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How Gender Pairings Affect Collaborative Problem Solving in Social-Learning Context: The Effects on Performance, Behaviors, and Attitudes

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ABSTRACT: This study aimed to investigate the effects of gender pairings on collaborative problem-solving performance, processes, and attitudes in a social learning context. Three types of pairings (i.e., male-male, female-female, and mixed pairings) were considered in an empirical study with 222 tenth-grade students. The selection of three different schools facilitated discussions regarding which schools were more divergent and competitive in a social learning context. The students were asked to solve computer science problems on a social media platform. The results revealed that (1) the single-gender groups had more focused discussions than the mixed-gender groups. Specifically, the male-male groups tended to develop and test their solutions directly without spending significant time on problem identification. Consequently, the single-gender groups exhibited superior performance compared to the mixed-gender groups in terms of applying their knowledge to problem solving. In terms of attitudes toward social learning, the female-female groups were more attentive to the benefits of social learning than the male-male groups. (2) The mixed gender groups had more diverse and divergent discussions compared to the single-gender groups. The educational implications of these findings are also discussed in this paper.

Keywords: Social learning, Gender pairing, Gender difference, Social media, Problem solving

1. Introduction

Based on the development and expansion of social media platforms, their usefulness in the field of education has received increased attention (Ranieri, Manca, & Fini, 2012; Al-Rahmi, Alias, Othman, Marin, & Tur, 2018; Moghavvemi, Sulaiman, Jaafar, & Kasem, 2018; Prestridge, Tondeur, & Ottenbreit-Leftwich, 2019). Because social media provides an interactive social learning environment, by forming connections between heterologous learning communities, students have more opportunities to exchange ideas and opinions with others, which helps foster knowledge construction (Kimmerle, Moskaliuk & Cress, 2011) and has a significant impact on learning performance (Puntambekar, 2006; Moskaliuk, Kimmerle, & Cress, 2012). Significant research efforts have been devoted to investigating how students interact and how their interactions influence learning (Liu & Tsai, 2008; Hou & Wu, 2011; Avcı Yücel & Usluel, 2016; Moghavvemi, Sulaiman, Jaafar, & Kasem, 2018). Such research contributes to developing effective instructional methods with respect to social learning (Moreno, Gonzalez, Castilla, Gonzalez, & Sigut, 2007; Al-Rahmi, Alias, Othman, Marin, & Tur, 2018) and provides opportunities for social learning and interaction, which can help students develop new perspectives by comparing and integrating divergent and conflicting opinions (Moskaliuk, Kimmerle, & Cress, 2012).

However, a social network involves a complex composition of individuals and their relationships, and these factors may influence knowledge sharing and learning performance (Eid & Al-Jabri, 2016). Therefore, team dynamics should be considered in social learning environments (Heo, Lim, & Kim, 2010; Kimmerle, Moskaliuk & Cress, 2011; Lin, Hou, Wang, & Chang, 2013; Avcı Yücel & Usluel, 2016; Son, Kim, Na, & Baik, 2016; Wong & Hsu, 2016). Individual differences are one of the main factors influencing social learning. Student characteristics and interaction styles (e.g., densities, positions, and ties in the social network) influence learning performance in different ways (Chung & Paredes, 2015; Wong & Hsu, 2016). Therefore, various grouping strategies considering individual differences have been considered to facilitate social learning, such as heterogeneous and homogeneous strategies. Many studies have advocated the use of heterogeneous groupings to leverage the diversity of student abilities and characteristics (Wilkinson & Fung, 2002) because heterogeneity can provide additional opportunities to learn from peers with different ability levels and backgrounds. Additionally, various pairing strategies can promote positive learning interactions for collaborative problem solving and improve learning performance (Chen & Chang, 2014).

Regarding pairing strategies, gender differences represent a significant factor that should be concerned in a social learning environment (Underwood, Underwood, & Wood, 2000; Prinsen, Volman, & Terwel, 2007; Zhan, Fong, Mei, & Liang, 2015). Some research has indicated that mixed-gender groups engage less in collaborative problem solving and develop fewer solutions compared to single-gender groups (Underwood, Underwood, & Wood, 2000). However, other research has indicated that mixed-gender pairs provide more divergent knowledge elaboration patterns, which is a significant predictor for learning performance (Ding, Bosker, & Harskamp, 2011). Additionally, males and females may perform differently in different gender pairings. For example, males tend to be more active in dominating the discourse in mixed-gender groups (Prinsen, Volman, & Terwel, 2007) and are more deliberate in terms of problem solving in mix-gender groups compared to single-gender groups. Female-only groups tend to share more personal opinions (Savicki, Kelley, & Oesterreich, 1998), distribute more information for problem solving (Ding & Harskamp, 2006), and are typically more satisfied with social learning (Savicki, Kelly, & Lingenfelter, 1996). Our review of Scopus journal articles published over the past decade indicated that most studies have limited their social learning scenarios to the context of a class or a school. In a larger social learning environment, the effects of group dynamics may be more complex and perceptible. Therefore, larger context requires additional exploration.

This study aimed to clarify how gender parings affect collaborative problem solving in a social learning context by analyzing student learning behaviors during social learning, which can contribute to the educational research field in terms of learning contexts and methodologies. Regarding learning contexts, previous studies have largely focused on discussing grouping strategies for collaborative learning in classroom environments. This study extended the learning context from a classroom to a cross-school social learning platform. Regarding methodologies, most previous studies have applied statistical or qualitative approaches. This study adopted both sequential analyses and statistical approaches to investigate the dynamic and sequential behaviors of students during collaborative problem solving to determine the impact of gender pairings on learning. We attempted to answer three major research questions.

- How do gender pairings influence student performance in terms of collaborative problem solving in a social learning context?
- How do gender pairings influence student behaviors during collaborative problem solving in a social learning context?
- How do gender pairings influence student attitudes toward social learning?

2. Literature review

2.1. Social learning and grouping strategies

In a social learning environment, students have more opportunities to exchange ideas and opinions with others, which helps foster knowledge construction (Kimmerle, Moskaliuk & Cress, 2011). Social learning theory (Bandura, 1977) suggests that individuals construct ideas by observing and imitating peer behaviors. Social constructivism (Vygotsky, 1978) claims that knowledge is constructed through interactions between individuals. The divergence and incongruity observed in social learning environments have been shown to have a significant impact on learning performance (Moskaliuk, Kimmerle, & Cress, 2012; Puntambekar, 2006). Enhancing communication and interaction can help elucidate the problems being discussed and facilitate the process of creativity (Al-Zahrani, 2015). Students who have many active bidirectional interactions with their peers tend to perform better in terms of collaborative problem solving (Chen & Chang, 2014).

Research on the implementation of effective social learning has received significant attention in recent years (Moghavvemi, Sulaiman, Jaafar, & Kasem, 2018). However, appropriate methodologies for utilizing social media in education are still under active investigation. Additionally, although previous research has indicated the benefits of cross-culture social learning, such as cross-organization or cross-country learning (Berkes, 2009; Douglas, Farley, Lo, Proskurowski, & Young, 2010), there has been a lack of research exploring the implementation and effectiveness of large-scale social learning.

To achieve social and academic heterogeneity for effective social learning, various grouping criteria considering individual differences have been studied (Chen & Chang, 2014). Heterogeneous grouping could be an effective method for encouraging divergent perspectives and fostering student cognitive restructuring and problem solving (Wilkinson & Fung, 2002; Zurita, Nussbaum, & Salinas, 2005). Heterogeneity promotes interactions among peers with different ability levels and backgrounds during problem solving through the exchanging of questions and explanations (Hoffman, 2002). It can also help students request clarifications, justifications, and elaborations for problem solving (Heller, Keith, & Anderson, 1991). These factors have been shown to be particularly important for low-ability students (Lou et al., 1996). Heterogeneous groups also tend to be more task-oriented (Nhan & Nhan, 2019). In addition to the use of heterogeneous groupings in terms of abilities and achievements, such groupings have been used to facilitate the understanding of the roles of ethnicity, culture, and gender in interactions and achievements (Wilkinson & Fung, 2002; Prinsen, Volman, & Terwel, 2007; Wang, 2011). However, the manner in which gender parings affect student interactions and problem-solving behaviors during social learning is still unclear.

2.2. Gender differences in learning

Gender differences have been considered as critical factors in computer-supported collaborative learning (Prinsen, Volman, & Terwel, 2007). In the context of face-to-face discussions, males tend to provide more initial suggestions than females. However, in computer-mediated communication, females tend to provide more suggestions and tend to look on communication more favorably than males (Hiltz & Johnson, 1990). However, males tend to be more confident than females in computer-supported collaborative learning environments (Joiner, Messer, Light, & Littleton, 1998).

In terms of cognition and learning, females seem to rely more on the use of memorization and rehearsing strategies, which can limit creative behaviors (Kim, 2007). In contrast, males tend to exhibit much less regulation and often question why they are studying a particular concept (Severiens & Dam, 1997). Although significant research has indicated that there are no major gender differences in terms of creativity (Kaufman, 2006), some research has indicated that males tend to perform better in terms of creative indexes (Matud, Rodríguez, & Grande, 2007; Tsai, 2013).

Gender differences have also been observed with regard to problem-solving abilities and strategies (Zhu, 2007). Males tend to be more flexible in applying problem solving strategies (Gallagher et al., 2000), while females are more likely to adhere to strategies they have already learned (Gallagher, 1998). Female interactive behaviors and problem-solving processes are also more sensitive to partner genders (Ding & Harskamp, 2006). Males tend to learn through arguments and individual activities, resulting in a more competitive atmosphere. In contract, females tend to solve problems through the use of conversation and collaboration (Croson & Gneezy, 2009). In the field of computer science, gender differences have also been observed with respect to self-efficacy, problem-solving approaches, and information processing styles (Burnett et al., 2010).

2.3. Gender pairing in collaborative learning

Some research has indicated that both genders can benefit from a collaborative learning environment. When comparing same- and mixed-gender groups, some research has indicated that both genders tend to engage less in collaborative problem solving and propose fewer solutions when placed in mixed-gender groups compared to single-gender groups (Underwood, Underwood, & Wood, 2000). Mixed-gender also tend to exhibit less verbal interaction. Males tend to be more active in dominating discourse and are typically perceived as providing better ideas than females in mixed-gender groups (Prinsen, Volman, & Terwel, 2007). Another study indicated that males in mixed-gender groups are more deliberate in terms of problem solving than they are in single-gender groups. Female-only groups have been shown to exhibit more self-disclosure and include more of their personal opinions (Savicki, Kelley, & Oesterreich, 1998). They also tend to exchange more information during problem solving (Ding & Harskamp, 2006), send more messages, and are more satisfied with social learning (Savicki, Kelly, & Lingenfelter, 1996). Female-only groups also tend to be less argumentative in the context of problem solving and general group interactions. In contrast, males tend to have discussions with less group development and communication (Savicki, Kelley, & Oesterreich, 1998).

However, previous studies have not yielded consistent results in terms of learning performance. Some research has shown that single-gender groups are more interactive when conducting computer-based tasks, but such differences do not always translate into enhanced task performance (Underwood, Underwood, & Wood, 2000; Wilkinson & Fung, 2002). Other research has indicated that females perform better in single-gender groups compared to males (Inzlicht & Ben-Zeev, 2000; Ding & Harskamp, 2006). In Whitelock et al.'s (1993) study, females and males with both similar and different views of physics achieved similar levels of performance. However, females tend to benefit more from other females with the same views. Additionally, in majority-male groups, males tend to ignore the opinions of females. Therefore, a more balanced grouping or single-gender grouping may be helpful for reducing inequities in interactions (Sanders, 2005).

3. Methodology

Facebook was considered as a social learning platform to assist in computer science learning in this study. Students were grouped into different gender pairings and asked to solve problems collaboratively through Facebook. Student problem-solving processes were analyzed in conjunction with their learning achievement. Student attitudes toward cross-school social learning were also analyzed to understand the effects of gender pairings. Figure 1 illustrates our research model.

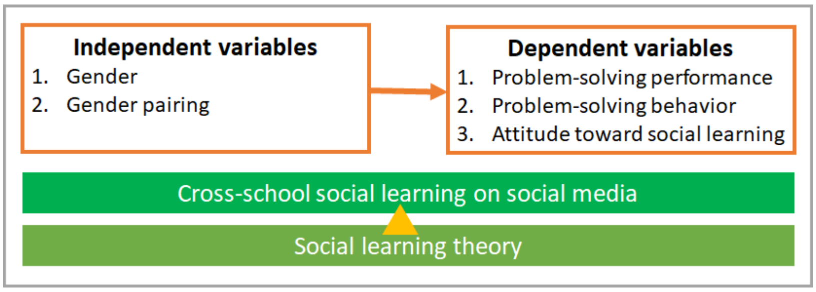

Figure 1. Research model

3.1. Participants and pairing groups

Our study participants consisted of 222 tenth-grade students (average age of sixteen) from six classes in three different high schools. School A was an all-female school, school B was a mixed-gender school, and school C was an all-male school. Students from all three schools were considered as average to high achievers based on their high school entrance exam scores. The gender pairing groups are detailed in Table 1 along with the assigned teacher for each class.

Table 1. The gender pairings for all lecture classes

Gender pairing	Lecture class			# of students
	School A	School B	School C	
Mixed-gender	A.1 (43 girls, teacher 1)	B.1 (33 boys, teacher 2)		76
Female-female	A.2 (42 girls, teacher 1)	B.2 (30 girls, teacher 2)		72
Male-male		B.3 (42 boys, teacher 2)	C.1 (32 boys, teacher 1)	74

During each lecture, each teacher explained the assigned topic to the students in their class. After each lecture, students were divided into different groups to engage in collaborative learning based on discussion through Facebook. Gender pairing groups were constructed using two lecture classes from two schools (a pool of approximately eighty students). From this pool, students were grouped into four teams consisting of approximately twenty students. Each team consisted of approximately ten students from one school and ten students from the other school. Previous studies have suggested that a suitable group size for cooperative learning ranges from two to six individuals in a face-to-face setting (Siavin, 1991) with more individuals for online settings (Hou & Wu, 2011). Because our research focused on a cross-school context and the target problem-solving tasks were relatively challenging, additional group members could provide additional social support for collaboration.

3.2. Procedure

The lecture classes were designed to teach computer science problem solving using the concepts of ***data representation*** (e.g., binary representation and data encoding/compression). All lectures were presented by two teachers who used identical teaching materials (Figure 2). Prior to the experiment, the details of the lectures and data collection were explained by the teachers and the students who participated in the study signed consent forms. Three private groups were set up on Facebook for the three types of gender parings. To help the students construct data representation knowledge and develop problem solving skills, we provided them with the opportunity to discuss problems on Facebook both during and after class. The experimental procedure is illustrated in Figure 3.

Figure 2. Teaching materials

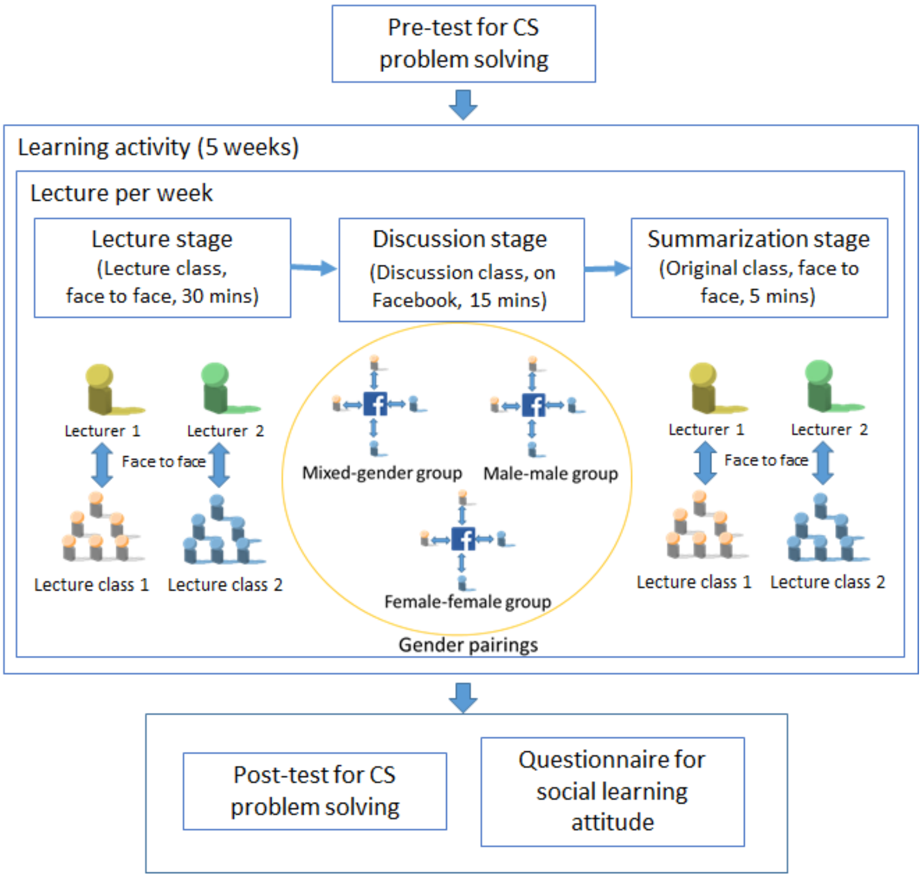

Figure 3. Experimental procedure

To analyze the initial abilities of the students, a pre-test focusing on computer science problem solving was administered prior to our experiment. Five weeks of computer science lectures were provided to the students. The two classes with same-gender pairings (e.g., A.1 and B.1, see Table 1) received the lectures during the same lecture time slots. Each of the four teams in a gender pairing class (e.g., A.1) was assigned a cooperative team from another class in the same gender pairing (B.1). During every fifty-minute in-class lecture, three instructional stages were carried out to facilitate social learning: the lecture stage, the discussion stage, and the summarization stage. In the lecture stage, the teachers explained the learning content to the students in each of their lecture classes (e.g., A.1 and B.1). In the discussion stage, teachers presented several problems to students, and asked the students to discuss solutions to the problems with their team members (e.g., a twenty-member team in the mixed-gender class) on Facebook. Students could post new ideas and respond to posts from other students in an attempt to develop collaborative solutions. The teachers did not intervene during this stage. In the summarization stage, the teachers provided a summary of what the students had discussed, as well as some additional suggestions for learning.

3.3. Instruments

3.3.1. Learning achievement test

Individual student initial abilities and learning achievements related to computer science problem solving were evaluated through a pre-test and post-test. The pre-test problems consisted of binary translation puzzles with thirteen blanks (see http://cse4k12.org/). Students had to solve the puzzle by applying their prior knowledge regarding binary translation.

Learning achievement was measured by examining two types of abilities: (1) the ability to apply what the students had learned to solve problems and (2) creativity in problem solving. Scores were graded according to the correctness of each problem-solving step. The item discriminations (point-biserial correlation coefficients) for application and creativity were 0.700 and 0.693, respectively. Q1 and Q2 represent the sample items for application (applying run-length coding) and creativity (developing a new algorithm for encryption) tests, respectively.

Q1. The vocabulary has nine words: {a, good, bad, excuse, is, worse, than, none, that}. Statistically, the frequencies of these words are 44, 32, 31, 17, 50, 28, 14, 19, 25, respectively. Please encode these words into binary codes and determine the code for the sentence "a bad excuse is worse than none."

Q2. The following paragraph appears in the article "A Grain of Sand" by William Blake. Please develop a method to encrypt this paragraph. You can use any symbol for representation (e.g., 0 or 1, black or white), but the code length should be as short as possible.
"To see a world in a grain of sand,
and a heaven in a wild flower,
hold infinity in the palm of your hand,
and eternity in an hour."

3.3.2. Collaborative problem solving behaviors

To understand the collaborative problem-solving processes used by the students, their discussion content (including posts and replies) were recorded and analyzed using a quantitative content analysis method (Pena-Shaffa & Nicholls, 2004). The discussion content was first encoded by a modified model developed from Wallas's (1926) problem solving stages, Garrison's et al. (2001) critical inquiry model, and Hou and Wu's (2011) knowledge construction and social interaction model. This modified model for collaborative problem solving encodes discussion content into six types (Table 2). The discussion types are mapped to six codes (C1 to C6) with twelve indices for further analysis.

Table 2. The coding table for discussion content

Type	Code	Index	Description
1. Problem identification	C11	Problem statement	Recognize and define the problem, and propose questions to understand the problem definition
	C12	Problem analysis	Analyze the problem elements and structure
2. Exploration	C21	Agreement	Agree with others' opinions
	C22	Disputation	Dispute others' opinions
	C23	Information providing	Provide information or cues for discussion
3. Integration	C31	Idea aggregation	Aggregate various opinions
	C32	Concept approval	Support opinions with existing literature or theories
4. Solution generation	C41	Solution testing	Verify and revise current solutions
	C42	Solution formation	Generate the final solution
5. Social interaction	C51	Social communication	Social interaction relevant to the learning task
	C52	Task coordination	Instructions or comments about task coordination
6. Digression	C61	Off-topic discussion	Posts that are completely irrelevant to the learning task

3.3.3. Attitudes toward social learning

Student attitudes toward cross-school social learning were evaluated using a questionnaire after all learning stages were completed. The questionnaire consisted of six Likert-type questions (see Table 3) with a Cronbach's alpha value of 0.87.

Table 3. The questionnaire questions

Question no.	Question
Q1	I like to use social media to assist collaborative learning.
Q2	Cross-school discussion on social media helped me improve the discussion quality in class.
Q3	Social media reduced my stress during collaborative learning.
Q4	Cross-school discussion on social media enhanced my learning.
Q5	Cross-school discussion on social media helped me express my ideas during discussion.
Q6	Social media engaged me in collaborative learning.

3.4. Data collection and analysis

ANCOVA tests were conducted to examine the effects of gender, gender pairings, and their interactions to determine whether these factors influence student learning. The pre-test grades were considered as the covariance for ANCOVA to account for the effects of the initial problem solving abilities of different groups.

After coding all posts and replies on Facebook according to the coding table (Table 2), the encoded discussion sequences for different gender pairings were analyzed using a sequential analysis method to identify significant discussion sequences.

4. Results and discussion

4.1. Learning achievement for different gender pairings

Descriptive statistics for the pre-test and post-test scores, and the ANCOVA results, are presented in Tables 4 and 5, respectively. The scores for both application and creativity range from 0 to 50.

Table 4. The descriptive statistics of the pre-test and post-test scores of problem-solving abilities for different gender pairing groups

Gender	Gender pairing	*N*	Pre-test grade		Post-test: Application		Post-test: Creativity	
			Mean	*SD*	Mean	*SD*	Mean	*SD*
Male	Mixed gender	33	9.88	3.92	23.33	15.75	37.88	18.88
	Single gender	74	10.93	3.82	28.65	16.33	37.16	21.20
	Total	107	10.61	3.86	27.01	16.27	37.38	20.42
Female	Mixed gender	43	11.16	3.68	17.44	13.82	24.42	21.47
	Single gender	72	10.46	4.12	21.67	15.56	30.21	23.34
	Total	115	10.72	3.96	20.09	15.01	28.04	22.74
Total	Mixed gender	76	10.61	3.81	20.00	14.88	30.26	21.34
	Single gender	146	10.70	3.96	25.21	16.28	33.73	22.47
	Total	222	10.67	3.90	23.42	15.97	32.55	22.10

Table 5. The ANCOVA results of problem-solving performance for genders, gender pairings, and their interactions

Performance	Factor	*F*	*p*	Cohen's *d*
Application	Gender	8.666	.004**	0.40
	Gender pairing	4.577	.034*	0.29
	Gender × gender pairing	0.027	.871	0.00
Creativity	Gender	11.508	.001**	0.46
	Gender pairing	0.630	.428	0.11
	Gender × gender pairing	1.471	.227	0.17

Note. $^{*}p < .05$; $^{**}p < .01$.

In terms of gender pairings, the single-gender groups exhibited better performance than the mixed-gender groups in terms of applying their knowledge to problem solving ($F_{(1,220)} = 4.577$, $p < .05$). Interactive effects between genders and gender pairing groups cannot be observed. One can see that significant differences exist in terms of the problem solving performances between genders. These differences can be observed in terms of both application ($F_{(1,220)} = 8.666$, $p < .01$) and creativity ($F_{(1,220)} = 11.508$, $p < .01$). Male students tended to exhibit better application and creativity performance (adjusted mean: application 26.05, creativity 37.67) than female students (adjusted mean: application 19.52, creativity 27.23).

Our results indicate that single-gender groups outperformed mixed-gender groups with regard to the ability to apply computer science knowledge to problem solving. This finding differs from the results of some previous studies indicating that only females performed better in single-gender groups when compared to mixed-gender groups (Keogh, Barnes, Joiner, & Littleton, 2000; Ding, Bosker, & Harskamp, 2011). Other research by Light et al. (2000) indicated that male performance was also better when working with only males. This might because males were often eager to dominate discussions in mixed-gender groups or because including females in a discussion led to more divergent opinions. In some cases, females tended to become argumentative with respect to male opinions, which sometimes manifested as shallow thinking. In mixed-gender groups, there was sometimes a tendency for males to spend large amounts of time presenting information and ideas to group members, perhaps in an attempt to display their abilities to the females in the group. This often prevented the groups from progressing further and developing their solutions. In some mixed-gender groups, a significant amount of time was spent proposing diverse opinions that could not be integrated to find clear solutions to problems. In contrast, both males and females in single-gender groups tended to have highly focused discussions. Additionally, male-male groups tended to cooperate mainly with peers from the same school. They were highly motivated to find solutions to problems to outperform the students from other schools. Some previous research has also indicated that males are often motivated to support their own groups, particularly when faced with threats from other groups (Matud, Rodríguez, & Grande, 2007).

In this study, learning activities were done across school boundaries in a social setting. The fact that students were mixed together in online discussions helped promote more divergent discussions in mixed-gender groups, which differs from the results of many previous studies. Single-gender groupings have previously tended to promote more focused discussion because members were not distracted by competitive conversations with the opposite sex. Prior research has also shown that single-gender groups often paid more attention to discussion tasks, resulting in higher grades in the application phase of testing.

4.2. Collaborative problem solving behaviors for different gender pairings

The extracted discussion content (3257 messages) was encoded according to the codes in Table 2. The coded results regarding the proportions of various discussion types are presented in Tables 6 and 7. All gender pairing groups posted more than 1000 messages. Most discussions were aimed at exploring information and ideas (43.2), while a small number of discussions focused on the integration of ideas (1.1%). The female-female class spent much more time on idea integration (25%) than the other two classes (mixed: 8%, male-male: 2%). The females spent less time on off-topic discussion (11.8%) than the other classes (mixed: 17.0%, male-male: 23.8%). The male-male class spent less time on problem identification (1.3%) than the other classes (mixed: 5.1%, female-female: 5.5%). The male-male classes spent more time working on solution generation (4.7%) than the other gender pairing groups. They spent some time on solution testing (3.3%), but spent much more time on digressive chat (23.8%) than the other pairings. The mixed-gender group spent more time on disputing the opinions of others (C22: 9.4%) than the other two groups (male-male: 5.9%, 5.6%). The female-female group tended to integrate opinions via aggregation (C31: 2.3%), but the other two groups seldom integrated their opinions (mixed: 0.7%, male-male: 0.2%).

Table 6. The number and proportion of messages posted by different gender pairing groups for each discussion type

Gender pairing	Discussion type						Total
	Problem identification	Exploration	Integration	Solution generation	Social interaction	Digression	
Mixed	58(5.1%)	476(42.2%)	8(0.7%)	22(2.0%)	371(32.9%)	192(17.0%)	1127
Male-male	14(1.3%)	447(43.0%)	2(0.1%)	49(.7%)	281(27.0%)	248(23.8%)	1041
Female-female	60(5.5%)	482(44.3%)	25(2.3%)	33(3.0%)	361(33.1%)	128(11.8%)	1089
Average	44(4.1%)	468(43.2%)	12(1.1%)	35(3.2%)	338(31.1%)	189(17.4%)	1086

The encoded messages were than analyzed using sequential analysis to elucidate the collaborative problem solving processes exhibited during social learning on Facebook. Figure 4 presents the resulting problem-solving processes for all gender pairings. Arrows are used to indicate significant sequences in discussion content and the numbers on the arrows represent *Z*-scores. In the mixed-gender class, students tended to discuss computer science problems by providing supportive suggestions. During discussion, they also exhibited significant social communication about the learning topic or discussed other off-topic subjects. In the male-male class, students exhibited similar collaborative problem solving processes. However, the male-male class conducted additional focused discussions to test their possible solutions. In the female-female class, students tended to identify and analyze problems before they explored solutions. There was also a large amount of social communication during the information exploration stage and the students often returned to the problem identification stage following this social communication.

Table 7. The proportion (%) of messages posted by different gender pairing groups for each discussion code

Gender pairing	Discussion type											
	C11	C12	C21	C22	C23	C31	C32	C41	C42	C51	C52	C61
Mixed	2.4	2.8	2.1	9.4	30.7	0.7	0.0	1.1	0.9	31.1	1.9	17.0
Male-male	0.4	1.0	3.0	5.9	34.1	0.2	0.0	3.3	1.4	25.3	1.7	23.8
Female-female	2.7	2.8	1.5	5.6	37.2	2.3	0.0	1.5	1.6	32.0	1.2	11.8

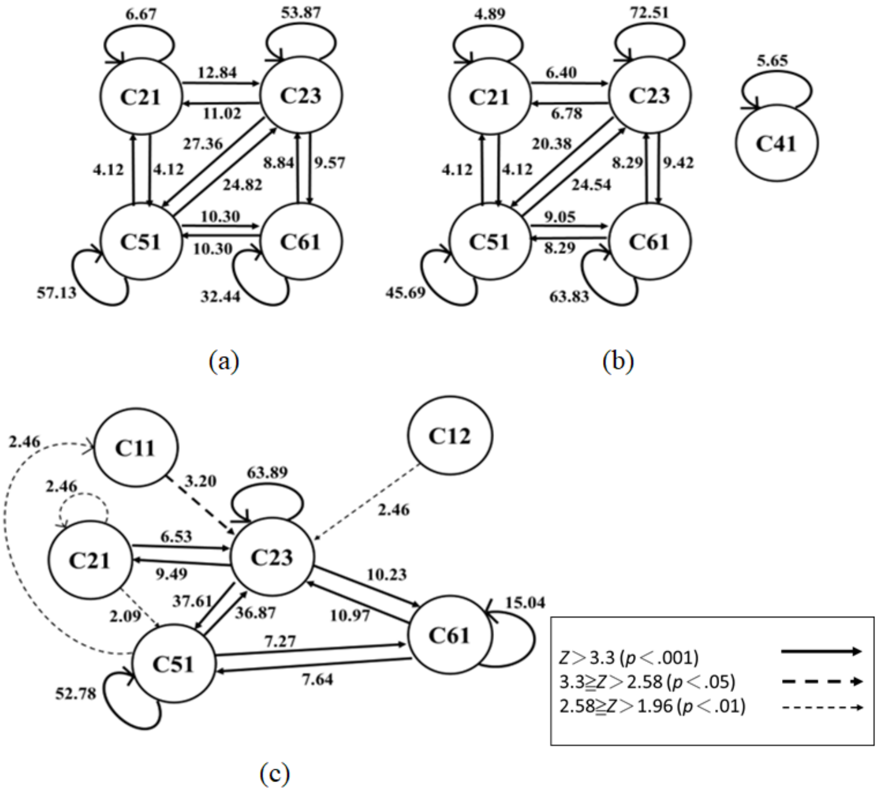

Figure 4. The collaborative problem solving processes during social learning for (a) the mixed-gender, (b) the male-male, and (c) the female-female groups

It should be noted that two types of interactions in the mixed-gender group were identified: male-dominated discussions in which males quickly proposed solutions to a problem before females could propose their solutions and very interactive discussions involving both males and females. In the first case, males often proposed solutions to problems without even joining the discussion series posted by the females. In the first type of interaction, males tended to engage in frequent disputes with other males in the mixed-gender group, apparently eager to demonstrate their abilities to the females in the group. Consequently, the mixed-gender group made many more posts (approximately twice as many) than the single-gender groups. Keogh et al. (2000) found similar results, where males in mixed-gender groups tended to dominate discussions and had many more disagreements than those in single-gender groups.

One of the problems for discussion focused on Huffman coding.

In the dictionary, we have the words: I, you, love, hate, and, the, spider, flower.
The corresponding frequencies of the words are: 18, 14, 6, 3, 20, 32, 2, 4.
Please encode the sentence: I love you and hate the spider.

The following conversation from a mixed-gender group shows how males tended to dominate the group discussion. Students S1, S2, and S3 are all males. The males in this group also attempted to find errors in their solutions to the problems and voiced differing opinions (disagreements) related to problem solutions.

S1: The code is 0111011101111101011111.

S2: 01 110 1110 111110 00 10 111111, I love and hate the spider

S1: I think something should be added to the front and rear.

S3: No. It is not necessary to add those elements for Huffman coding. You are thinking of Morse code.

S1: S2, you missed a word: YOU!

In the second type of interaction in mixed-gender groups, males and females often had diverse perspectives and had difficulty coordinating their discussions. Consequently, they could not agree on a clear direction for solving their computer science problems. The following conversation on Facebook is a good example of how such conversations proceeded in the mixed-gender group. Students S4, S5, and S8 are males, while students S6, S7, and S9 are females. This group was examining a problem involving Huffman coding. They provided various ideas and information about Huffman coding, but after a long and non-focused discussion, they could not identify an appropriate direction for developing solutions to the Huffman tree.

S4: Let me draw the coding tree!

S5: I have no idea.

S6: S4, have you finished that?

…

S7: Let's discuss the pros and cons of this coding method.

S6: Ok.

S7: The pros: it can be used for secret communication.

S7: It is not easy to crack, but is easy to compress.

S8: We need more people involved in this discussion.

S6: The cons: it is not suitable for text content.

S5: It is simple RAR compression.

S6: There will be a lot of numbers.

…

S9: 11011110111010111111001111111

S6: I don't understand.

S5: WTFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF

…

However, in many cases, the male-male group spent little time on information exploration and often proceeded to propose and test solutions to problems directly (Figure 4(b)). High-achievement students often quickly found strategies to solve problems and solicited other students to support them. Compared to the other two groups, the male-male group tended to solve problems more effectively. The following example illustrates the effect of having high-achievement students in a student group. S10 and S11 are high-achievement students (they achieved perfect scores on both the pre-test and post-test). These two students proposed the initial steps for the problem solution by listing the frequency of each word and drawing the corresponding Huffman tree (Figure 5). S14 from their group then agreed with their ideas and assigned each word a code based on the frequencies and Huffman tree. Therefore, some hints in the initial stage may motivate successful ideas for problem solving.

S10: I, you, love, hate, and, the, spider, flower. The frequencies: 18, 14, 6, 3, 20, 32, 2, 4.

S11: I drew a Huffman tree like this.

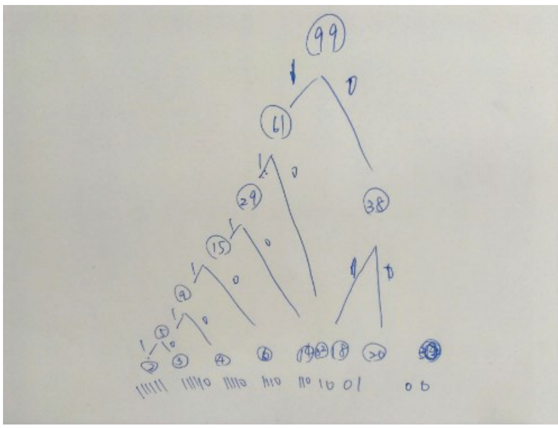

Figure 5. The Huffman tree drawn by the student

S10: I→(0,1) love→(1,1,1,0)
S12: I don't understand.
S10: you→(1,1,0) and→(0,0)
S13: Good afternoon.
S14: the→(1,0) and→(0,0) flower→(1,1,1,1,0) hate→(1,1,1,1,1,0)
S15: The advantages and disadvantages of the Huffman tree: this algorithm compresses the text or binary files efficiently…
S14: spider→(1,1,1,1,1,1,)
S16: http://www.delightpress.com.tw/bookRead/sknd00004_read.pdf
S15: The main feature of Huffman coding: the resulting code should be unique…

4.3. Attitudes toward social learning for different gender pairings

Student attitudes toward social learning on Facebook were obtained from six four-point Likert-type scale questions in a post-experiment questionnaire (1: strongly disagree, 2: disagree, 3: agree, 4: strongly agree). Table 8 presents descriptive statistics for the social learning attitudes of different genders and gender pairings, and Table 9 presents analysis of variance (ANOVA) results for genders, gender pairings, and their interactions. Because a Levene test showed the variances to be significantly different between genders, as well as between the interactions between genders and gender pairings, a Welch test was used instead of a traditional *F* test to analyze these differences. The results indicate that females agree with the effectiveness of social learning more than males ($F_{(1,220)} = 9.715$, $p < .01$). Additionally, the genders and gender pairings exhibit interactive effects ($F_{(2,219)} = 4.085$, $p < .01$). For example, students in the female-female group had much more positive attitudes than those in the male-male group (Table 10). However, students in the mixed- and single-gender groups had similar perceptions regarding social learning.

Table 8. Descriptive statistics regarding attitudes toward social learning

Gender	Gender pairing	*N*	Questionnaire result	
			Mean	*SD*
Male	Mixed	33	2.68	0.64
	Single	74	2.54	0.68
	Total	107	2.58	0.67
Female	Mixed	43	2.77	0.57
	Single	72	2.86	0.44
	Total	115	2.83	0.49
Total	Mixed	76	2.73	0.60
	Single	146	2.70	0.59
	Total	222	2.71	0.59

Table 9. The ANOVA results of attitudes toward social learning

Factor	*F*	*p*	Cohen's *d*
Gender	Welch: 9.715	.002**	0.42
Gender pairing	0.179	.673	0.00
Gender×gender pairing	Welch: 4.085	.008**	0.47

Note. $^{**}p < .01$.

Table 10. Pairwise comparisons of attitudes toward social learning for different gender pairing groups

Group (I)	Group (J)	Mean difference (I-J)	*p*
Male-mixed	Male-single	0.147	.702
	Female-mixed	-0.087	.925
	Female-single	-0.179	.467
Male-single	Female-mixed	-0.234	.195
	Female-single	-0.326	.004**
Female-mixed	Female-mixed	-0.092	.800

Note. $^{**}p < .01$.

The statistical results indicate that females in the female-female groups had better attitudes toward social learning than males in the male-male groups. The responses to the open-ended questions reveal that males in the male-male group wanted to interact with and learn from females. This could explain why some males in the male-male groups exhibited more negative attitudes. Previous research has indicated that males often use social media to form new relationships (Muscanell & Guadagno, 2012). Therefore, some males might have wished to form relationships with females from other schools, as indicated by the following feedback:

"We should discuss the problems with the girl's high school."

"I am strongly opposed to discussion with another boy's school. We should discuss the problems with girls to understand diverse thinking methods."

Males in the mixed-gender groups were more positive about using social media, perhaps because females were included in the discussion. Males in the mixed-gender groups were often eager to discuss computer science problems, perhaps to impress the females. This could explain why the mixed-gender groups tended to have more disagreements with respect to problem solving because males might have been competing for attention from the females in the group. Some males preferred to interact more with females, perhaps based on the belief that more diverse discussions would occur, as indicated by the following feedback:

"It was helpful to discuss the problems with students from another school, especially the girls. This made me more engaged in the discussion."

"This was a great learning activity and I like to learn with girls."

Although some students in the male-male group initially disliked working with males from another school, most group members were still able to consider the ideas of others and benefit from the divergence of discussions. A few students provided the following comments:

"I was exposed to various ideas, which fostered my multi-perspective thinking."

"I could observe and learn from various opinions."

5. Implications for instructional practices

The insights gleaned from this study can aid educators in the design of more adaptive teaching/grouping strategies, particularly in the area of problem solving. Single-gender grouping helps students focus on problem solving and allow students to apply the information they know to solving problems more efficiently. However, the diversity of discussion induced by mixed-gender groupings is often necessary to facilitate breakthroughs with regard to expanding existing thinking and reaching solutions to complex problems. More efficient instructional guidance should be employed to improve student enthusiasm and provide opportunities to listen to diverse ideas. Diverse ideas are a critical component in the process of creative thinking (Jang, 2009). Our findings provide useful insights for applying gender pairing to foster effective group discussions. In the initial stages of problem solving, it appears that mixed-gender groups may be more effective at inspiring more diverse opinions and creative ideas. However, in the later stages of problem solving, it appears that single-gender groups may be more effective at helping students reach convergent solutions.

In single-gender schools, cross-school collaborative learning through social media may introduce new and divergent ideas to students. In mixed-gender schools, collaborative learning with single-gender groupings may help foster more focused and deep discussions among students. We also found that cross-school competition encourages students to be more active in problem solving, particularly males. Although some researchers have argued that online learning eliminates the gender cues and encourages more participation and cooperation (Arbaugh, 2000), a cross-school setting may stimulate competition and encourage more participation. Appropriate instructional strategies (e.g., peer review) could be designed to help students benefit from competition and cooperation in social learning.

To extend the applicability of our research findings to other problem-solving scenarios, it should be noted that instructional strategies should be adapted according to student ages, learning subjects, and social media platforms to improve effectiveness.

6. Conclusions

This study addressed three research questions and empirical analysis was conducted to explore the effects of gender pairings on collaborative problem-solving performance, processes, and attitudes in a social learning environment. Our findings for each of the three research questions can be summarized as follows. (1) Single-gender groups exhibited better performance than mixed-gender groups in terms of applying acquired knowledge to problem solving. Additionally, significant differences existed in terms of problem solving behaviors between genders. Males tended to exhibit higher levels of both application and creativity performance than females. (2) Students in male-male groups tended to focus on problem solving, although they also engage in more off-topic discussion. They also tended to develop and test solutions directly without spending much time on problem identification. In mixed-gender groups, males tended to dominate the discussion and different genders tended to propose divergent opinions. (3) Females exhibited better attitudes toward social learning activities. This was particularly evident in the female-female groups, which could be attributed to the fact that students could observe many diverse ideas. Additionally, although the male-male groups exhibited the highest levels of performance, they also expressed more negative attitudes toward an interactive environment based on a lack of female participation. The findings and implications of this study can facilitate additional research on the use of social learning to develop effective instructional strategies.

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