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Small or Large? The Effect of Group Size on Engineering Students' Learning Satisfaction in Project Design Courses

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ABSTRACT

This study investigated the effect of group size on engineering college students' learning satisfaction in project design courses. A self-developed questionnaire titled Learning Satisfaction Toward Project Design Courses was employed to assess college students' learning satisfaction. The survey instrument was constructed using an exploratory factor analysis and reliability testing comprising three constructs: individual learning satisfaction, skill development satisfaction, and group learning satisfaction. Research participants were 480 senior electrical engineering students who had enrolled in project design courses at public research-based universities in Taiwan. The results showed that students expressed positive attitudes toward project design courses, particularly for skill development satisfaction. The small-group format (≦ 4 students) enabled students to achieve higher satisfaction in knowledge acquisition, learning performance, and skill development, particularly in oral presentation, paper writing, and problem solving. However, gender and time allocation in projects did not influence students' learning satisfaction in project design courses.

Keywords: group size, capstone design, project design, learning satisfaction, survey research

INTRODUCTION AND LITERATURE REVIEW

Because engineering profession often involves in product design and development for a large-scale project, in-service engineers are expected to work in a group-based model where team members need to collaboratively contribute their efforts to achieve an ultimate goal (Graaff, 2012). To develop an authentic engineering practice in schools, engineering college students (i.e., preservice engineers) are also provided many opportunities to engage in project-based learning (PBL) (Todd et al., 1995). Such project participation enables students to gain useful group work experiences (O' Doherty, 2005), which are listed as crucial competencies in the engineering and technology industry (Katz, 1993).

PBL is based on three theoretical ideas: (a) active construction, (b) situated learning, and (c) social interaction (Krajcik & Blumenfeld, 2006). First, during the PBL process, engineering college students actively construct their knowledge base by building a tangible project. Second, students who participate in PBL are situated in real-world learning contexts where they play the role of an engineer to solve problems. Finally, to fulfill the requirement of PBL, students need to socially interact with their group members by exchanging their conceptual understanding regarding a meaningful project design. However, when engineering instructors practically implemented a PBL approach, a project management issue often exerted a huge impact on student learning (Moor & Drake, 2001).

Compared with the development of technological products (hard skill) in the engineering design courses, project management is identified as a soft skill (Andersen, 2012). Knuston and Bitz (1991) contended that project management combined science with art, and proposed that project management comprises five basic elements: (a) forming a project team, (b) defining project objectives, (c) planning project details, and (d) managing project scope, and (e) controlling project schedule. Of these five elements, Paretti, Layton, Laguette, and Speegle (2011) asserted

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Contribution of this paper to the literature

- Developing a survey to evaluate the effect of group size on students' learning satisfaction in project design courses.
- Providing new evidence for the learning benefits of the small-group format in project design courses.
- Identifying that gender and time allocation in projects did not influence students' learning satisfaction in project design courses.

that the first stage is a critical aspect of project management and further explained that several teamwork problems often appear after project groups are decided.

Empirical studies have reported various learning perspectives regarding teamwork problems in engineering projects. For example, Felder and Brent (1996) found that a PBL teaching method in engineering curriculum can generate several learning problems: (a) students might constantly complain of their fellow group members' inactivity, (b) some students might piggybacked on other group members' hard works, (c) and students might not work well in a collaborative learning fashion. Chou and Chen (2008) employed a wiki platform to implement PBL for college students who majored in information technology and management and reported that students disliked the random assignment of group members. Most students preferred to work with their friends. Chou, Chen and Lin (2015) indicated that group composition did not significantly influence students' ability to learn engineering, but a particular group type might exhibit considerable learning improvement. However, according to Griffin, Griffin, and Llewellyn's (2004) study, of several learning factors that influence teamwork projects, group size in engineering projects was the most critical, but the least investigated, topic.

The topic of group size was extensively studied in the field of social psychology (Thomas & Fink, 1963). The link among group size, project performance and member satisfaction was reported in a previous study (Strong & Anderson, 1990). For example, Ziller (1957) used an experimental method to examine the relationship between group size and project performance and reported that a larger group size tended to increase the quality of the output. In the studies of Schellenberg (1959) and Hackman and Vidmar (1970), students in smaller groups showed higher member satisfaction. Cosse, Ashworth, and Weisenberger (1999) found that team size positively corrected with team performance and member satisfaction. Curral, Forrester, Dawson, and West (2001) indicated that larger teams tended to have poorer team processes. However, although related studies have constantly appeared in the literature, little is known regarding the effect of group size on learning satisfaction in engineering and technology education.

In PBL environments, an optimal group size remains undetermined. Slater (1958) suggested that a group size of five is more appropriate for teamwork activities. O'Dell (1968) indicated that a group size of two demonstrated low hostility. Strong and Anderson (1990) found that group size, ranging from two to six, was common in the literature. In Cosse, Ashworth, and Weisenberger's (1999) study, a team size of two to four members was appropriately used for instructional investigation. In Griffin, Griffin, and Llewellyn's (2004) study, a team size of five to eight members was an average group size for capstone design courses. According to Pembridge and Paretti's (2010) survey report, the average group size for capstone design courses in the United States ranged from four to six members. However, these studies did not outline a size standard for defining a group structure (i.e., small or large size).

While analyzing the effect of group size, other potential factors might also influence college students' learning satisfaction in engineering design projects. In engineering learning environments, female students' ways of knowing (Belenky, Clinchy, Goldberger, & Tarule, 1997) might be different from that of their male counterparts. A study by Chou and Chen (2015) on female engineering students articulated that gender is a potential factor influencing students' learning performances. Chou and Chen (2016) further confirmed the effect of gender on engineering students' epistemological beliefs. In addition to the gender effect, time allocation in engineering design projects is another potential factor. In Griffin, Griffin, and Llewellyn's (2004) study, although time allocation in projects was evaluated, the effect of time allocation was not used to examine students' learning satisfaction. Therefore, whether gender and time allocation influence students' learning satisfaction in engineering design projects warrants further investigation.

In Taiwan, engineering departments in universities need to fulfill the course accreditation policies outlined in the Institute of Engineering Education Taiwan (IEET), which is similar to Accreditation Board for Engineering and Technology (ABET) in the United States. One engineering course criterion of the IEET requires senior students to complete two capstone design courses in their last year of college (IEET, 2017). Regardless of the type of engineering programs, students enrolling in capstone courses are responsible for forming a project group to develop specific engineering products. The goal of one-year teamwork experiences is to train students to become competent engineers (IEET, 2017). According to Liu's (2015) survey report, project design was a common course title

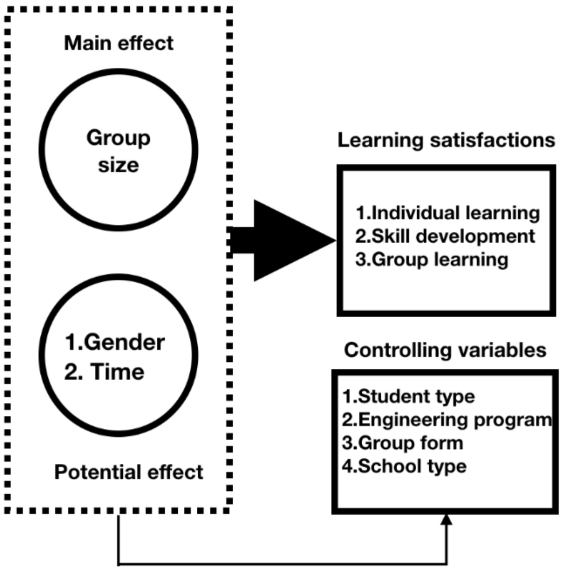

Figure 1. Research design of the study

representing the concept of capstone course in Taiwanese colleges. However, project management issues, particularly group size, remained uncommon in previous related studies.

On the basis of the aforementioned information, the current study investigated the effect of the group size on engineering students' learning satisfaction in project design courses. Senior Taiwanese college students who were majoring in electrical engineering and had enrolled in project design courses were potential research participants. Through the construction of an exploratory factor analysis, a valid satisfaction questionnaire was developed for surveying students' individual learning satisfaction, skill development satisfaction, and group learning satisfaction in PBL environments. The research questions were as follows:

1. What was the current status of engineering college students' learning satisfaction toward project design courses?
2. What was the major effect of group size on students' learning satisfaction in project design courses?
3. What were other potential factors (gender and time allocation) influencing students' learning satisfaction in project design courses?

RESEARCH METHODS

Research Design

The study adopted a quantitative survey research method to fulfill the research questions. **Figure 1** depicts the research design of the study. Engineering students' learning satisfaction, which comprised three domains of satisfaction (individual learning, skill development, and group learning), was a dependent variable. Group size was an independent variable and a major effect. Gender and time allocation in projects were potential independent variables and factors influencing dependent variables. To control extra interferential factors, student type (senior), engineering program (electrical engineering), group form (natural selection) and school type (public research-based university) were selected for controlling variables. The overall research design of the survey questions between independent and dependent variables is outlined in **Table 1**.

Table 1. Survey Question Design

Structure	Items	Question Design
Part One: Independent variable (Background)	1	1. Gender (Multiple question): a. Male b. Female
	1	2. Group size (Fill in the blank question): ____
	1	3. Time allocation (Multiple question): a. 0~5 b. 6~10 c. 11~15 d. 16~20 (or higher)
Part Two: Dependent variable (Learning satisfaction)	5	1. Individual learning (5-point Likers-type)*
	5	2. Skill development (5-point Likers-type)*
	5	3. Group learning (5-point Likers-type)*

*5-point: 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree and 5. Strongly agree

Table 2. Results of the Validity and Reliability Test (n = 155)

Item	Individual Learning	Skill Development	Group Learning
1-1	0.79		
1-2	0.81		
1-3	0.84		
1-4	0.84		
1-5	0.71		
2-1		0.82	
2-2		0.76	
2-3		0.78	
2-4		0.86	
2-5		0.79	
3-1			0.67
3-2			0.70
3-3			0.73
3-4			0.76
3-5			0.61
Eigen-Value	3.13	3.21	2.41
Variance%	63.66	64.2	57.4
Reliability	0.86	0.86	0.73

Total variance was 60%

Total reliability coefficient was 0.81

Research Instrument

The study employed a self-developed questionnaire titled Learning Satisfaction toward Project Design Courses (LSPDC) to assess college students' learning satisfactions. The LSPDC is a 15-item 5-point Likert scale and contains three psychological constructs: individual learning satisfaction, skill development satisfaction, and group learning satisfaction. Overall scores in each construct ranges from 5 to 25. Higher scores represent higher learning satisfaction in a specific construct of capstone design courses.

The LSPDC was constructed in three developmental stages. First, the questionnaires developed by Hackman and Vidmar (1970), Cosse et al. (1999), and Griffin et al. (2004)'s questionnaires served as a basis for a question pool. At this stage, 21 question items were developed. Second, to ensure the content validity, three professors of engineering and two professors of education were invited to review the initial questionnaire. Next, some ambiguous questions were removed and the description of some questions was modified. Finally, the subsequent 15-item questionnaire was administered to 155 engineering students to examine instrument quality. At this stage, an exploratory factor analysis and reliability testing (**Table 2**) were performed to validate the questionnaire. Overall, the total variance (> 50%), the Eigen-value (>1), and reliability coefficient (>0.7) for each factor indicated an excellent condition for the reliability and validity of the LSPDC (Aiken & Groth-Marnat, 2006).

Research Participants

The study adopted a purposeful sampling (Gall, Gall, & Borg, 2007) to collect relevant data. The potential participants of the study were senior electrical engineering students who had enrolled in project design courses at public research-based universities in Taiwan. Prior to the study, the principal researcher mailed a notification message to instructors who offered the project design courses at targeted universities. The mail content described the purpose of the study and inquired about the group form in the engineering projects. Only the natural selection

Table 3. Profiles of the Research Participants (n = 480)

Type	Number
1. Gender	
A. Male	308
B. Female	107
2. Group Size	
A.≦4 (2, 3, 4)	219
B. > 4 (5, 6, 7)	261
3. Time allocation (Hour Per Week)	
A.≦ 10	329
B. > 10	151

Table 4. Mean Scores for Survey Constructs (n = 480)

Survey Construct	M	S.D.
Individual Learning Satisfaction	3.79	0.81
Skill Development Satisfaction	3.92	0.81
Group Learning Satisfaction	3.01	1.03
Total	3.57	1.30

method for forming a project group was chosen for further questionnaire distribution. The survey implementation period was 1 month before the commencement of senior students' college in June. During the research campaign, the research team sent a web link to potential research participants and subsequently obtained 480 copies of valid questionnaires. Table 3 summarizes the profiles of the research participants. Overall, the range of group size was from two to seven. For further data analysis, a group size of four was used as the median for segregating the two groups into small and large groups.

Data Analysis

The descriptive and inferential statistics were employed for interpreting the quantitative data. In descriptive statistics, the mean and standard deviation were reported to interpret the survey items and constructs. In inferential statistics, an analysis of variance (ANOVA) and the t-test were performed to investigate the effect of group size on students' learning satisfaction. Because of an unequal status in variables, the Kruskal–Wallis (KW) test was conducted to confirm the effect of gender and time allocation on students' learning satisfaction.

RESULTS AND DISCUSSION

Engineering Students' Learning Satisfaction

The results of descriptive statistics regarding engineering students' learning satisfaction are listed in Tables 4–5. Overall, students' learning satisfaction (M = 3.57) toward project design courses was slightly positive. The highest score was obtained for skill development satisfaction (M=3.92), whereas the lowest score was identified for group learning satisfaction (M = 3.01). In other words, students perceived that project design courses might improve their skills in different domains. In addition, students expressed a neutral attitudes toward negative comments in the construct of group learning satisfaction.

Table 5. Statistical Details of Questionnaire Items (n = 480)

Survey Item	M	S.D.
1. I was satisfied with the group work model	3.66	0.83
2. Most of my opinions could be accepted or were emphasized by my group members	3.82	0.76
3. My contribution would influence the quality of work	3.89	0.82
4. I acquired the professional knowledge and skills I needed	3.93	0.83
5. I obtained a satisfied score based on my workload	3.66	0.85
6. Project design courses developed my oral presentation skills	3.84	0.88
7. Project design courses developed my paper writing skills	3.92	0.80
8. Project design courses developed my collaborative learning skills	3.96	0.85
9. Project design courses developed my problem solving skills	4.09	0.72
10. Project design courses developed my management skills	3.79	0.81
11. Group members did not complete their assigned tasks, which influenced overall teamwork performance	3.19	1.05
12. Our group size was inappropriate for teamwork development	2.97	1.00
13. Group members controlled the learning process, which influenced the teamwork learning atmosphere	2.90	1.03
14. Diverse individual abilities in our group easily created different arguments	2.97	1.06
15. Group members were not good at expressing their emotions and opinions, which created communication barriers	3.92	1.03

Note: Items from 11 to 15 are reverse questions (original scores have been modified)

Table 6. The Results of ANOVA (n = 480)

Survey Construct	SS	DF	MS	F	*p*	Post Hoc
Individual Learning Satisfaction	67.49	1	67.49	7.34	0.00**	A > B**
Skill Development Satisfaction	58.49	1	58.49	5.76	0.02*	A > B **
Group Learning Satisfaction	0.37	1	0.37	0.02	0.89	
Total	232.6	1	232.6	5.47	0.02*	A > B **

*p < 0.05 ** p < 0.01 A: Size (≦ 4), B: Size (> 4)

Table 7. The Results of the t-test (n = 480)

Survey Item	*t*	Comparison
4. I acquired the professional knowledge and skill I needed	3.06**	A > B
5. I obtained a satisfied score based on my workload	4.07**	A > B
6. Project design courses developed my oral presentation skills	2.26*	A > B
7. Project design courses developed my paper writing skills	2.18*	A > B
9. Project design courses developed my problem solving skills	2.71**	A > B

*p < 0.05 ** p < 0.01 A: Size (≦ 4), B: Size (> 4)

Effect of Group Size

The results of ANOVA and the t-test are listed in **Tables 6–7**. The findings revealed that group size exerted a strong effect on students' learning satisfaction. Significant differences were identified in individual learning satisfaction (F = 7.34, $p < 0.01$), skill development satisfaction (F = 5.76, $p < 0.05$), and total LSPDC (F = 5.47, $p < 0.05$) between the large and small groups. The post hoc analysis indicated that students' satisfaction was significantly higher in the small group than in the large group in individual learning satisfaction ($p < 0.01$), skill development satisfaction ($p < 0.01$), and total LSPDC ($p < 0.01$).

By examining detailed survey items, significant differences were observed in item 4 ($t = 3.06$, $p < 0.01$), item 5 ($t = 4.07$, $p < 0.01$), item 6 ($t = 2.26$, $p < 0.05$), item 7 ($t = 2.18$, $p < 0.05$) and item 9 ($t = 2.71$, $p < 0.01$) between the large and small groups. The comparison analysis showed that students in the small group had significantly higher satisfaction than their counterparts in the large group for those five survey items. In other words, compared with the large group, the small group enabled students to achieve higher satisfaction for skill development in oral presentation, paper writing, and problem solving and for individual learning in knowledge acquisition and learning outcome.

Effects of Gender and Time Allocation

The results of the KW test for gender and time allocation are summarized in **Tables 8–9**. No significant differences were found in the three survey constructs ($p > 0.5$) and total LSPDC ($p > 0.5$) between male and female students and between A (≦ 10) and B (> 10) groups' students. In other words, gender and time allocation did not exert any potential effect on students' learning satisfaction in the three survey constructs and total LSPDC.

Table 8. Kruskal–Wallis Test Results by Gender (n = 480)

Survey Construct	χ^2	*p*	Male (M)	Female (M)
Individual Learning Satisfaction	1.25	0.09	3.68	3.85
Skill Development Satisfaction	1.09	0.19	3.87	4.01
Group Learning Satisfaction	1.20	0.11	3.09	2.88
Total	0.68	0.74	3.57	3.58

Table 9. Kruskal–Wallis Test Results by Time Allocation (n = 480)

Survey Construct	χ^2	*p*	A (M)	B (M)
Individual Learning Satisfaction	1.27	0.08	3.75	3.88
Skill Development Satisfaction	1.10	0.18	3.89	3.98
Group Learning Satisfaction	0.75	0.63	3.04	2.95
Total	0.67	0.76	3.56	3.60

Time allocation: A (≦ 10), Size B (> 10)

Overall Discussion

Regardless of the main effect (group size) or potential effects (gender and time allocation), engineering students' perceptions of individual learning satisfaction and skill development satisfaction were slightly positive in the project design courses. Students perceived that the project design courses might cultivate their individual performances, particularly regarding knowledge acquisition, and support their skill development in various domains, particularly in problem solving, which indirectly reflected the curriculum spirit of capstone design course (Graaff, 2012; Katz, 1993; Todd et al., 1995). However, according to the responses obtained for group learning satisfaction, students tended to neutralize the negative description in reverse survey questions. This phenomenon might be attributed to the natural selection method for forming a project group in which students might not criticize their peers because of being familiar with each other (Chou et al., 2015) or to a cultural factor under which Chinese students tend to create a harmonious learning environment (Chou & Chen, 2010).

The information in descriptive statistics indicated that the range of group size in project design courses was from two to seven. A group size of four members served as a median to segregate two group structures: small and large groups. The group size was close to the optimal size reported in previous research (Cosse et al., 1999; Pembridge & Paretti, 2004; Slater, 1958). Based on this group size standard, a further analysis in inferential statistics indicated that students in small groups showed significantly higher satisfaction in individual learning, skill development, and overall learning than did their counterparts in large groups. The findings were consistent with those of previous studies that reported the learning benefits of small groups (Curral et al., 2001; Hackman & Vidmar, 1970; Schellenberg, 1959). In addition, in the constructs of individual learning satisfaction and skill development satisfaction, students in small groups demonstrated higher satisfaction for professional knowledge acquisition, learning performance (course score), and three skill developments: oral presentation, paper writing, and problem solving. In other words, students preferred the small-group format to support their project design in specific skill development and learning achievement (Griffin et al., 2004).

Students' responses in gender-related items indicated a disapprobation phenomenon. Male engineering students dominated in PBL environments. The analysis of time allocation also showed that most of the engineering students spent less than the appropriate 10 hours engaging in weekly project design. The findings are similar to those reported by Griffin et al. (2004) that engineering students' average weekly time allocation was between 7 and 11 hours. However, despite the slight difference reported in the three survey constructs between male and female students and between the two types of time allocation groups, the inferential statistics still revealed that gender and time allocation did not influence students' satisfaction in project design courses. The results contradicted the findings of previous studies that identified a pronounced effect of gender on engineering learning (Chou & Chen, 2015, 2016).

CONCLUSION

Responses to Research Questions

This study investigated the effect of group size on engineering college students' learning satisfaction in project design courses. Regarding the first research question, the findings indicated that students expressed positive attitude toward project design courses, particularly for skill development. Regarding the second research question, the statistical report confirmed that group size exerted an impact on students' individual learning satisfaction, skill development satisfaction, and overall learning satisfaction. In particular, the small group format enabled students to obtain higher satisfaction in knowledge acquisition, learning performance, and skill development in oral presentation, paper writing, and problem solving. However, as for the third research question, gender and time allocation (as two potential factors) did not influence students' learning satisfaction in project design courses.

Research Limitations and Suggestions for Future Studies

Because of the unique survey research design, the effect of group size identified in the study may be difficult to generalize and apply to other learning contexts. Future studies should consider possible research limitations of the study. First, in this study, only electrical engineering students were recruited as research participants. Future studies may obtain different responses by targeting gender-neutral engineering programs, such as chemical engineering or industrial engineering. Second, some engineering instructors may not use the natural selection method for forming project groups. Future studies can compare differences in learning satisfaction between naturally selected and instructor-assigned groups. Third, curriculum goals in capstone design courses may be a minor difference among research-based universities. Future studies may investigate the difference to confirm the role of the group size. Finally, this study did not allow research participants to report their course grades. Future studies can attempt to examine the relationship between students' learning satisfaction, group size, and course grades.

Instructional Implications

The study offers some instructional implications for engineering instructors who are eager to improve the curriculum quality of project (or capstone) design courses and for educators who attempt to employ a teamwork model to promote STEM education in the Asia-Pacific region. First, collaborative learning in the small-group format may enable students to develop their professional skills, particularly for oral presentation, paper writing, and problem solving by avoiding potential free riding or piggybacking problems. Second, applying a small group size in project design courses may enable students to obtain their satisfied scores and acquire expected knowledge, perhaps because of a higher harmonious atmosphere. Finally, a group size of four may provide an optimal teamwork standard in the PBL environment. If the number of students in a group work crosses this threshold, it may influence overall satisfaction, individual learning satisfaction, and skill development satisfaction.

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