "3" represented "applicable to some extent", the"4" represented "fairly applicable", and the "5" represented "applicable to a high degree".

We selected CCQ instead of other questionnaires because of its advantages as mentioned. However, there were limitations in this study. First, it was developed in Sweden and then translated into English; the Chinese version was revised based on the English version [8]. Culture differences haven't been paid attention to because the brief paper-and-pencil creativity tasks or problem content is culturally relevant for the subjects [44]. Second, statistical results from the questionnaire can provide primary findings—it may show an overall status of research objective under hypotheses in our work. For example, we can get which factors are more significant than others but can't get reasons for that. Moreover, if creativity is studied within a socio-cultural theoretical framework, there have been complaints that it is not very appropriate for examining factors by the scoring system [44]. Therefore, it is necessary to broaden and deepen the findings from CCQ by interviews; other factors except climate and their relationships are expected to be studied as well.

3.3 Interviews with team leaders

In contrast to the statistical nature of the quantitative research, qualitative research is naturalistic, interpretive, and multidimensional [48]. As mentioned, eight team leaders participated in the interviews to share their perceptions of the influ-

Table2. Theoretical Factors of the Creative Climate Questionnaire

Factors	Description
Challenge	*The degree to which the people of the organization are emotionally involved in its operations and goals and find pleasure and meaningfulness in their job.*
Freedom	*The independence of behavior exerted by the members of the organization. In climates with a great deal of freedom people are given autonomy to define much of their own work.*
Idea support	*The ways new ideas are treated. In the supportive climate managers and colleagues receive ideas and suggestions in an attentive and receptive way and there are possibilities for trying out new ideas.*
Trust/openness	*The degree of perceived emotional safety in relationships. When there is a strong level of trust, everyone dares to present ideas and opinions since initiatives can be taken without fear of reprisals or ridicule in case of failures.*
Dynamism/liveliness	*In a dynamic climate, new things happen all the time and there are frequent changes in ways of thinking about and handling issues.*
Playfulness/humor	*The perceived ease and spontaneity, a relaxed atmosphere with laughter and jokes.*
Debates	*Encounters, exchanges, or clashes among ideas, viewpoints, and differing experiences and knowledge. Many voices are heard and people are keen on putting forward their ideas.*
Idea time	*The amount of time one can use for developing new ideas. Organizations characterized with much idea time are giving possibilities to discuss and test impulses and suggestions that are not planned or included in the task assignment.*
Risk taking	*The tolerance of uncertainty in the organization. In the high risk-taking climate, decisions and actions are rapid, arising opportunities are seized upon, and concrete experimentation is preferred to detailed investigation and analysis.*
Conflicts	*The degree of emotional and personal tensions in the organization. In climates with high levels of conflict, groups and individuals dislike each other and there is considerable gossip and slander.*

ences on students' group creativity development. There are two aims of the interviews:

1. to examine the findings of climate survey from a different perspective and by a different research method;
2. to gain a broader data collection for some new findings in order to get more overall conclusions. It is a deeper exploration of factors influencing students' group creativity based on the CCQ survey.

All the interviewees in this study had triple roles relating to their work: professors in academic research, supervisors in educating students and leaders or organizers in group management. Thus the data validity may be ensured for they have rich experiences in project work. The interviews are attempted to explore the following issues:

- Principles of group composition;
- Group process in project work;
- Factors influencing group climate;
- Project management within Chinese educational context.

The interviews were recorded and transcribed. Each of these interviews covered a number of points that had been specified in advance. Data were generated from the content analysis on the points made by the interviewees. However, it was found that most of interviewees tended to offer more positive ideas and experience than answers to questions regarded as being sensitive by themselves, for example, conflict in teams, disadvantages of project-organized learning, rules or reasons for eliminating members, self-assessments of their work, etc. This may bring limitations to any discussion of weakness in project-organized learning on group creativity development in this study.

4. FINDINGS AND DISCUSSIONS

The data analysis focuses on the two questions relevant to the aim of this paper:

1. which factors will influence group creativity development in project-organized teams in engineering education in China?
2. how do the factors influence group creativity development interactively?

The two questions lead us to some discussions as follows.

4.1 Which factors influence group creativity?

From the work on climate survey, we obtained an overall status of group climate in sample teams by the statistics of mean value for each factor in CCQ (Table 3). The ten factors are well evaluated by members, which mean the group climate is inspiring in these teams. Four factors including "challenge", "openness/trust", "conflict", and "risk taking" should be paid more attention according to statistics results:

1. "Challenge" and "openness/trust" achieve a higher score than the other factors, which means the two factors are most inspiring to group climate.
2. "Conflict" is evaluated at the lowest score in all factors. It is a negative factor, so a lower score is generally better. Therefore, conflict seldom exists in these teams.
3. "Risk taking" is evaluated at the lowest score in nine positive factors. It is considered the

Table 3. Mean Scores of Factors of Creative Climate

Dimension of climate	Min	Max	N	Mean	SD
Freedom	*2.00*	*5.00*	*126*	*3.90*	*.62*
Idea Support	*2.00*	*5.00*	*126*	*3.90*	*.72*
Trust/Openness	*2.00*	*5.00*	*126*	*4.00**	*.65*
Dynamism/Liveliness	*2.00*	*5.00*	*126*	*3.86*	*.71*
Playfulness/Humor	*2.00*	*5.00*	*126*	*3.58*	*.66*
Debates	*1.00*	*5.00*	*126*	*3.72*	*.74*
Conflict	*1.00*	*4.00*	*126*	*1.95***	*.69*
Risk Taking	*1.00*	*5.00*	*126*	*3.41***	*.64*
Idea Time	*2.00*	*5.00*	*126*	*3.71*	*.67*
Challenge	*2.00*	*5.00*	*126*	*4.23**	*.63*

*Note: *factors are evaluated with higher score than others (challenge, trust/openness); ** factor is evaluated the lowest score in nine positive factors (risk taking); *** negative factor, a lower score is generally better (conflict)*

Table 4. Group leaders' perception on factors influencing group creativity

Themes in the interviews	Factors influencing group creativity
Principles of group composition	• *Small group* • *Diversity in group members' ability, background, knowledge, personality, etc* • *Members' cooperative skills, sense of obligation and commitment, high level of motivation, etc* • *Membership change positively*
Group process in project work	• *Clarity of common goal and individual contribution* • *Communication and interaction among members* • *Rewards measures* • *Task assignment*
Factors influencing group climate	• *Challenge of project task* • *Group openness* • *Working relationships among group members* • *Communication and cooperation in group* • *Members' interests*
Project management within Chinese educational context	• *Resource assigned and expended* • *Time schedule*

most unwelcome factor by members in their group work.

In later interviews, more valuable data were generated:

1. Findings from the CCQ survey such as factors of challenge, conflict, trust/openness and risk taking were examined further.
2. Factors such as motivation, diversity, new number's ability, group size, project management, group openness, etc. were found (see Table 4).
3. These factors influenced group creativity interactively.

The two parts of findings achieved by different methods led us to a further discussion against the present Chinese engineering educational background.

4.2 *How do the factors influence group creativity?*

Based on the questionnaire, "challenge" is the most positive factor influencing group creativity, which is examined by interviews. All the interviewees have a common point on this factor, which means team members feel motivated, energized, and committed to making contributions. The climate is dynamic and inspiring. Members find their work to be personally fulfilling and meaningful to their teams, as one of interviewees said:

> To innovate is our motivation of project work. The project is a common interest for all members, and it is an opportunity to convince and develop oneself. Members are very excited when they succeed in solving some difficult technology problems. Interviewee A

Therefore, students' intrinsic motivation and working interest are encouraged in project work [49]. According to Cooper and Jayatilaka [50], intrinsic motivation arises from positive reactions to qualities of the task itself; intrinsically motivated individuals engage in a task primarily out of their own interest in it. Because they enjoy the task itself and the process of searching for new solutions, intrinsically motivated individuals are more likely to expend energy exploring the problem and finding creative solutions.

From team leaders' perceptions, measures of rewards is one way to stimulate motivation in these teams, for example, rewarding someone who makes a rapid progress or solves problems in new ways. Although some studies suggested that extrinsic motivation can't improve creativity effectively because people tend to focus on the rewards rather than on the task itself [2, 39], company management experience showed that the inter-

action between the intrinsic and extrinsic motivations effectively can increase creativity [51], which means some extrinsic rewards can stimulate passion, pride, commitment, and ownership to contribute to creativity, on the condition that a prominent task characteristic stimulates intrinsic motivation. Furthermore, the team leaders think project work makes varied demands on students and requires them to use knowledge and skills interdependently in parallel with cooperation with others. Thus diversity is one important principle of group composition. Actually, increasing the diversity of group membership can improve the number and type of innovative ideas coming into the group. Diversity in information, experience, and skills can lead to more comprehensive and effective decision making and high level group creativity. Therefore having variety in terms of functional background, education, company, tenure, and knowledge is known to have some positive effects on group decision performance.

> For the projects need cooperative work among people from different fields. It is difficult to solve complex problems only with one specialty. Members come from so many specialties in our group: computer, mechanic, control, metallurgy, and process engineering. It is interesting that so many people can solve one problem together: they have different background, different ways of thinking, different perspectives, but they have one common goal. Interviewee G

On the other hand, the divergence of views resulting from diversity will create multiple perspectives, disagreement, and conflict. That is, when diversity begins to threaten the group's safety and integration, then creativity will be likely to suffer [4]. In climate survey, "conflict" was evaluated on a lowest score. It is a negative factor, which means team members behave in a more mature manner; they have psychological insight and control of impulses. The teams welcome, accept, and deal with diversity effectively. This was confirmed in the later interviews. Meanwhile, group size was suggested by team leaders as a key to deduce disagreements in groups. Small groups (no more than 10 members) are welcomed in project work in general, which is shown in Table 5.

Team leaders suggested that large numbers of people have trouble in interacting constructively as a group, and even more trouble in agreeing on specifics actions. The quality of decision making is reduced and conflict increased because of high diversity. Effective interaction in a larger group is also difficult. In addition, large groups also confront more complex constraints, like crowd or herd behaviors, that prevent the intense sharing of viewpoints needed to build a team, but groups of big size should be broken into subgroups, as one of group leaders said:

> In general, it is appropriate to build a group with 5 or 6 members. Our experience shows that there are difficulties in management and interaction in larger groups. Students can't benefit from this learning environment. If the project is so complex that it needs larger number of people to engage in it, we will divide the larger group into several smaller ones. Interviewee C

In practice, working groups are information processing units—like individuals, they encode, store, and retrieve it. Effective interaction among its members makes groups become more productive in terms of their creative output, thereby pushing group members towards mutual beliefs. Therefore "small numbers" is a more practical principle for group creativity.

As introduced, high personnel turnover rate happens in these teams. Most projects need one year at least, but graduates have to leave and newcomers join the teams. Because group membership change interferes with existing work routine, it requires the groups to spend a substantial amount of time and effort in socializing newcomers, especially when they lack task-relevant skills. Thereby the newcomers' ability is expected to meet the requirements of group work.

> When we introduce a new one, his/her expertise is an important element to consider. We need creative, cooperative, responsible young guys and they must have strong interests in the project work and should develop a good relationship with the others. Interviewee H

However, we can also view that membership change may bring group openness to some extent, since it happens regularly. Compared to closed groups, open groups have a shorter time perspective and hence implement decisions more quickly, work harder to minimize turnover-related problems, and are more receptive to new ideas [4]. In an open group, it is easy to generate feelings of safety in relationships, which can encourage everyone to present ideas and opinions actively, without fear of reprisals or ridicule in case of failures. Hence the newcomers can produce creativity easily.

From the findings of CCQ, there is a problem among these teams in that risk taking isn't encouraged. It indicates that most of these teams work in a risk-avoiding climate. There is a cautious, hesitant mentality within the teams. Team members lack decisiveness, try to be on the 'safe side' and often 'sleep on the matter'. They may set up

Table 5. Team Leaders' Perception on Group Size

Interviewee (team leader)	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Number of group members expected	*5–10*	*≤ 8*	*5–10*	*5–10*	*≤ 6*	*5–10*	*3–5*	*3–5*

committees, defer decisions to the other teams, and cover themselves in many ways [4]. Hence it can be regarded as potential barrier to group creativity. The reason for a lack of risk taking was studied in later interviews. The following are some replies from team leaders:

- Few of us would like to risk, because it means time delays, since our project work must be finished before deadline as planned. Interviewee B
- Risk will lead to which is not expected. Interviewee D
- It is not feasible to take risks, because the resources of projects are limited. Interviewee E
- Science research should be encouraged by risk-taking, of course. But we prefer to avoid it in practice, which means we can avoid a heavy loss in resource in a way. Interviewee F

Thereby we could conclude that the management system and group leaders' attitude leads to a risk-avoiding climate in these teams. Because most projects are supported by the government or a company, resources are limited and time schedule is rigid. Students can participate in parts of project work, rather than having opportunities to design or plan projects by themselves. However, according to previous work, students should be encouraged to learn from failure and the process of exploration from wrong answers to correct ones [12]. Furthermore, creativity does require a certain tolerance for risk [44]. Because doing something creative means breaking away from usual ways. Every creative idea replaces something—some concept, method, or technique—which necessarily entails risk.

From a culture perspective, to view project-organized teams in the Chinese educational context, the role and attitude of teachers in a group creativity-shaping process needs to be discussed. Some studies have shown that learners' creativity can be stimulated by the teacher's pedagogic strategies. Teachers who see themselves as the ultimate authority will place little emphasis on developing students' creative thinking. On the other hand, teachers who work to help every student reach their potential will encourage creative behavior [5]. As mentioned, the interviewees in this paper play three roles in the project teams: group leaders, supervisors and professors. In order to finish a project task successfully before deadlines, they tend to assign tasks to students clearly and plan resources effectively. They tend to highlight the learning outcomes and efficiency rather than the creative process in the project. These points are matched with our interviews. For example, the leaders emphasized positive membership change for productive outcome. Moreover, influenced by the Confucian tradition in Chinese culture, professors tend to expect obedience and respect rather than challenging ideas from students [45], especially when they play the role of leaders to control resource in teams. Thus the barriers to group creativity development in these teams are basically from current management system and Chinese culture influences. As Wu [52] proposed, it is due to "emphasizing examination outcomes and ignoring the process of learning", and "stressing creativity taught as knowledge and neglecting creativity inspired through the process of involvement" in higher education in China.

To summarize, findings and discussions based on empirical work led us to a deeper understanding of group creativity as a socio-cultural concept. A series of factors from aspects of group composition, group process, group climate and cultural context are found having their effect on group creativity interactively. Meanwhile, we can recognize the strength and weakness of the current application of project-organized learning in engineering education in China. This strategy may stimulate motivation, offer opportunities for students to learn skills of solving practical problems in teamwork, which are necessary for group creativity development. However, students can't plan or manage projects by themselves due to the educational project management system. Moreover, the method of team composition and attitudes of educators working in teams influenced by Chinese culture can also be thought to be potential barriers to fostering creative engineers. In other words, "student-centered learning" isn't realized by this strategy. This brings us to considerations that other strategies such as Problem and Project-based Learning (PBL) may be a more suitable way to group creativity development in engineering education in China in the future, since it holds to the philosophy that "student-centered learning" and teacher's work as "facilitator" rather than "transmitter" of knowledge in learning [13, 15, 53]. Accordingly, some research on group creativity in a PBL environment is necessary to be explored for more possibilities of improvement of engineering educational strategies.

5. CONCLUSION

This paper takes a point of departure, namely, a socio-cultural perspective to group creativity, aiming to study factors influencing its development in project-organized teams in engineering education within a Chinese context. Multiple methods including questionnaires and interview were employed. Some findings from theoretical and empirical work were described and discussed. In these teams, factors such as the challenge of tasks, diversity, conflict, group size, group openness, newcomers' ability, etc. influence group creativity development interactively. Student motivation can be stimulated by challenge of project tasks. Diversity is one important group building principle, though it can bring conflict among members. Small groups are preferred, because they can reduce conflict in groups and make management easier. Newcomers' ability is expected to be qualified with group work, while group openness is

helpful to accept newcomers. One problem of this learning strategy is that students are not encouraged in risk taking, due to the project management system, group leaders' attitude, and Chinese cultural influences. Thus PBL is suggested as a more suitable way to foster creative engineers in China. These findings will probably contribute to implications for engineering education innovation in the future. Hopefully, more comprehensive studies on group creativity development in engineering education are expected to be explored; PBL can be an example to be discussed on its role in fostering creativity for future engineers.

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