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From Initiators to Free-Riders: Exploring the Spectrum of Female Engineering Students' Functional Roles in Project-Based Learning using Phenomenography*

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Collaborative learning has been proposed as a strategy to improve engineering female students' learning by providing the opportunities to work in a supportive group. However, female students still face multiple challenges especially in a male-dominant group. To gain a deeper understanding on female students' team experiences and thereby improve their performance, this research investigates the spectrum of team roles among female engineering students in project-based learning. Using a phenomenographic approach, which features investigating the variation of experiences, we mapped twenty-one female engineering students' diverse roles in three dimensions-task, social, and individual roles in a qualitative manner. A variety of roles were identified, ranging from initiators, task assistants, to task outsiders (task), from coordinators, conflict mediators, communication outsiders (social), and from challenger-lovers, recognition-seekers, to free-riders (individual). Moreover, factors such as gender ratio and group dynamics, were found to be associated with their role-taking. The exploration of female students' functional roles provided an overall understanding about the diversity in female students' functional roles and associated factors influencing their role-taking. Suggestions as related to group arrangement, task division and other aspects in PBL were discussed for future course design.

Keywords: Female engineering students; functional roles; project-based learning

1. Introduction

Engineering profession has been regarded as a male-dominant field due to the low representation of females, whose percentage was reported as 15.7% in higher engineering education in U.S. and 25.7% in Europe in 2017 [1]. In China, although female students accounted for 30.3% amongst engineering undergraduates in 2018, in several engineering subjects such as mechanical engineering, aeronautical engineering and automation engineering, the average acceptance rate of female students was less than 20%. Especially in the discipline of computer-science, the average percentage of females was only 12.5% in 2018 [2]. In addition to low representation, female engineering students were found to encounter higher attrition rate, lower self-efficacy, and lower self-reported learning outcomes than their male peers [3, 4]. However, lower confidence and self-reported learning outcomes as female students were found in traditional learning context, in general they rated themselves as more effective and with better communication skills in teamwork than male peers [5]. Possible reason is that women's ways of knowing have been found to be featured with "Connected Knowing", e.g., knowing through adopting the lens of another person [6]. Also, female engineering students were found to engage more in group work than their male peers [7].

In this way, PBL (project-based learning and problem-based learning) has been proposed as a supportive environment for female students because of more collaboration and interaction opportunities, while at the same time particular challenges for female students have also been observed, especially for a male-dominant group [3, 8]. According to Kurt Lewin's [9] group dynamics theory, a team as a whole would exert pressures on individual members, influence their thoughts, actions and group roles, and also affect team cohesiveness and productivity. Many researchers pointed out that female students might experience anxiety and stress, and some of them failed to integrate into their peers and gain the membership of engineering groups in teamwork processes, which require females to devote more efforts and could influence their learning outcomes and persistence in engineering negatively [10–12]. With those challenges, although several studies have reported female engineering students' performance and experience in a collaborative learning setting, more attentions are needed to explore how female students collaborate and interact with group peers in their community of practice in PBL environment.

In order to expand our understanding of female students' teamwork experience in PBL context, this study focused on the diversity of female students'

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team roles from female students' perspectives, which is an important component of group dynamics and could affect students' professional identity development and learning experience [10]. Using a phenomenographic approach, we attempted to answer the following questions: (1) From female students' perspectives, what kinds of team roles did female engineering students take in a collaborative PBL context? (2) How did those roles come about in the collaborative PBL context?

2. Literature Review

Gender study constitutes an important part in engineering education. As found by previous empirical studies, female engineering students in general were faced with lower entrance opportunity and higher attrition rate, and they had lower confidence on their learning outcomes than male students [5, 12, 13]. As an important influence factor on females' retention rate and academic performance, their self-efficacy was also reported at lower levels than male peers [14]. Many female engineering students has less confidence in their professional abilities, which became a barrier that challenged students' persistence in engineering. However, prior studies also pointed out that although women might feel less confidence in their engineering abilities in the beginning of their study, as they progressed with more experience, they can develop more self-efficacy and show better academic performance than male [4]. In addition, when it comes to learning methods and teamwork skills, women were found to demonstrate more interests and confidence than men [3, 5, 13]. In terms of impact factors of their competence beliefs, Hirsch, Heyman, and Cano (2013) found that students' learning experience in an interactive environment played significant roles. The tense atmosphere, especially the competitive context, could affect females' self-efficacy and lead to negative emotions like anxiety while a non-competitive environment could help female students increase their confidence.

Nonetheless, improvement of female students' confidence and performance in their engineering study did not mean all of them could gain the membership of engineers and feel accepted during their study. Vogt and colleague [15] pointed out that gender discrimination, inequality and marginalization were reported by female students with high frequency. Females who sensed the feeling of unwelcome and suspicion from male peer students and professors might have poor learning experiences and bear heavier burdens [10, 11]. For female engineering students, in order to integrate into the communities of engineering, they perceived themselves with heavier workload levels and higher anxiety levels than males, which had negative influence for them to develop the sense of belonging as future engineers [12].

Considering the challenges faced by female students in their studies in engineering, some researchers pointed out that collaborative learning can be a helpful strategy to increase female engineering students' self-efficacy and improve their learning outcomes [16]. Female students tended to seek more collaborative learning opportunities and support than male students, because they believed by learning collaboratively, they can support each other and be more productive and effective [7, 16]

As one of the core learning methods to conduct collaborative learning, project-based and problem-based learning (PBL), where students are provided a pathway to solve real-world problems and gather work-related experience [17], were identified as an effective method to benefit female students with improved learning experience and learning outcomes. The experiences of working as real engineers in PBL programs could help female students better develop professional identity and prepare for engineering career [10]. In PBL context, female students reported themselves with higher levels of satisfaction and effectiveness in teamwork because of better communication skills and teamwork skills than male peers [5]. However, despite of the potential benefit on PBL for female students, females still faced difficulties and challenges in PBL environment, such as having limited chance to take non-technical tasks, devoting more efforts to integrate into male peers and to be heard, compromising their identity and so on [10, 18].

Similar to findings in a western context, in general female engineering students in Chinese universities were reported to have lower college entrance opportunities and employment status than males [19, 20]. As to the possible causes, low self-efficacy, professional interest, types of parents' jobs and Chinese traditional culture were reported be associated with these phenomena [20–22]. Meanwhile, many female engineering students in China also assessed themselves with lower learning outcomes and less positive attitudes towards future engineering jobs [23]. In male-dominated engineering majors, female students experienced higher levels of pressure in terms of adaptation and psychology. In order to improve current situation, similar measures were proposed to improve female engineering students' learning, such as, creating a more female-friendly engineering education system, engaging students in more practical learning experiences, inviting more female engineering faculty, and giving more encouragement to female students [22, 24, 25].

The aforementioned findings on collaborative learning and PBL among female engineering students provided the basis for this research. Although researchers have explored female engineering students' learning outcomes and experience, few studies focused on female engineering students' team roles and experience in a PBL setting, particularly in Chinese universities. Considering the widely use of PBL and the challenges faced by female students, it is important to fill in the gap and have better understanding of female students' learning experience in PBL, which is a topic of value to both the Chinese and the global context. The purpose of this study was to improve female students' learning experience by exploring their team roles and how these roles were formed in a group project setting, using a phenomenographic approach, with the guidance of the functional roles model [26].

3. The Theoretical Framework

Team roles were regarded as important impact factors on group dynamics of which they are also a part [9, 27]. In order to improve team management, researchers concluded several team roles theories that have been applied in practice and theorized, including Benne and Sheats' [26] functional roles model, Belbin's team role theory and Margerison's nine key team roles. Team roles theories such as Belbin's team role theory and Margerison's key team roles model, summarizing necessary role types for a successful team, have mostly been used for team management in the context of enterprise operation. Whereas Benne and Sheats proposed a framework for role behaviors describing both positive roles and negative roles within a group, which is more suitable for exploration of the variety of roles in the process of student team learning and has served as a foundation for the development of other team role models [28]. It has been widely used in the fields of management, education, and psychology [29–31]. In terms of engineering education, this model has also been proved useful in exploring students' functions and team performance [32]. In order to identify the group roles of female engineering students during teamwork processes, we adopted Benne and Sheats' [26] functional roles model as the theoretical framework. This model classified group functional roles into three categories, namely, task roles, social roles, and individual roles. This model highlights the diffusion of various functions across group members to help group growth and productivity, therefore permitting here an exploration of the variety of roles within a group. Sample roles with brief descriptions in every dimension are presented in Table 1.

The task roles are related to the group goals that are shared by all group members. In other words, the roles in this dimension are performed to facilitate the fulfillment of a common task in group working [34]. Social roles are also called group building and maintenance roles. As the name suggested, roles in this category are related to the group's operation, or in Benne and Sheats' words, ''the functioning of the group'', such as members' relationship within a group and the way a group works [26]. Group members who play social roles take actions to build or maintain group-centered attitudes, strengthen the cooperation between group members and improve the atmosphere during work. Individual roles are related with the satisfaction of individual objectives, which is often irrelevant to group goals or other members' needs. Group members playing these roles may show ''individual-centered'' performance or exert negative influence on group building and maintenance [26, p.42]. Individual roles include eight sub-type roles.

Benne and Sheats' functional roles model has been further tested and adopt widely by research in management, education, and psychology [29–32]. Particularly, Zancanaro, Lepri, and Pianesi [30] applied this model to explore students' functional roles in face-to-face interactions. Through observing students' performance, classroom distribution, and team roles structure, they verified the three dimensions of task roles, social roles and individual roles, and demonstrated the feasibility of this model in detecting students' team roles.

In addition, several researchers pointed out that the functional roles model could be used as a tool to analyzed team-level interactions, which is an indicator for team outcomes and productivity, and might be used to predict the team cohesion and performance [31, 34]. Using functional roles model, Stewart et al. [35] explored the distribution of various group roles among software engineering students. Their study pointed out that a successful team kept a balance of task roles and social roles. Also, negative individual roles can pose a significant threat to team performance. In particular, female students were found to have strengths in programming in the task dimension and coordination in the social dimension [34]. Laeser et al., [32] first used this theory to explore gender differences in engineering students' group contributions, among 80 females and 258 males in the Colorado School of Mines (CSM). Through a classroom observation tool, participants' performance of displaying given functions was recorded and categorized by two separate observers, and the percentages of agreement between two observers were over 75%. Different from prior gender research using the

Table 1. Sample Roles in the Dimension of Task Roles [26]

Group Role	Description
Dimension of Task Roles	
Initiator-Contributor	Propose new ideas; determine the team tasks and goals; suggest solution; find a new way of organizing the group for the task ahead
Information Seeker	Asks for clarification of suggestions frequently; comply with the authoritative views or facts
Opinion Giver	State own opinions; give suggestions in group's view
Elaborator	Spell out suggestions with examples; deduce reasons of idea adopted by team
Coordinator	Summarize the relationships among various ideas; pull suggestions together
Orienter	Define positions of group members; point out team direction and goals;
Evaluator-Critic	Set standards of group functioning; evaluate practicality, logic and procedure of group discussion.
Procedural Technician	Perform routine tasks like distributing materials and manipulating objects; take technical operation
Recorder	Record suggestion, group decision, product of discussion
Dimension of Social Roles	
Encourager	Show recognition to other's suggestion; praise and encourage other team members to bring up ideas, opinions, and suggestions
Harmonizer	Mediate the differences between team members; relieve tension in conflict situations through jesting
Compromiser	Resolve conflicts when his ideal is involved; admit his error to offer compromise
Gatekeeper	Communicate with others; facilitate participation of members outside the team
Group-Observer and Commentator	Write down various aspects of group process; feed data with proposed interpretations into evaluation procedure
Follower	Serve as audiences in group discussion; follow teams' movement
Dimension of Individual Roles	
Aggressor	Express disapproval of values; joke aggressively; envy other's contribution
Blocker	Tend to be negativistic; show stubbornly resistant; disagree without reasons; raise issues after the group has bypassed them
Recognition-Seeker	Seek attention to himself in different ways; report personal contributions; act in unusual ways for superior positions
Self-Confessor	Seek audience for personal, non-group oriented expression
Playboy	Show cynicism, nonchalance, horseplay, lack of involvement and other "out of field" behaviors
Dominator	Assert authority in groups; give directions authoritatively; interrupt the contributions of others
Help-Seeker	Call forth other's sympathy responses and help; express insecurity, personal confusion or depreciation of himself

functional model, no significant gender differences were found between engineering students' team functional roles in dimensions of task roles and social roles. It should be noted that this study only involved ten roles within the dimensions of task roles and social roles. They stated that task roles and social roles were indispensable elements of teamwork, and those ten functions were recognized as critical aspects of the team process [35]. In general, although several researchers had applied the functional role model to female engineering students, their individual roles and other functional roles among task and social dimensions are still unclear.

4. Method

4.1 Sampling

Purposeful sampling was used in this study. For diversity of team roles, female engineering students were recruited from three types of classes (A, B, and C) of the one-semester course – Introduction of Engineering in two engineering schools in a leading Chinese university H, which has conducted and improved PBL practices in engineering majors for one decade. Engineering School X is composed of mainly Chinese students and Chinese faculty (A and B). Engineering School Y is a school that is cooperatively run by University H and a U.S. University L (C) with mainly Chinese students and international faculty members at the undergraduate level. There were about 40 students in every Type A classes, with percentage of female students ranged from 2% to 10%. Type B class is an honor class with students that on average had higher academic records than the students from Type A. It had 38 with the 10 % percentage of female students. Type C class had around 120 students with female student percentage of 16%. Female students were recruited by oral invitation or email invitation from the three classes, to allow for variety and representativeness of our participants. A total of 21 female engineering students were recruited (Table 2).

Table 2. The Basic Information of Participants

Number	Name	Self-Identified Team Role	Type of Class	No. of Female Students/No. of all students in the team
1	Zora	Member	A	2/4
2	Wendy	Leader	A	1/5
3	Freda	Member	A	1/4
4	Cathy	Member	A	2/4, in the same group with Lena
5	Zita	Member	A	2/5
6	Zandra	Leader	A	1/3
7	Lena	Leader	A	2/4, in the same group with Cathy
8	Laura	Member	B	1/6
9	Kitty	Member	B	1/3
10	Linda	Member	B	2/6, in the same group with Lucy
11	Lucy	Member	B	2/6, in the same group with Linda
12	Mary	Member	B	1/3
13	Zahra	Member	B	2/5
14	Zofia	Leader	B	1/3
15	Zoe	Member	C	2/5, in the same group with Fanny
16	Fanny	Member	C	2/5, in the same group with Zoe
17	Grace	Leader	C	3/4
18	Pansy	Member	C	1/4
19	Helen	Member	C	1/4
20	Calla	Member	C	1/5
21	Rosina	Member	C	2/5

For A and B, students were required to complete one open-ended project in a group in eighteen weeks. Students selected their own project and constructed their design for a product. In class C, students were required to complete two open-ended projects within sixteen weeks. First project was assigned by the professor and required to be finished within the first five weeks. The second project was required to be completed within next eleven weeks. In all three classes, students formed self-selected groups. But in Class C, based on our observation and the interview responses, in two of the three sessions, female students were asked to form a pair in a group instead of being alone in an all-male group. The three different types of PBL course setting brought us more opportunities to explore the diversity of female students' team roles, based on participants' individual experience.

4.2 Data Collection Procedure

Methodologically, with the aim to explore diversity of female students' functional roles in PBL, a phenemenographic approach was adopted to examine the range of functional roles performed by female engineering students. This method enables researchers to identify "the key aspects of the variation of the experience of a phenomenon rather than the richness of individual experiences" [36, p. 77]. With the guidance of the phenemenographic approach, this study focuses on picking up key aspects of female students' teamwork experience and providing the spectrum of their functional roles in PBL. As a qualitative method, data are mainly collected via interview and observation in phenemenographic [37]. In this study, qualitative data were collected through semi-structured one-on-one interviews (with one of the interviews conducted with two participants at the same time per their request). We also observed the first class (when they usually formed the team) and at least one of the class gathering during their team work for at least one session for each type for data triangulation purpose. In observing the class, particular attention was paid to female students' interactions with other members. Data from interviews were the main data source that were used to analyze female students' group roles.

As the theoretical framework of this study, Benne and Sheats' functional roles model served as a guidance for the design of the interview protocol. Sample questions of the interview protocol are shown in Table 3.

4.3 Data Analysis

In the process of data analysis, the records of classroom observation were used for an understanding about team assignment/organization in the classes and for a preliminary idea of female students' roles in teamwork. The information provided by interviews were transcribed and reviewed to analyze female students' group roles. For the sake of privacy protection, pseudonyms are used in the transcripts for all interviewees.

Table 3. Sample Questions from the Interview Protocol

Descriptive Questions
Can you briefly describe the processes of completing your project in the course of Introduction of Engineering?
Questions in the Dimension of Task Roles
How did your team accomplish your goals and complete the project?
How do you evaluate your team's performance in completing the tasks of the project?
Questions in the Dimension of Social Roles
How would you describe the processes of communications and discussions in your group?
How would you describe the interaction and communication atmosphere in your group?
Questions in the Dimension of Individual Roles
What expectations did you have about yourself in the beginning of the project?
What aspects do you think you did well in the group project? What do you think would be the areas for improvement?

With regard to the coding process, a structured codebook was built upon the analyses of four information-rich transcripts, which constitutes a relatively stable frame for coding [38]. In developing the structured codebook, three categories (task roles, social roles and individual roles) were defined as priori codes in the first step. Based upon the priori first-level codes, open-coding was used to identify students' specific roles in these three categories. Although Benne and Sheats' functional roles model provides various team roles in three dimensions, we still keep open attitudes towards new team roles with the model as reference because of female students as a minority group and the PBL context. After open-coding, codes were collapsed and classified in the three dimensions of functional roles. In qualitative research, researchers are regarded as "the primary instrument for data collection and data analysis", and they need to be "responsive and adaptive" during this process [39, p.5]. For this research, a female researcher (first author) with past educational research training and prior PBL experiences was engaged in the research data collection and analyses. The researcher was involvedly in daily journaling and self-monitoring in conducting the data collection and analyses to be aware of any potential bias and influences from prior experiences.

To enhance the credibility of data analysis, all transcripts were read multiple times and coded by the lead coder with researchers' self-reflection. In auditing procedures, two external researchers were invited to code a part of transcripts to provide additional perspectives for the purpose of triangulation in data analysis. Resulting in the inter-rater reliability (IRR) for every dimension over 80%, codes are modified and/or refined during and after the auditing process through three rounds of discussing the coding results. A revised codebook was formed through this process and then used for data analysis. Chinese was used in coding processes, but to present this study in English, all codes and quotation were translated carefully and revised for three rounds with the auditing of two experts in English. A prior version of work-in-progress was published in a conference proceeding (removed for blinded review). This current work presents an updated and complete version of the results.

5. Results

Based on the analyses of the semi-structured interviews guided by Benne and Sheats' functional roles model, we found that female students in project groups had taken on a variety of roles in each dimension as follows. Due to the limitation of space, in every dimension, typical samples of team roles with students' quotations were picked to illustrate female students' performance and experience in teamwork.

5.1 Task Roles

Task roles are related to selection and implementation of team goals. Up to12 roles were identified in this dimension, and detailed frequency of each role from qualitative analyses can be found in Table 4. Female students with a high degree of participation played the roles of an initiator-contributor. Meanwhile, some female students served as a task assistant in their groups. Still some other students who failed to integrate into the group, played the roles of task outsiders in their groups.

The diversity of each female students' task roles can be found in Fig. 1, where every circle represents a female student's multiple task roles, with each branch of curve indicating different task roles. A circle was positioned roughly according to their difference in participation levels but not in an exact manner. The colors on behalf of team roles present the participation levels of every roles in general but also not in an exact manner, because even same roles were still shown with different performance according to the situation and they

Table 4. Codes in the Dimension of Task Roles

Roles	Codes	Frequency	Count of Students
Initiator-contributor	Proposing a topic or a goal	27	5
	Assigning tasks	22	7
	Discussing the design and function of a project	13	5
	Working as a team leader	6	5
Orienter	Adjusting the working plan according to test results	57	10
	Testing a plan	37	8
	Discussing the design and function of a project	13	5
	Conducting market research	6	4
Energizer	Scheduling, supervising and propelling the progress	61	12
	Being aware of each member's responsibility and working progress	29	8
	Adjusting schedule according to the time limit	8	6
Evaluator-Critic	Reflecting on the project and proposing plans for improvement	19	5
	Criticizing team members' performance	10	3
	Evaluating the project from different perspectives	5	2
Task Assistant	Doing auxiliary work that requires little technical knowledge	105	15
	Obeying the arrangement of the team	54	10
	Assisting in making a product	38	9
	Assisting in the presentation of a project	27	10
Information-seeker	Seeking external resources, information, advice and support	35	7
	Asking team members' opinions, ideas and resources	15	5
	Obtaining information about the project from other team members	5	4
Information-opinion-giver	Expressing one's opinions or ideas about the project	69	11
	Winning support from other team members	15	4
Information Coordinator	Integrating team members' opinions and information	6	2
Technician	Producing a product with one's technical knowledge and skills	90	10
Recorder	Writing minutes of group meetings	9	4
Technique-learner	Taking a long time in learning new things	6	3
	Being gradually involved in the team and in the project	5	2
	Increasing one's engagement through practicing	3	2
Task Outsider	Taking no part in making the product	8	5
	Contributing few constructive opinions	8	4
	One's opinions and advice being ignored by male members	6	4

cannot be identified with a specific grade for the elaboration of participation levels. According to Fig. 1, it can be observed that the students often played different yet related task roles at same time. For example, in Zora's case, she took on the roles of an information-opinion giver as well as a coordinator, both of which were related to the integration of information.

Based on qualitative analyses, factors that are associated with their task roles were also identified, including individual factors, such as personal interest in projects, self-confidence, prior project experience and competence level; and external impact factors, such as, gender ratio in the team, team members' attitudes, male students' attitudes towards female students, and the leadership styles of team leaders. Typical task roles and associated factors will be illustrated and discussed in more details by examples as follows.

Initiator-contributor

Five in twenty-one participants took on the role of an initiator-contributor. These women usually came up with the project theme and led the whole project team. Just as one of them said,

> "It's my proposal to design an intelligent control device, so those men said, because it was *my idea*, I should be the leader . . . I mainly *played the role of a supervisor*. We had a task plan specifying the responsibilities of each member during each time frame. I *organized weekly meeting* so everyone can report their progress and the problems they encountered . . . I think this *leader position helped me integrate with those men*. We had a lot of communications; they would listen to my idea. In addition, if you are very engaged, it can form a very positive atmosphere." – Wendy

In this case, Wendy came up with a plan, organized the group as the tasks unfolded, and assigned everyone different tasks. She also held weekly meet-

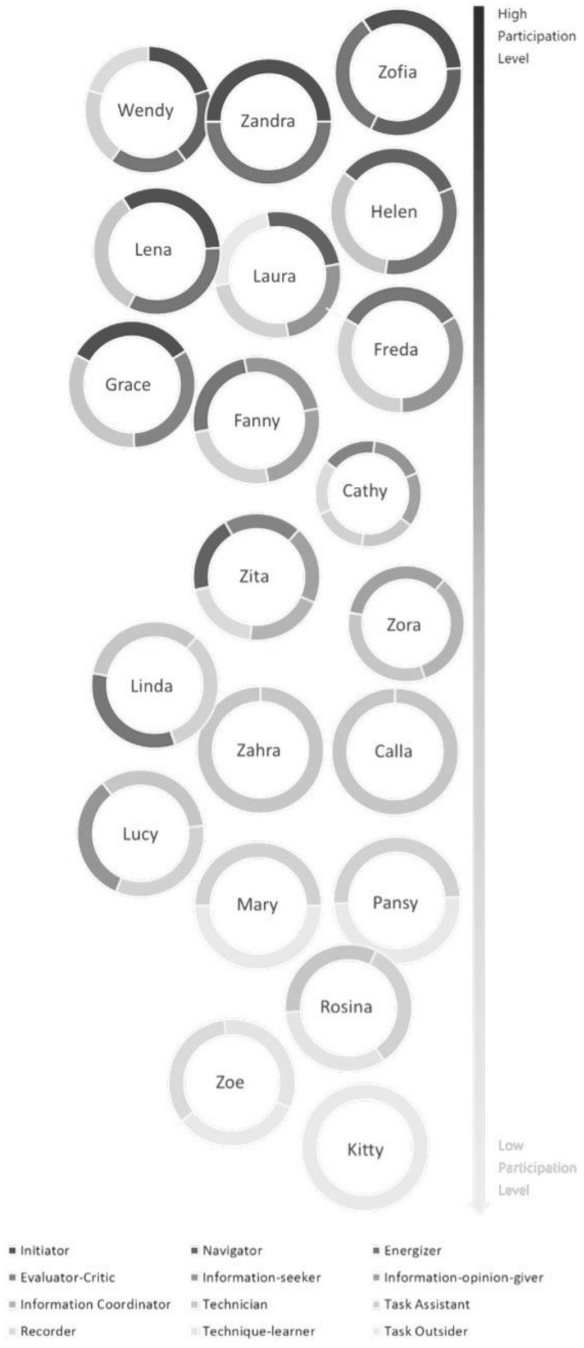

Fig. 1. Individual Female Engineering Student's Task Roles.

ings to check each member's progress and discuss the problems they encountered in the process. As an initiator, she showed active performance, steered the project management, and became a core member of her group.

Information coordinator

The following case shows that female students also play the role of an information coordinator in a group, which means they help optimize their product by gathering ideas and suggestions from the group members.

> "I usually *asked opinions from all the others*, so that everyone can express their own opinions, and their ideas might inspire another . . . But I was not the team leader, therefore I *definitely would not try to control too much*. You see, if the team leader was present, I don't think it's good to be involved too much, to control too much. So, I *would not try to involve myself a lot*." – Zora

In this case, Zora self-reported that she often asked other members' opinions and ideas for a better product. But she also avoided controlling too much and becoming a decision-maker when she was not a team leader, in order to show respect for her team leader. Moreover, participants who take the role of an information coordinator such as Zora often pull ideas and suggestions together for discussion and organize ice-breaking activities for group building.

Task assistant

According to the qualitative data, being a task assistant is found as the most common role played by female engineering students in teamwork. Female students who take the role of an assistant tend to follow leaders' task assignment, and they are often assigned with, to some extent, technically "peripheral work", such as purchasing materials, writing reports, preparing the presentation slides and so on. In contrast, limited opportunities are provided for female students in the process of design and production. Two quotes concerning the role of a task assistant are shown as follows:

> "To tell the truth, my group tasks were *all of those non-technical stuff*, like *buying materials, organizing documents and making PowerPoints* . . . Maybe it is because those male students in my group considered that I'm a female student. They always *arranged me to do some easier work*. Nevertheless*, I did hope I could try the production process*." – Laura

> "When there is only one female in the group, it's common for the female student to do things such as *writing the report instead of the hard, manufacturing type of things*. In addition, boys are more interested in these things; they had a lot of ideas. And, they have the technique, or enjoy digging into it. Therefore, my main role was to *assist them* so that they can concentrate on the task." – Wendy

As illustrated by the quotes above, Laura's tasks had little to do with the core technical procedure, thus her function in a group is to assist other members by doing some non-technical work, such as "buying materials", "organizing documents", "making Power Points" and "writing reports", as mentioned above. In Wendy's case, although she was the leader of the team, few of her tasks were about technique issues, and her job was mainly to provide assistance for other male members. They expressed their desires to be more involved in the

hands-on process, from which they can acquire more practical experience and hands-on skills.

Task outsiders

In all of twenty-one female students that we interviewed, there were five students who exhibited the roles of task outsiders. They performed non-essential tasks and failed to integrate into the group most of the time. Sometimes they did not take the roles of their own accord. Still, external reasons were found to affect their task roles too.

> "I *felt sad* at the beginning because those boys made the product in their male dormitory, where I *couldn't get in!* So, I had to *stay in my dormitory with nothing to do* when those boys did teamwork in their place. It really *made me upset* and *felt like I was not needed in the group*. Other girls in my dormitory encountered similar situations like this and they had the same feelings as I did." – Kitty

> "As for the production process . . . I was a little ashamed. The other four students in my group were competent, but I felt that *I had little talent* [related to this work], and *I had no previous project experiences*. So, I only watched them working on the project on the side and did not take part in this process. I just learned from the working process by observing." – Pansy

As Kitty said in the interview, she failed to take part in the working process because the workplace was inaccessible to her, which made her quite sad. In the second case, Pansy did not participate in working process because she felt less competent than her peers in hands-on skills and had no previous project experiences. She only stood beside and observed how her partners worked on the project as an outsider.

5.2 Social Roles

Social roles are related to the maintenance and the building of a team. Up to 11 kinds of social roles were identified, including harmonizers, coordinators, followers, communication outsiders and so on (Table 5). It shows that female engineering students played a variety of social roles in their working processes. Students that are initiative played the roles of a coordinator, a team spirit-promoter and an encourager. Some students served as a harmo-

Table 5. Codes in the Dimension of Social Roles

Roles	Codes	Frequency	Count of Students
Coordinator	Organizing group meetings	37	8
	Creating a friendly atmosphere of communication	27	8
	Promoting communication and discussion between members	17	6
	Communicating with male members actively	6	4
Team-spirit Promoter	Motivating team members with a positive attitude	9	4
	Promoting teambuilding	8	4
Encourager	Encouraging and motivating members to complete a project	4	3
	Approving other team members' ideas	2	1
Gatekeeper	Communicating with others on behalf of the team	23	8
	Helping other members to express themselves explicitly	8	4
Harmonizer	Playing different roles in a team according to the personality of other members	10	4
	Coordinating and facilitating the interactions between other members	7	4
	Adjusting communicative strategies according to other members' response	5	3
	Employing different communicative strategies with different members	2	1
Disagreement-advocate	Regarding disagreement as an ignitor of creative ideas	6	4
	Preparing solutions for possible disagreements	1	1
Conflict Mediator	Reconciling team members	89	14
	Keeping calm when there are conflicts within the team	4	2
Caring Person	Comforting the members who have negative emotions	12	6
	Taking care of other members' emotions	6	3
	Self-regulating one's negative emotions	5	2
Compromiser	Being prone to compromising without weighing pros and cons	7	4
	Taking actions to avoid conflicts	5	2
	Reducing management of the team in order to maintain one's authority as a team leader	2	1
Follower	Following the majority's opinion	10	4
Communication Outsider	Being isolated by male members in communication	9	4
	Not doing well in communication with male members	2	1

nizer or a compromiser when their team met conflicts. Still, there were students who were not engaged in the group communications (communication outsider).

The diversity of each female students' social roles can be found in Fig. 2. In Fig. 2, every circle represents a female student's multiple task roles, with each branch of curve indicating different social roles. A circle was positioned roughly according to their difference in participation levels but not in an exact manner. Again, it can be found that each female played several yet often related social roles. For instance, with good communication skills, Freda took on the roles of a team spirit-promoter, a harmonizer, a disagreement-solver and a compromiser all at the same time. In Laura's case, she played roles of a follower and a communication outsider, which were both identified as more in the passive end of the engagement spectrum.

In terms of impact factors, we found that individual factors like competence level and personality trait, and external factors like communication atmosphere and emergency events could influence female students' social roles in their groups. Typical social roles and associated factors will be illustrated and discussed in more details by examples as follows.

Conflict mediators

In the dimension of social roles, most female students reported that they played the role of a conflict mediator, in that they tried to reconcile the disagreement among other members, relieve tensions in conflict situations and promote a harmonious atmosphere in the group work. According to the interviews, the work is mainly done by reasoning, or having a personal talk with individual members. For example:

> "One male student in my group was a leader of the debate team in our school, and he was eloquent, a little aggressive and autocratic. But the other man who had different opinions with him was an introvert. He had his own idea, but he didn't try to argue because he is not good at expressing himself. If he was angry, he would just sit alone and keep silent. Thus, I *talked to them separately*, just to *improve their relationship*. In the end, they are ok with each other after the project." – Zora

In Zora's case, she played such a role through having personal talk with each member that was involved in the conflict and contributed to the group by resolving the conflicts that hindered the work progress.

Gatekeepers

Apart from the two social roles discussed above, several female students also self-reported their

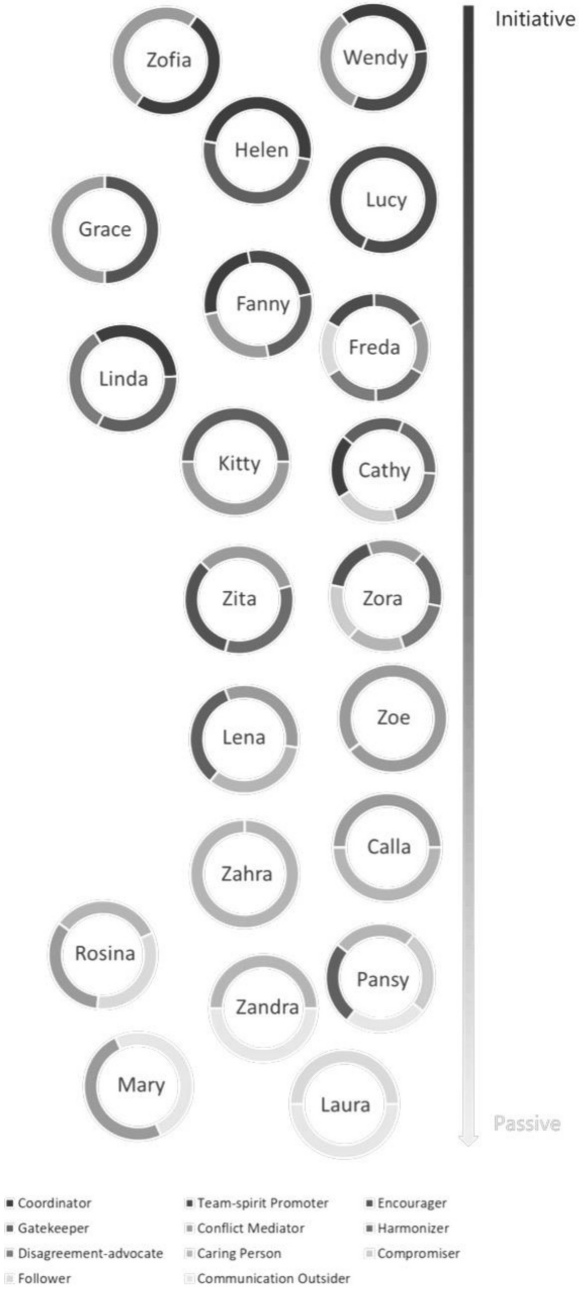

Fig. 2. Individual Female Engineering Student's Social Roles.

strength in having effective communications. Because of their good communication skills, they usually play the role of a gatekeeper, who act like a spokesperson, that is, they summarize all team members' ideas or opinions and present them in a clear manner to audiences such as teachers, teaching assistants and specialists.

> "I'm *good at expressing ideas*, so *most presentations were done by me*. They provided all information I needed for me, and I was responsible for the presentation, the exhibition." – Cathy

As what Cathy said, she usually acted as a gatekeeper in her group due to her good communication

skills and presentation skills. Based on the resources provided by other team members, she, as a representative, presented the results of the whole project to teachers, experts and so on.

Followers

Female students who played the role of a follower reported that they did not have any good ideas, thus often accepted the ideas of others. When these female students felt that their male peers did not hear their voice or when the group was having conflicts, they chose not to express their opinions and kept silent during group discussions and the decision-making process. As a result, they only passively accepted their work assignment and followed the leaders of the group, ensuring that they kept up with the flow as the project proceeded. For example,

> "I didn't have many ideas, so usually *I did whatever the leader told me*, which usually included buying materials, improving the product's appearance, et cetera . . . Sometimes I had my own opinion, but when we were having a conflict, I would *choose not to express my ideas* for fear that the situation would become worse." – Laura

> "Two male members had very strong personalities and sometimes were a little stubborn, so I *usually followed them* so that I would have few conflicts with them." – Freda

Some female students preferred to be a follower as a way to avoid conflicts. They tended to follow leaders' arrangement and kept silent in group discussions, especially when working with people with strong personalities.

Communication outsiders

In the dimension of social roles, a communication outsider is one of the most common roles in male-dominated project groups. Among the twenty-one students we interviewed, six female students self-reported the feeling of being a communication outsider in their groups, especially in those groups with only one female student. Communication outsiders experienced disconnections with the group activities. They felt being isolated and unable to integrate into the group.

Table 6. Codes in the Dimension of Individual Roles

Roles	Codes	Frequency	Count of Students
Active Participant	Taking the initiative in teamwork	21	9
	Learning new things actively	16	5
	Accumulating practical experience	13	5
	Choosing a task for oneself	7	3
	Insisting on participation when being ignored by male members	4	2
	Helping those in need actively	4	3
	Refusing to be an outsider	3	3
	Completing tasks in advance	3	1
Challenge-lover	Accumulating practical experience	13	5
	Improving professional competence	6	4
	Preferring the team with strong members in order to learn more	3	3
Leadership-lover	Enjoying the feeling of freshness and the sense of achievement that a project can bring	19	9
	Being willing to be a team leader	6	3
	Learning leadership skills actively	2	1
Self-reflecting Thinker	Improving one's confidence and cognitive abilities	12	7
	Improving one's self-learning ability	6	3
	Reflecting on one's strengths and weaknesses	3	2
	Reflecting on whether a project has achieved its original goal	1	1
Friendship-seeker	Making new friends	4	2
Cooperation-seeker	Preferring to work with a female member to complete a task	19	6
	Hoping to finish a project with others' companionship	4	2
Recognition-seeker	Winning other members' recognition by making contributions	5	2
	Accompanying other members though taking no part in making the product	5	3
	Hoping to be treated equally	2	1
Acquaintance-reliant	Taking different actions according to the familiarity with other members	9	6
Leadership-withdrawer	Avoiding being a team leader	25	8
	Hoping not to assume major responsibilities	20	10

> "Sometimes I *didn't know how to get along with the men* because I was the only female in my group, which made me *feel nervous*. I seldom spoke to them, so I felt I *could not integrate into the group* . . . I guess they may not think I'm competent enough to deal with those technical problems, so they *seldom discussed those problems with me*." – Zandra

In this case, Zandra became a communication outsider because she was not comfortable in a male-dominated group. One possible reason for her role of an outsider was her perception that the male students believed that female students were in weaker positions and lacked engineering skills compared to male students.

5.3 Individual Roles

In the dimension of individual roles, roles are related to individual needs or expectations. We found ten roles in this dimension, including challenger-lovers, active participants, passive participants, leadership avoiders and so on (Table 6). Participants with a strong motive to improve themselves often welcome challenges. They were more willing to take on leadership roles, and therefore played the roles of active participants. Meanwhile, half of the participants self-reported that they were not willing to take on leadership roles or major responsibilities of the group. Around half of the female students exhibit partially a mindset of a "free-rider", they wanted to reply on the other competent students (male or female students) in the group, and just took on limited responsibilities. Some students were unable or reluctant to change the status of unable to fit into the male-dominant group.

Individual female student could also demonstrate multiple roles at same time in this dimension (Fig. 3). Again, it can be found that each female played several yet often related individual roles. For instance, Wendy who loved challenges, were also willing to act as a leader and enjoyed a sense of achievement obtained through the project. Freda and others who tended to avoid leadership roles, also demonstrated passive behaviors.

In addition, we also explored the impact factors of their individual roles. Individual needs and expectations were the main factors in this dimension. Meanwhile, gender ratio and team structure would also influence how female students' individual roles came about. Typical social roles and associated factors will be illustrated and discussed in more details by examples as follows.

Active participants

An active participant means someone who often takes responsibility initiatively and offers help for others with a positive attitude. Among all participants, four students took the roles of active participants. They had a strong willingness to learn new things and gain practical skills. They often volunteered themselves and were very well engaged in the whole process of projects.

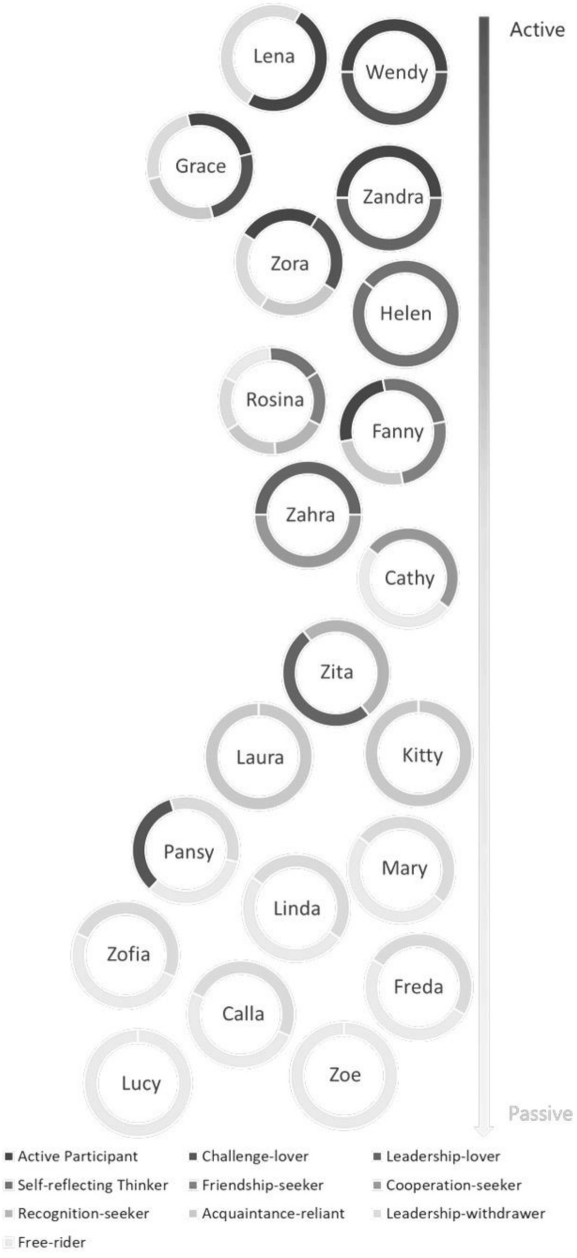

Fig. 3. A Profile of Each Female Engineering Student' Individual Roles.

> "I hope I can be a *useful person* in my group, either as a leader or as a member. On one hand, I *need to do my duty well*; on the other hand, I'm *willing to help other members in my group if they need some help*." – Wendy

In Wendy's case, she played the role of an active participant in her group because she hoped to be a useful person. She was responsible for her tasks and was always ready for helping other members.

Free-riders

Different from active participants, free-riders have a negative attitude and lack involvement. They devote limited effort to the project and prefer teams with more capable members to reduce their own duty.

> "Maybe we girls were not good at hands-on work, so many girls would love to *escape their duties* and *hope for other capable people to finish the project* if they had the opportunities . . . when boys in my group made the product in their male dormitory*, I cannot join them, but I don't care. I would not ask for more duties or more participation*." – Zofia

As Zofia said in the interview, she did not want to put too much effort into the project, so she was willing to maintain the situation where she was, e.g., not being involved in the product-making processes. In her opinion, female students are not good at hands-on work, so it is common for female students to rely on the male students to finish the team projects.

5.4 Comparisons Across Three Dimensions

In addition to the findings based on each dimension, this study also summarized female engineering students' functional roles in dimensions of task roles (blue series), social roles (orange series), and individual roles (green series) on an individual basis, which is illustrated in Fig. 4. Different shades of color in each series represent different role in the corresponding dimension. The lighter the color is, the more passive (having lower participation level) the respective role shows. For each individual, three circles are used to represent her three different dimensions. Participants' three-circles are positioned roughly according to their participation level (horizontal axis) and the uniformity across three dimensions (vertical axis). The larger the size of a circle, the higher the frequency of the respective role has for one particular person (not comparable across different persons).

As shown in Fig. 4, most female students' functional roles showed high consistency among three dimensions, that is, there are more students in the upper half (high uniformity) than the lower half (low uniformity). For example, as a team leader, Wendy played the roles of an initiator-contributor and an energizer in the dimension of task roles, and served as a coordinator, a team-spirit promotor and a gatekeeper in the dimension of social roles and an active participant in the dimension of individual roles. All the roles that she took in the three dimensions could reflect her high participation level and positive attitudes, as manifested by her contributions for the team. In contrast, Mary was found to have lower participation levels in all three dimensions, and she was not able to integrate into

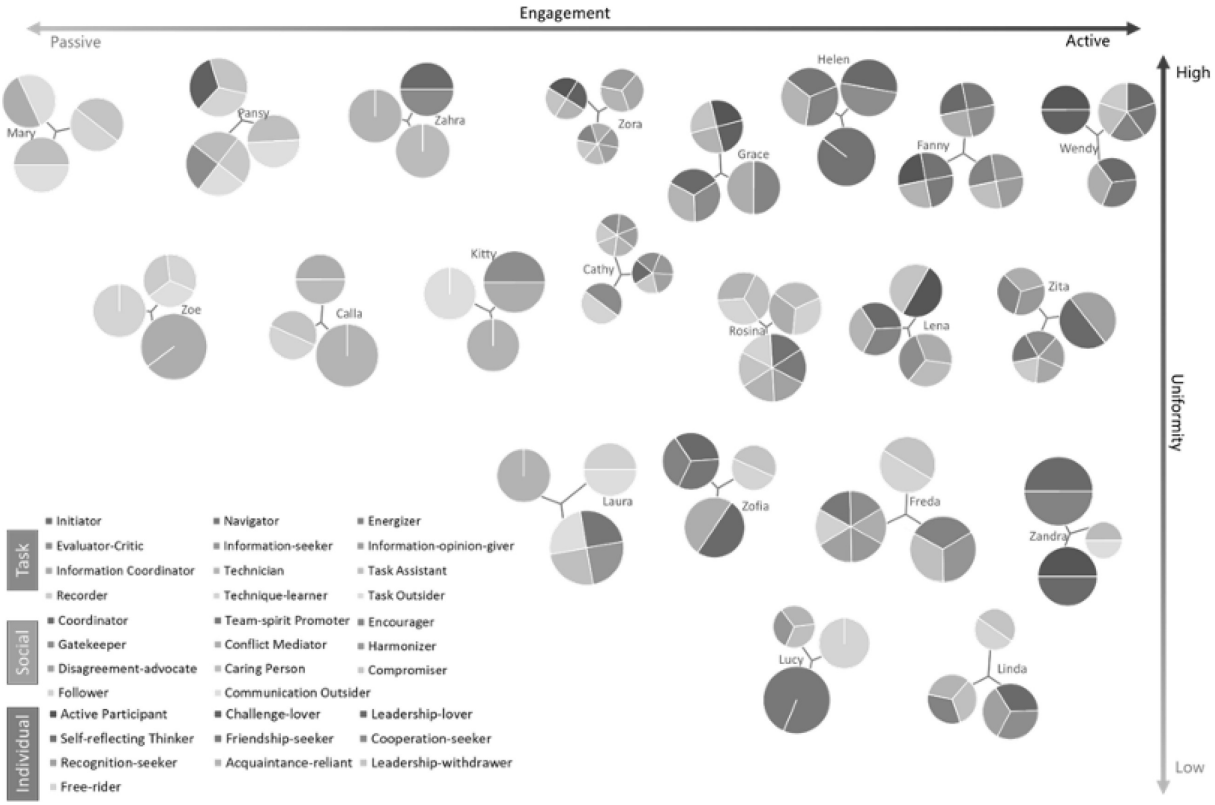

Fig. 4. Individual Female Engineering Students' Functional Roles in Three Dimension.

her male peers throughout the team working processes. This is again an example of students with high uniformity across three dimensions. The high uniformity across three dimensions observed in most students suggests the close knit among the different dimensions, in which the needs and expectations in the individual dimension could impact the role-taking in other dimensions. For instance, Zoe self-reported her desire to get "a free ride" in the class. So even when she realized that she was not involved, she would choose to remain that way. She ended up "not doing much".

Nevertheless, some female engineering students showed distinct performances across dimensions. A notable example is Kitty's case: she was found to be a task outsider in the dimension of task roles and an acquaintance-reliant in the dimension of individual roles, both of which represent low participation levels. However, partially due to her outstanding communication skills and presentation skills, Kitty manifested active attitudes in the dimension of social roles and played the roles of a spokesperson and a conflict mediator in her team. Another case, Linda performed the roles such as a technician in her task roles, and a coordinator and a gatekeeper in her social roles. However, she expressed her hope to not be a leader and take a free ride if possible. As to possible causes, she mentioned that she had to take on the responsibilities due to the task assignments in the team, despite the fact that she did not want to put in so much effort on the project. It suggested that functional roles played by female students were not only affected by individual expectations, but also influenced by external factors like groups' task divisions, leadership styles and so on.

6. Discussion

In sum, our findings demonstrated a range of functional roles performed by female engineering students in the dimensions of task, social and individual roles in the context of PBL. The findings of the current study fill the gap of female engineering students' group roles among existing research on PBL from female students' perspectives. With the use of a phenomenographic approach, we were able to identify various functional roles performed by female students in a group project. We examined female engineering students' functional roles in a group project context, including 12 task roles, 11 social roles and 10 individual roles. Based on the empirical study, our findings expand our current understanding about female students in several ways, including their team performance, various functional team roles and potential impact factors of their roles. In addition, this study enriches Benne and Sheats' functional roles model by adopting a female specific perspective.

First, our findings enrich the functional roles model by adding new roles because of the unique perspective from and the focus on female engineering students and the distinctive features of PBL. We applied Benne and Sheats' definitions for the three dimensions. Meanwhile, throughout the analyses, we remained open to new roles which may not be in Benne and Sheats' original model which was developed in a team but not necessarily a project-based collaborative learning environment. Specifically, in the dimension of task roles, the original model included only roles that are constructive to the completion of the group tasks, such as a "task assistant" or a "coordinator". However, in a collaborative learning environment, students may not fully engage in completing the tasks and therefore can take on roles such as "technique learner" or "task outsider", which can signify a stage of the learning process for students, or a stage of marginalization. This classification of outsider in task differs from a "communication outsider" in social roles or a "free-rider" in individual roles, which were often related to the social or emotional aspects of the students. Moreover, in the dimension of social roles, we also found new roles, such as the "caring person", who takes notice feelings of team members and tries to ease their discomfort when needed. In the dimension of individual roles, we identified new roles such as, a leadership-lover and a leadership-avoider. As a gender study, this research enriched Benne and Sheats' functional roles model and provided empirical evidence based on qualitative data from female engineering students.

Meanwhile, different from previous studies that highlighted the marginalization faced by female students [4, 7, 16, 40], this research demonstrated the range of functional roles, including technical and leader positions, that can be performed by female engineering students. Prior research had observed female engineering students' lower grades or more learning difficulties than males in PBL [32]. However, in this study, quite a few female students were found to take on active leadership roles or act as a technical expert. For instance, some female students took the roles of initiator-contributors and orienters in their groups, who set up the team goals, supervised and urged team members to finish their tasks. Some females with good communication skills played the role of a gatekeeper, and some female students served as harmonizers in their group because of their decent persuasive skills based on their self-assessment [41, 42]. Moreover, even though some women who self-reported having poor technical skills could not integrate into male-dominated groups, they still kept a positive atti-

tude, learned new things actively and finally made their indispensable contribution to their project team. Female students were more likely to conduct helping behaviors and contributes to team building and group dynamics development. Overall, female students in this study were observed to have a range of functional roles in teamwork processes, including both roles which signified marginalization, as well as roles which can make significant contributions to their groups. Considering lower confidence level of female students [5], more encouragement supported by empirical evidence are needed for female students to help them improve self-efficacy and professional identity in PBL context.

Based on our findings, for the improvement of female students' learning experience and future PBL implementation, several suggestions are proposed for different stakeholders. First, concerning factors related to female students' various functional roles, echoing the results in previous research, factors such as group size and gender ratio, were found to be associated with female students' performance and engagement [4]. Effective actions can be taken to improve female students' learning experience by professors throughout the whole process of PBL. When designing the PBL practice, having two or more female students in a group was found to be helpful to reduce the risk of marginalization. Strategies can be taken by professors to ensure a more balanced group gender ratio and to include gender equity education partially to increase students' awareness to establish a more female-friendly environment [43, 44]. Second, female students' interest, prior learning experiences, expectations and motivations could also be associated with their performance in a group project context [4, 32]. Prior PBL trainings were found to be helpful for students in increasing their engineering identity and accumulate practical experiences [10]. We suggest that ''warming-up'' activities and pilot projects could be arranged at the beginning of the project courses, in order to enable students to gain teamwork experience and improve teamwork skills [43]. Third, during PBL, some routines can be arranged to ensure effective task divisions or assignment, such as reporting task roles regularly and rotating roles [45–47]. Engineering staff need to take the role of facilitator to help students achieve effective teamwork and improve all team members' learning outcomes in PBL. Fourth, based on our interviews, female students who took the positions of a leader were found to be easier in their integration to the male-dominant groups. Hence, equal opportunities should be given for female students for leadership roles. More models of female engineers could also be introduced to female engineering students to enhance their confidence of professional skills and leadership. Last but not least, according to female students' self-reports, male students' attitudes toward them had influence on their learning experience. Therefore, to establish a female-friendly environment, lectures or workshops related to gender issues in teamwork could be held to involve the effort from male students and engineering staff, and to raise their awareness of gender equality.

As for the limitation of this study, here we focused on first-year female engineering students, for whom PBL can be a new learning experience. According to Marra's research [4], senior female engineering students could become more experienced and show higher self-efficacy in their academic performance. Further study could include students from different academic levels. Perspectives from male students and engineering staff can also be incorporated into future studies to explore gender differences in students' functional roles and provide an additional frame of reference.

7. Conclusion

This research examined female engineering students' functional roles in PBL to understand their learning experience in a male-dominant engineering course. The exploration of female students' functional roles provided an overall understanding about the diversity in female students' functional roles and associated impact factors. Suggestions as related to group arrangement, task division and other aspects in PBL were discussed for future course design. Our findings provide practical suggestions for multiple stakeholders in engineering education and can be used to inform the design of engineering curriculum and the incorporation of effective teaching and learning activities for female students.

References

1. National Science Foundation. *Women, minorities, and persons with disabilities in science and engineering*, 2013 Retrieved from: https://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab2-10-updated-2016-08.pdf.
2. The Ministry of Education of China. *Educational statistics in 2013*, 2013. Retrieved from: http://en.moe.gov.cn/Resources/Statistics/edu_stat_2013/2013_en02/. (In Chinese)
3. D. Baker, S. Krause and C. Roberts, An intervention to address gender issues in a course on design, engineering, and technology for science educators, *Journal of Engineering Education*, **96**(3), pp. 213–226, 2007.

4. R. M. Marra, K. A. Rodgers and D. Shen, Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy, *Journal of Engineering Education*, **98**(1), pp. 27–34, 2009.
5. H. K. Ro and D. B. Knight, Gender differences in learning outcomes from the college experiences of engineering students, *Journal of Engineering Education*, **105**(3), pp. 478–507, 2016.
6. M. F. Belenky, B. M. Clinchy, N. R. Goldberger and J. M. Tarule, *Women's ways of knowing: The development of self, voice & mind*, New York, NY: Basic Books, 1986.
7. G. S. Stump, J. C. Hilpert and J. Husman, Collaborative learning in engineering students: Gender and achievement, *Journal of Engineering Education*, **100**(3), pp. 1–24, 2011.
8. X. Du and A. Kolmos, Gender inclusiveness in engineering education is problem-based learning environment a recipe? *European Journal of Engineering Education*, **7**(5), pp. 25–38, 2007.
9. K. Lewin, *Resolving social conflicts*, New York: Harper and Row, 1945.
10. X. Du, Gendered practices of constructing an engineering identity in a problem-based learning environment. *European Journal of Engineering Education*, **31**(1), pp. 35–42, 2006.
11. M. Stephen, A study into the factors that influence female engineering students' career choice: a case study of Mutare Polytechnic, Zimbabwe, *Scientific Research and Essays*, **2**(6), pp. 211–216, 2007.
12. R. Torres, M. Torres, S. Ferreira, A. Sousa and L. Moreira, Welcome to engineering: Gender equality in learning and integration among first year students, *The International Journal of Engineering Education*, **34**(1), pp. 45–55, 2018.
13. M. Besterfield-sacre, M. Moreno and L. J. Shuman, Gender and ethnicity differences in freshmen engineering student attitudes: A cross-institutional study, *Journal of Engineering Education*, **90**(4), 4 pp. 77–489, 2001.
14. M. Williams and C. George-Jackson, Using and doing science: Gender, self-efficacy, and science identity of undergraduate students in STEM, *Journal of Women and Minorities in Science and Engineering*, **7**(3), pp. 125–143, 2014.
15. C. M. Vogt, D. Hocevar and L. S. Hagedorn, A social cognitive construct validation: Determining women's and men's success in engineering programs, *The Journal of higher education*, **78**(3), pp. 337–364, 2007.
16. S. B. Berenson, K. M. Slaten and L. Williams, Voices of women in a software engineering course: Reflections on collaboration. *Journal on Educational Resources in Computing*, **4**(1), pp. 3–18, 2004.
17. K. Edström and A. Kolmos, PBL and CDIO: Complementary models for engineering education development, *European Journal of Engineering Education*, **39**(5), pp. 539–555, 2014.
18. Y. V. Zastavker, M. Ong and L. Page, Women in engineering: Exploring the effects of project-based learning in a first-year undergraduate engineering program. Paper presents at the *2006 IEEE Frontiers in Education Conference (FIE)*, **36**, pp. 1–6, 2006.
19. D. Wen, A comparative study on the gender disparity in higher education opportunity, schoolwork achievement and graduate employment in China, *Tsinghua Journal of Education*, **26**(5), pp. 16–21, 2005. (In Chinese)
20. C. Guo, M. Zeng and X. Ding, Gender Gap in Science and Engineering in Chinese Universities, *Research in Higher Education*, **28**(11), pp. 89–101, 2007. (In Chinese)
21. R. Zhao, *A thesis submitted in partial fulfillment of the requirements for the master's degree of education*, Doctoral dissertation, Wuhan: Huazhong University of Science and Technology, 2007. (In Chinese)
22. X. Wang, X. Zhang and R. Zhao, Study of women students' willing and path to choose engineering education, *Journal of Xi'an Jiaotong University (Social Sciences)*, **12**(6), pp. 89–94, 2010. (In Chinese)
23. M. Ye, *Study of an adaptive transformation platform of the CDIO in engineering education*. Doctoral dissertation, Hangzhou: Zhejiang University, 2013. (In Chinese)
24. S. Guan and L. Lian, A study of female engineering students' self-efficiency, *Jiangsu Higher Education*, **6**(1), pp. 72–75, 2016. (In Chinese)
25. Z. Li, L. Yin and D. Ma, Analyses and strategies of women talents' growth processed in the field of science and technology, *Science and Technology Association Forum*, **21**(11), pp. 146–148, 2018. (In Chinese)
26. K. D. Benne and P. Sheats, Functional roles of group members, *Journal of Social Issues*, **4**(2), pp. 41–49, 1948.
27. D. R. Forsyth, *Group dynamics*, Boston: Cengage Learning, 2009.
28. M. Belbin, *Management teams: Why they succeed or fail*, London: Heinemann, 1981.
29. P. E. Mudrack and G. M. Farrell, An examination of functional role behavior and its consequences for individuals in group settings, *Small Group Research*, **26**(4), pp. 542–571, 1995.
30. M. Zancanaro, B. Lepri and F. Pianesi, Automatic detection of group functional roles in face-to-face interactions. Paper presents at the *2006 International Conference on Multimodal Interfaces*, **8**, pp. 28–35, 2006.
31. W. Dong, B. Lepri, F. Pianesi and A. Pentland, Modeling functional roles dynamics in small group interactions. Paper presents at the *2013 IEEE Transactions on Multimedia*, **15**(1), pp. 83–95, 2013.
32. M. Laeser, B. M. Moskal and R. Knecht, Engineering design: Examining the impact of gender and the team's gender composition, *Journal of Engineering Education*, **92**(1), pp. 49–56, 2003.
33. K. D. Benne and B. Muntyan, *Human relations in curriculum change*, New York: Dryden Press, 1951.
34. G. L. Stewart, I. S. Fulmer and M. R. Barrick, An exploration of member roles as a multilevel linking mechanism for individual traits and team outcomes, *Personnel Psychology*, **58**(2), pp. 343–365, 2005.
35. L. Y. Eberhardt, *Working with Women's Groups*, Minnesota: Whole Person Association Inc, 1987.
36. J. Bowden and E. Walsh, *Phenomenography*, Melbourne: RMIT Press, 2000.
37. F. Marton, Phenomenography – A research approach to investigating different understandings of reality, *Qualitative research in education: Focus and methods*, pp. 28–49, 1986.
38. K. M. MacQueen, E. McLellan, K. Kay and B. Milstein, Codebook development for team-based qualitative analysis, *Cultural Anthropology Methods*, **10**(4), pp. 31–36, 1988.
39. S. B. Merriam, *Qualitative research in practice: Examples for discussion and analysis*, California: Jossey-Bass Inc, 2002.
40. G. M. Walton, C. Logel and J. M. Peach, Two brief interventions to mitigate a "chilly climate" transform women's experience, relationships, and achievement in engineering, *Journal of Educational Psychology*, **107**(2), pp. 468–483, 2015.
41. A. Joshi, By whom and when is women's expertise recognized? The interactive effects of gender and education in science and engineering teams, *Administrative Science Quarterly*, **59**(2), pp. 202–239, 2014.

42. X. Du, K. K. Naji, S. Sabah and U. Ebead, Engineering students' group-based strategy use, forms of collaboration and perceptions of assessment in team projects – a case study in Qatar, *International Journal of Engineering Education*, **36**(1), pp. 296–308, 2020.
43. M. Goldschmidt and F. X. Bogner, Learning about genetic engineering in an outreach laboratory: Influence of motivation and gender on students' cognitive achievement, *International Journal of Science Education*, **6**(2), pp. 166–187, 2016.
44. L. A. Stein, D. Aragon and D. Moreno, Evidence for the persistent effects of an intervention to mitigate gender-stereotypical task allocation within student engineering teams. Paper presents at the *2014 IEEE Frontiers in Education Conference (FIE)*, **44**, pp. 1–9, 2014.
45. X. Du and A. Kolmos, Increasing the diversity of engineering education–a gender analysis in a PBL context, *European Journal of Engineering Education*, **34**(5), pp. 425–437, 2009.
46. X. Du and K. K. Naji, Engineering students' collective agency and professional identity in a Problem and Project-Based learning environment: a case in Qatar, *Journal of Civil Engineering Education*, **147**(4), p. 04021007, 2021.
47. K. K. Naji, U. E. Ebead, A. Al-Ali and X. Du, Comparing models of Problem and Project-Based learning (PBL) courses and student engagement in civil Engineering in Qatar, *EURASIA Journal of Mathematics, Science and Technology Education*, **16**(8), em1867, 2020.

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