Computer-supported collaborative learning and gender

Ding, Ning

CHAPTER SEVEN

Exploring the Gender Difference in Students' Knowledge Elaboration Process in CSCL[6]

Abstract:
The aim of the study is to explore the gender difference in the knowledge elaboration process in Computer-Supported Collaborative Learning (CSCL). A sample of 96 secondary school students, aged 16, participated in a two-week experiment. Students were randomly paired. They were asked to solve six moderately-structured problems concerning Newtonian mechanics. Students' pre- and post-test performances were analyzed to see whether gender and group composition (mixed or single gender) were significant factors for their problem solving learning in CSCL. Their online interactions were analyzed to unravel the dynamic process of individual knowledge elaboration. We found that female students' learning performance is sensitive to their partner gender, but that is not the case for male students. Within the mixed-gender dyads, the male students tend to outscore the females. The multilevel analyses revealed how the female students are at a disadvantage in mixed-gender collaboration.

7.1 Introduction

Computer-Supported Collaborative Learning (CSCL) has become a promising heuristic way in school practice, and in the past decade it has been increasingly applied as an integral part of physics education. Yet, to date, very little CSCL research has been directed towards the issue of gender pairing. Questions such as whether in CSCL female and male students benefit equally from the mixed- and single-gender dyads, whether the knowledge elaboration process in mixed-gender dyads presents a different picture in comparison to that in single-gender dyad, and how learning performance is related to the knowledge elaboration process still need empirical investigation.

---

6. This chapter is based on Ding, N., Bosker, R. & Harskamp, E. (2009). Exploring the Gender Difference in Students' Knowledge Elaboration Process in CSCL , submitted to Science Education

This study aims at investigating the gender-pairing in physics problem-solving in a synchronous CSCL setting. We start with a literature review on gender problem in collaborative physics learning. In the following sections, we will discuss some technological properties of CSCL that may influence students' knowledge elaboration. Secondly, a brief summary of the design of the experiment is given. Following this, we will explore the gender difference in learning performance and knowledge elaboration patterns. Based on the initial results, we will study the relationship between students' gender, knowledge elaboration and learning performance with the help of multilevel analyses. Finally, the research implications will be discussed.

7.2 Gender Difference in Collaborative Problem-Solving

Collaborative learning is hinged on the idea that the learners possess different unshared prior knowledge (Weinberger, Stegmann & Fischer, 2007). In order to accomplish a learning task collaboratively, students have to experience a process going from unshared to shared knowledge (Pfister, 2005). As for dyadic collaboration, each dyad can be viewed as a unit with its own properties, but comprising two relatively independent cognitive units. Each independent unit varies in the degree of contribution to the final result during the collaboration. Collaboration carries risks and these risks are essentially high when gender, computer and task are entangled. Our previous study (Ding & Harskamp, 2006) has shown that, in collaborative problem-solving in physics, female students' learning is sensitive to their partner gender while it is not the case for male students. Females in the mixed-gender dyads perform worse than females in the female-female dyads. Within the mixed-gender dyads, males outperform their female partners on the problem-solving tests. The previous literature offers some possible explanations. Gender is one of the important reasons influencing learners' participation and cognitive knowledge elaboration in collaborative learning.

First of all, female and male students have different communication styles. Markel (1998) asserts that females' communication patterns are more focused on maintaining the group, while males' patterns focus more on completing the task. Female students prefer cooperation to competition (Johnson & Johnson, 1989; Tobias, 1990; Kahle & Meece, 1994). Females are more likely to hedge, qualify and justify their assertions (Fahy, 2003; Smith, McLaughlin, & Osborne, 1997) while males tend to assert opinions strongly as facts (Blum, 1999; Fahy, 2002; Herring, 1993 & 1999). Cross and Madson (1997) state that females tend to be more oriented towards interdependence than are males. When female students solve the problems with a male partner, they tend to ask questions or paraphrase problem information. Their male partners are more likely to provide help and offer suggestions. However, females in the single-gender dyads are not so submissive. They put forward their ideas and develop problem solving strategies actively. This roughly may be in line with the studies on single-gender classes claiming that females in single-gender physics classes are more confident, have higher interest levels and can achieve better than females in mixed-gender classes (Haussler & Hoffmann, 2002). The collaboration between female students seems to be better balanced than that in mixed-gender dyads. The gender difference in communication style can potentially affect how female and male students exchange messages (Jeong, 2004).

Secondly, we noticed a gender difference in the ways of representing knowledge during problem solving (Ding, 2008a). Physical concepts are not purely abstract understandings of representations as a means for understanding. Numerous physics educators have stressed the importance of students developing an ability to recognize, manipulate and translate concepts from representation of concepts (Meltzer, 2005), mainly through verbal (text-based) and visual (pictorial) representations. Some research suggests that females perform better than males on verbal abilities tests, while males outperform females on tests of visual-spatial ability (Kellogg, 1995). Females preferred information to be presented in a single mode although they can use all of the sensory modes in learning (Wehrwein, Lujan & DiCarlo, 2007). There is a gender difference in the way that students process knowledge while solving a physics problem. Female students prefer using verbal representations to convey problem information while males are more adept at visualizing the problem components and the problem solving strategies. Females score slightly higher on verbal ability and males have a slightly larger standard deviation on general and specific ability scores. Then, when a female student is collaborating with a male student on a physics problem, it may be problematic for both of them to elaborate knowledge and work out a solution because they tend to use different ways to represent problem information.

In comparison with single-gender collaboration, the interaction in mixed-gender groups is an awkward experience (Howe, Tolmie, Anderson & Mackenzie, 1992; Howe & Tolmie, 1999). In Underwood, Underwood and Wood's studies, the authors used Bales' coding system to look into the turn-taking of use of computers in the mixed-gender dyads. It has shown that the lower levels of verbal interaction and slightly poorer performance than single-gender dyads. Underwood et al pointed out that female and male students in the mixed-gender dyads did not engage in true collaboration because they were not jointly focused on the problem. According to Teasley and Rochelle (1993), collaboration should be a coordinated and synchronous activity resulting from a share of knowledge and a joint construction.

7.3 Knowledge Elaboration in CSCL

Koschmann et al (2005) point out that in computer-supported collaborative learning, knowledge and meaning can be understood as jointly created through interaction which is mediated through computers. As for how computers function as mediating resources in learning, Hmelo-Silver (2003) claims that the prerequisite to delve into collaborative learning is to make sense of students' conversation and the tools mediating their roles. Suthers (2006) distinguished two roles technology plays in CSCL: communication medium and constraint. Some studies have reported that ICT has a more positive effect on males in extending their interest span (Passey, Rogers, Machell, McHugh and Allaway, 2003), but other studies cannot find a significant difference between males' performance and females' (Joiner, Messer, Littleton and Light, 1996; Underwood & Underwood, 1994). It seems that the positive attitude of males towards computer cannot be translated into an advantage with learning over females (Harrison et al, 2002).

Prinsen, Volman and Terwel (2007) reviewed thirteen studies on gender problem in Computer-Mediated Communication (CMC) and CSCL. They focused on three aspects: degree of participation, kind of participation, and experience of participation. The review study uncovered a male dominance in CMC. The group gender composition is also found to have an important effect on students' learning achievement. Yet, simply looking into students' participation degree cannot give us a clear picture about how students process the knowledge cognitively and benefit from collaborative learning. In CSCL, some properties of computer-mediated synchronous communication may play an important role in students' knowledge elaboration while collaborating.

The text-based Computer-Mediated Communication (CMC) dominantly applied in CSCL practices is assumed to alleviate the gender gap due to the reduced contextual cues. Students' interactions are preserved in a shared context, which seems to be privileged to deepen students' thinking and facilitate a high level elaboration. Due to the explicit back-references, CSCL affords the opportunity to trigger more thoughtful and reflective discussions. Warschatter (1997) has proposed three factors of CSCL contributing to close the gender gap. 1) the reduced contextual clues masking the gender characteristics; 2) the reduced nonverbal cues such as frowning that can intimidate partners; 3) the opportunities of self-regulating learning. However, this is still a controversial claim, especially in a synchronous CSCL setting. On the one hand, the reduced shared context is expected to have reduced utility (Suthers, 2006). The shared context represents the multiple facets that facilitate the negotiation of interpersonal questions. Moreover, due to the ease of typing and exchanging messages, synchronous CSCL may generate numerous fragmented and incoherent interactions. Students' explanations appear very often in simple forms (Ding, 2008c). On the other hand, as aforementioned, female and male students have different communication styles and ways of representing knowledge. The pressure to respond in live-talk may also hinder female students to develop own problem solving strategy. The breakdown in interaction may exacerbate the potential problem in mixed-gender collaboration.

Therefore, the idea that CSCL can alleviate the gender gap is still worth probing. Besides the gender difference in communication styles and representation manner, there is a need to explore whether there is a difference between mixed-gender and single-gender dyads with regard to the knowledge elaboration process, and whether students' learning achievement is affected by it.

Insight into learners' interactions is an important step to unravel the dynamical nature of individuals' knowledge elaboration (Arvaja; Hakkinnen, & Jarvela, 2007; Brown & Palinscar, 1989). Doing so is based on the rationale that students' discourse data represent their cognitive processes of learning to a certain degree (Chi, 1997). However, there is no consensus regarding how to code students' interactions in an appropriate way (Hmelo-Silver & Brommer, 2007). Some researchers focus on the cognitive quality of students' interactions (e.g. Gudzial & Turns, 2000) because representing information and high level cognitive processing of information are closely intertwined in science problem-solving (Kozma & Russel, 1997; Toth, Suthers & Lesgold, 2002). Making inferences to students' external representations during problem solving can deepen our understanding of students' cognitive elaborations (DeWindt-King & Goldin, 2003).

Kumpulainen and Mutanen's (1999) differentiate three dimensions of peer-group interaction by focusing on the nature of cognitive processing: off-task activity, procedural processing, and interpretative or exploratory processing. The off-task activity refers to those social talks that are irrelevant to the collaborative task. Procedural processing refers to the routine execution of task without improving the ideas. Students engage in problem solving task, but they may merely stay at a superficial level of knowledge processing. Interpretative or exploratory processing refers to students' deep engagement in problem solving activity, which is characterized by critical thinking and a systematic analysis of problem information. Based on that, Ding (2008c) endowed each message with an elaboration value: -1, 0 or +1. Then, the sums of the elaboration values for each individual learner were plotted along the timeline respectively. Such kind of visualization has revealed, at least, three patterns of knowledge elaboration. The divergent pattern (on the left in Figure 7.1) featured by two diverging curves shows an increasing cognitive discrepancy between two participants. The cross pattern (in the middle in Figure 7.1) illustrates that students' knowledge elaboration processes are closely intertwined. The participants keep a close eye on their partner's processing and take turns dominating the knowledge elaboration. The parallel pattern (on the right in Figure 7.1) shows two roughly parallel curves, indicating that the cognitive gap between the two participants stays the same during collaboration.

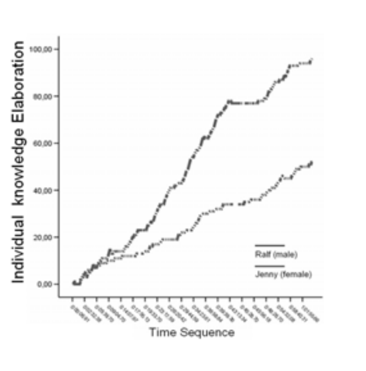
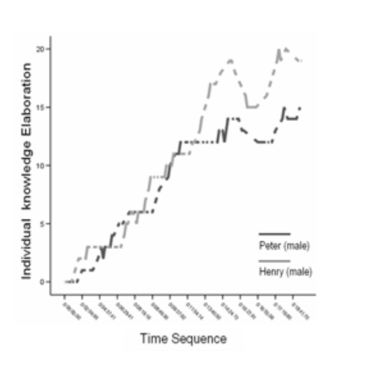
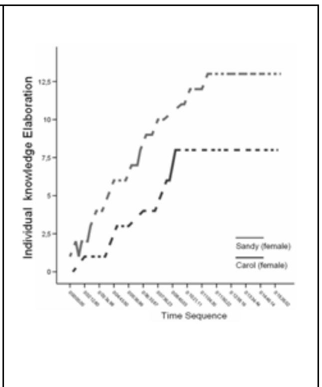
		
divergent pattern	cross pattern	parallel pattern

Figure 7.1 Knowledge Elaboration Patterns (Ding, 2008c)

In collaborative problem solving, a dyad can be viewed as a unit made up of two interdependent cognitive units (Dillenbourg, Baker, Blaye & O'Malley, 1995). With the help of the patterns, we are able to trace the knowledge elaboration process of the interdependent units, and explore the gender difference in CSCL.

7.4 Research Questions:

The research questions of the study were: in CSCL,

- is there a difference in knowledge elaboration process between mixed- and single-gender dyads?

Hypothesis: Due to the properties of computer-mediated synchronous communication, it is hypothesized that students' knowledge elaboration process may be different in mixed- and single-gender dyads.

- is there a gender difference in learning achievement?

Hypothesis: CSCL is hypothesized to entail the influence on female students because not all properties of CSCL follow directly from the computer technology. Female students' learning achievement may be sensitive to their partner gender, but this may not be the case for the male students.

- is there an interaction effect of group gender and knowledge elaboration on students' learning achievement?

Hypothesis: Students' knowledge elaboration process is assumed to correlate with their learning performances. We hypothesize that the patterns can, to some extent, explain the differences in students' learning achievement of male and female students in differently composed dyads.

7.5 Materials and Methods

7.5.1 Participants

The study was conducted in a secondary school in Shanghai, China. The school is one of the top ten schools in Shanghai. Ninety-six students, aged 16 from two classes of grade ten, participated in the two-week experiment. There were 49 females and 47 males. Students come from families with various social backgrounds. During the experiment, students were randomly paired within the class. The purpose of random pairing was to minimize the chance of the dyad with an expert and a novice student. There were three *groups*: a group of mixed-gender dyads (MG, n=25), a group of female-female dyads (FF, n=12), and a group of male-male dyads (MM, n=11). Students were categorized into four *conditions*: females in mixed-gender dyads (F in MG, n=25), males in mixed-gender dyads (M in MG, n=25), females in female-female dyads (F in FF, n=24), and males in male-male dyads (M in MM, n=22).

7.5.2 Procedure

Participants came from two parallel classes taught by the same teacher. In students' previous physics tests, there was no significant difference between the two classes. All participants followed three regular physics lessons concerning Newton's second law taught by the same physics teacher. Students were administered a 40-minute pretest concerning Newton's second law. After that, they were given a 40-minute preflight training about how to use the online program "Physhint". The experiment lasted two weeks, including six 40-minute experiment sessions. Students were asked to solve six problems. For each dyad, the participants were separated and distributed to different classroom to avoid face-to-face interaction (Figure 7.2). The whole experiment sessions were overseen by the local teacher and the research assistant. Students were exposed to the same number of experimental hours and the same instructional materials.

Figure 7.2 Experiment Session

On the last day, all students participated in a 40-minute posttest. It had also four moderately-structured problems, similar to the pretest. In both pre and posttests, students were required to solve the problem independently. Both pre- and posttest were paper-pencil test. In each test, students were required to solve three problems independently, without any help from peers. Problems used in pre and posttests and the experiment sessions were all about Newton's second law. They were selected from the database with the similar degree of difficulty. Students' pre and post test performances were scored by the local physics teacher. The full mark of both pre and posttests was 100. Each episode to solve the problem was granted with five points.

7.5.3 PhysHint

The computer program "PhysHint" was compiled with SQL to facilitate a synchronous online collaboration. It aims at improving students' skills of solving moderately structured physics problems. Technically, it can afford 100 dyads to work on the problems at the same time. There are five sections in the PhysHint interface, as shown in Figure 7.3.

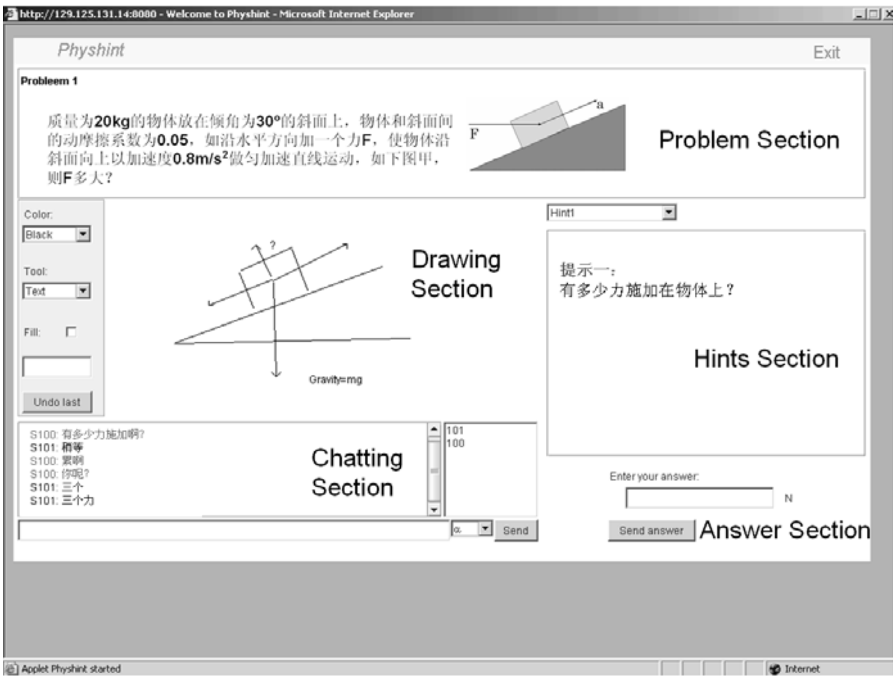


Figure 7.3 Interface of PhysHint

The *problem section* shows the problem information. The problem could not been read until both partners logged into the system. Doing this prevented one student from having more time to read and think about the problem than his/her partner (see the sample of the problem in Table 7.1). In this experiment, six physics problems in the database were used.

Four problems (Problems 1, 2, 3, 6) had only one question, while Problems 4, 5 included two sub-questions.

I am going to push a box (20kg) lying on the slope to move upwards with acceleration $0.8m/s^2$. I was told that the friction coefficient between the box and the slope is 0.05, and the angle between the slope and the ground is 30^o. If I am going to apply a force in the horizontal direction, what's the magnitude of it? (answer with two decimals is preferred)

Table 7.1 Sample problem in the PhysHint program

The *hints section* offered each student five "hints" for each problem. All the hints were compiled on the basis of Schoenfeld's (1992) five episodes of problem solving: reading the problem, recalling prior knowledge, making a plan, implementing the plan, reflecting on the answers. To strengthen students' communication we gave different students within the same dyad different hints so that they had to engage in exchanges about what they read (see the sample of hints in Table 7.2).

Table 7.2 Sample of Hints

Student A:	**Student B:**
Hint 1: How many forces are applied on the box?	Hint 1: Except its own gravity, is there any other forces applied on the box?
Hint 2: How to visualize these forces?	Hint 2: What is the Newton's Second Law?
Hint 3: The forces can be analyzed in two directions.	Hint 3: What are the directions of these forces?
Hint 4: How to combine the calculations on both directions?	Hint 4: The final solution is based on the calculation on both directions
Hint 5: Do you think that this is the best way to solve this problem?	Hint 5: Have you got a better solution?

In the *drawing section*, students were able to draw the variables and vectors using geometric forms, arrows and lines. They could also illustrate the objects with different colors. What one student drew would be automatically shown on his/her partner's computer. The *chatting section* resembled the MSN Messenger or Yahoo Messenger that students were familiar with. In the texts shown we used different colors (black and blue) to distinguish between the two students in the same dyad. After the students arrived at the answer, they submitted this answer using the *answer section*. The final submission of the answer was based on mutual agreement of the dyad. For each problem each dyad had two chances to submit an answer. The second time they failed to give a correct answer, a pop-up window with a "*worked-out example*" (Figure 7.4) was generated.

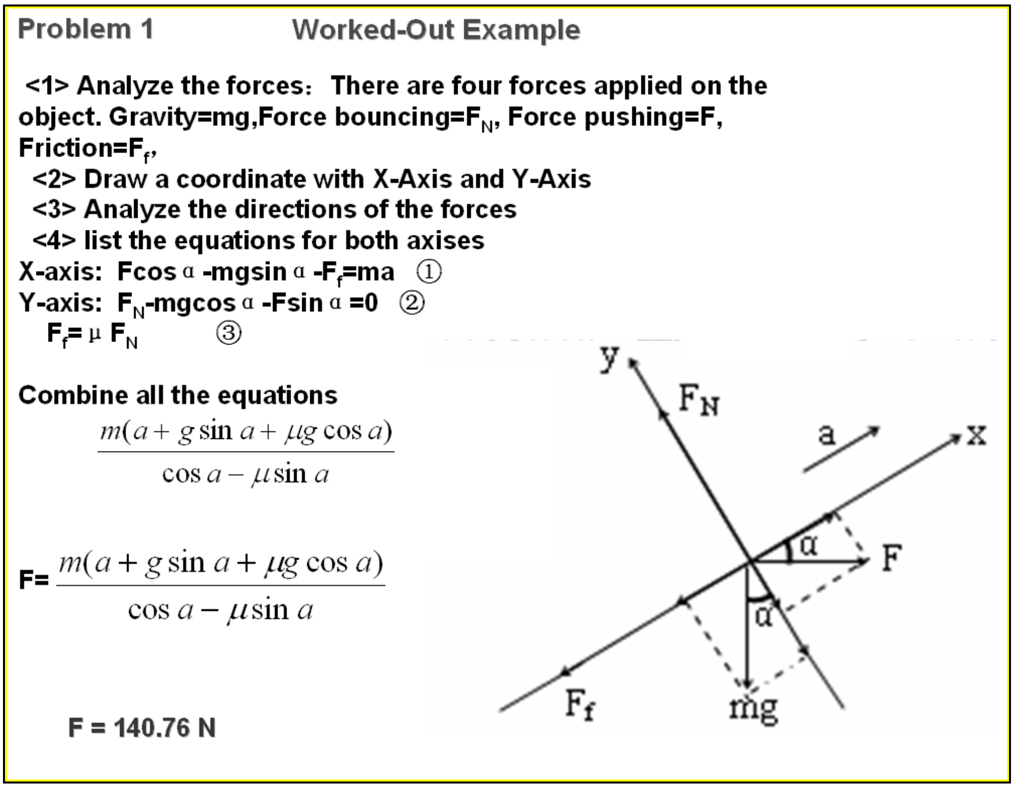


Figure 7.4 Sample of Worked-Out Example

7.5.4 Data Collection and Analyses

Students' online messages were collected and analyzed through the "elaboration values" (Ding, 2008c). Table 7.3 shows the detailed coding system.

Table 7.3 Elaboration Values

Number	Description	Example
+1	on-task message elaborating on knowledge or contributing to the final solution.	*Student A: How many forces applied on the box?* *Student B: I think, four*
0	on-task message but no improvement of knowledge elaboration or problem solving	*(Student B: There are four forces applied on the box.)* *Student A: OK.*
-1	off-task messages distracting the problem solving process	*Student B: Guess, what will be in our next English test?*

According to its content and contextual relation, we quantified each message using the value -1, 0 and +1. If the message was off-task and distracted the students' attention while problem solving, it was given minus one (-1). If it was a task-related message but did not improve the solving process, it was given zero (0). The rote performance or symbol manipulation affected the learning and the application of physics knowledge to little avail. The presence of a lot of messages of 0-valued messages indicated that the students communicated sufficiently, but they stopped at a surface level. This serves to distinguish between the superficial and the elaborative talk in collaboration. When a message was pertinent to the task and was contributive to the final success in problem solving, it was endowed with a one (+1). It has been shown that discourse beyond a concrete level of the problem space may foster the individual acquisition of knowledge in learning scenarios based on complex problems (Hogan, Nastasi, & Pressley, 2000).

There are two points that should be pointed out. Firstly, we acknowledged the importance of elaborative questions. Our previous finding indicated that female and male students had different communication styles. In collaborative problem solving, female students tended to use question to start the discussion or express own ideas. An elaborative question not only kept the collaboration on the right track, but it fostered the partner's knowledge elaboration. Therefore, not only interpretative or exploratory processing would be endowed +1 point, but also the elaborative question. Secondly, our study focused on a computer-mediated synchronous learning environment with dearth of shared social context. CSCL is characterized by a large amount of in-coherences in interactions, sometimes even "messy" talks. So, when we evaluated each individual message, we did not merely relate it to the previous one message, but to the whole context.

After quantifying each message, we aggregated the values of each participant within the dyads, and plotted the sums according to the time sequence respectively. Then, we came to the elaboration patterns.

7.6 Results

7.6.1 Implementation of the Study

Due to the strict school rules, nobody dropped out during the experiment. For all the students in the experiment, there was no significant gender difference in their previous physics tests. Yet, the local teacher reflected a phenomenon. Although the female students did not significantly lag behind males on physics tests in grade 10 and 11, there was an obvious tendency for males to choose physics as their major when they entered the grade 12. During the experiment sessions, we also noticed that the female students were much quieter than males. Almost all of them, as required, brought their calculators and own draft sheets. On the contrary, half of the male students forgot to bring these with them.

In condition MG, female and male students were randomly paired to solve the problems in a CSCL setting. It is interesting to find that when the female students knew that they were paired with a male student, two female students raised their hands and asked for the possibility of working with a female student. But this didn't happen to the female-female and male-male dyads.

The study was based on a quantitative analysis of students' learning achievement and a content analysis of students' online interaction. In the experiment, all online interactions were documented automatically by the server computer. These included their visual and verbal messages. During the six experiment sessions, students have produced 45862 online messages with 27,571 (60.35%) task-related interactions. For these on-task messages, 474 were visual representations. Table 7.4 shows the numbers and standard deviations of all messages, on-task and off-task messages, and visual representations for all six problems per student. For instance, throughout the entire six experiment sessions, each female student in the mixed-gender dyads (F in MG) has on average generated around 434 messages. Among these 434 messages, about 231 were on-task messages and 203 were off-task messages. But for all six problems, each female student in MG group only produced about three visual representations on average. There was a significant difference in visual representations between female and male students ($F_{(3,92)}$ =18.47, p=.00). Male students generated significantly more visual representations during problem solving than the female students. This echoes our previous findings about a gender difference in ways of representing knowledge in physics problem-solving. For other categories, there was no significant difference found.

Table 7.4 Mean numbers and standard deviations of messages per person for all six problems

Condition	Messages	On-task messages	Visual representations	Off-task messages
Female in mixed-gender dyads (n=25)	433,76(113,03)	231,04(69,97)	3,04(1,67)	202,72(100,14)
Male in mixed-gender dyads (n=25)	479,20(118,14)	293,88(86,27)	4,68(1,70)	185,32(117,35)
Female in female-female dyads (n=24)	494,46(116,41)	327,25(98,91)	5,00(1,96)	167,21(80,95)
Male in male-male dyads (n=22)	507,77(139,46)	299,73(114,18)	7,32(2,12)	208,05(104,51)
Total (n=96)	477,73(122,97)	287,20(98,24)	4,94(2,38)	190,53(101,33)

7.6.2 Knowledge Elaboration

In order to get to the process quality of CSCL the process of mean-making has to be unravelled. But analyzing students' interaction content is one of the challenges in CSCL research (Lipponen, Rahikainen, Lallimo & Hakkarainen, 2003) because CSCL is featured by its dynamically evolving context of interaction (Hmelo-Silver & Brommer, 2007).

Five Chinese sophomores majoring mechanics engineering were trained as independent coders. They were very knowledgeable about Newtonian mechanics. They were instructed about how to value each message from a knowledge elaboration perspective, how to avoid treating each message as an isolated meaning, and how to code through the "Elaboration Value" system. After quantifying each message, they went on visualizing the knowledge elaboration process for each individual student by plotting the sums of "elaboration values" sequentially. We selected the data of all six problems. Due to the huge amount of data, each coder spent more than 20 hours on coding. The interrater reliability calculated by a Pearson product-moment correlation is 0.74.

Table 7.5 shows the total number of knowledge elaboration patterns of each group (MG, FF, MM) for all six problems. For instance, for all the six problems, the whole mixed-gender group has produced 31 cross patterns, 37 parallel and 78 divergent patterns. The proportion of the divergent patterns was 52%. It indicates that for half of the problem-solving activities, students in the mixed-gender dyads were involved in divergent patterns. Table 7.5 shows the number of different patterns for the three types of dyads. When defining students' individual elaboration patterns, we focused on the majority of the problem solving time, and on the major feature that characterized the dyad. For instance, whether the curves became entangled with each other or remained parallel in a divergent pattern, we named this simply a divergent pattern because the dominant feature was two curves diverging from each other. Apart from the aforementioned patterns, there were some patterns that the coders found difficult to categorize. For example, half of the time the curves got crossed while for the rest of the time they stayed parallel. Such patterns were called "ambiguous patterns".

For the cross patterns, the difference between the single- and mixed-gender groups was not significant, $F_{(2,95)}=1.85$, $p>.05$. Neither was the difference of parallel patterns significant, $F_{(2,95)}=2.23$, $p>.05$. But for the divergent patterns, the group of mixed-gender dyads has generated significantly more divergent patterns than the other two groups, $F_{(2,95)}=3.40$, $p<.05$.

Table 7.5 Sum of students' knowledge elaboration patterns for all six problems

	Cross Patterns	Parallel Patterns	Divergent Patterns	Ambiguous	Total
mixed-gender dyads *(dyad n=25)*	31 (20,67%)	37 (24,67%)	78 (52,00%)	4 (2.67%)	150
Female-female dyads *(dyad n=12)*	21 (29,17%)	29 (40,28%)	19 (26,39%)	3 (4,17%)	72
Male-male dyads *(dyad n=11)*	15 (22,72%)	27 (40,90%)	19 (28,79%)	5 (7,58%)	66

7.6.3 Learning Performance and Knowledge Elaborations

Our previous studies that were conducted in a computer-alike learning environment suggested that female students in single-gender dyads outperformed females in mixed-gender dyads, but this was not the case for male students. In order to answer the research question, whether this problem carries over into CSCL, we analyzed students' pre- and post-test performances. The ANOVA test with "pre-test" as the dependent variable, "group" and "gender" as the independent factors shows there was a significant difference between male and females students in pre-test scores ($F_{(1,92)}=5.49$, $p=.01$), but no for the group composition ($F_{(1,92)}=.01$, $p=.91$) nor for the interaction between gender and group composition, ($F_{(1,92)}=2.03$, $p=.16$). Neither was there a significant difference between females in MG and FF conditions ($F_{(1, 47)}=1.00$, $p>.05$), nor was there a significant difference between females and males in the MG condition ($F_{(1, 45)}=1.03$, $p>.05$).

In analyzing the posttest scores as the dependent variable, multilevel analyses were performed. By doing so, we acknowledge the fact that the students within a dyad share something in common (the observations are dependent rather than independent). Moreover, we can carefully assess the effect of dyad properties (especially their gender composition) next to individual student characteristics, and at the same time do justice to the fact that the number of dyads involved is only half of the number of students involved - which has implications for the correct estimation of standard errors. And finally cross-level interaction effects (between dyad characteristics and student characteristics) can be explored this way (Snijders & Bosker, 1999; De Wever, van Keer, Shellens, & Valcke, 2007).

Before discussing the multilevel analyses, it is necessary to give a brief review of the data. There were 96 students. They were randomly paired to form 48 dyads. Each dyad belonged to one of the three groups: mixed-gender (MG, n=25), female-female (FF, n=12) and male-male dyads (MM, n=11). A two level model with individual student at level 1 and the dyad at level 2 was constructed. The dependent variable was the students' posttest scores, with gender (level 1) hierarchically nested within the group gender composition (level 2) and elaboration patterns (level 2). Table 7.7 presents the results of the multilevel analyses with estimation for individual posttest scores.

We first established an empty model without any independent variables (Snijders & Bosker, 1999). The intraclass correlation is 127.92/(127.90+66.88), or 0.66, which means that 66% of the total variance in students' posttest scores is accounted for by the dyadic level. Because there was no significant difference between the two types of dyads at the pretest, we did not include the pretest as a covariate in the analyses.

Then, we added explanatory variables to the model step by step. In Model 1 and 2, the coefficients were students' gender and group gender were introduced as predictors, respectively. Model 1, the males were the reference group, and in Model 2 the single-gender dyads were the reference group. The reduction of deviance suggested that very little of the differences between students was explained by their gender ($\chi^2(1)=.04$, $p>.05$) or group ($\chi^2(1)=.15$, $p>.05$). In short, there are no significant gender and group-composition effects. Female students achieved as well as the male students on the posttest. Students in the mixed-gender dyads performed almost the same as those in the single-gender dyads.

Then, we focused on the combination of gender and group, by introducing the interaction effect of group composition*gender (because of the coding of the variables this boils down to females in mixed gender groups versus all others). Inclusion of this interaction term now leads to two effects being significant (gender, and the interaction between gender and group composition), and this model fits the data better than the previous models ($\chi^2(1)=5.65$, $p=.02$). Female and male students' learning achievement seems to be sensitive to their partner gender: female students perform best in single-gender dyads, male students perform worse in single-gender dyads, and female and male students perform equally well in mixed-gender dyads. In order to explore what might be the cause of this, we looked into students' interaction content, more specifically how this varies across the various conditions.

Table 7.7: Summary of the model estimates for the two-level analyses of students' post-test scores.

Parameter	**Model**							
	0	1	2	3	4	5	6	7
Fixed								
Intercept	72.65 (1.83)	72.41 (2.12)	73.132 (2.86)	84.97 (2.80)	84.99 (2.80)	88.13 (3.13)	81.59 (3.77)	88.36 (4.37)
Gender		0.46 (2.13)	0.456 (2.12)	11.69 (5.02)*	10.81 (2.93)*	4.91 (4.17)	5.14 (3.99)	-6.56 (5.74)
Groups			-1.380 (3.70)	5.57 (4.50)	10.37 (2.83)*	11.22 (2.75)*	22.02 (4.50)*	11.80 (5.73)*
Female in MG vs. others				-13.41 (5.52)*	-12.53 (3.72)*	-14.31 (3.75)*	-14.67 (3.60)*	3.93 (7.76)
Divergent					-7.21 (0.75)*	-8.50 (0.98)*	-5.83 (1.34)*	-8.59 (1.63)*
Gender * Divergent						2.46 (1.30)	2.50 (1.27)	7.37 (2.17)*
Groups * Divergent							-4.03 (1.39)*	-0.16 (1.95)
Female * Groups * Divergent								-7.08 (2.64)*
Variance								
Group Level	127.90 (33.63)	126,39 (33.38)	125.93 (33.28)	111.47(30.26)	16.16 (12.10)	9.64 (11.43)	2.89 (10.39)	0.82 (9.65)
Individual Level	66.88 (13.65)	67.34 (13.75)	67.34 (13.75)	66.11(13.49)	66.10 (13.49)	68.93 (14.07)	69.04 (14.09)	66.05 (13.48)
Deviance (-2 Logliklihood)	751.45	751.41	751.26	745.61	693.90	690.65	682.83	675.897
Decrease in Deviance		0.04	0.15	5.65*	51.71*	3.25	7.83*	6.93*

* *p< .05*

7.6.4 Interaction between Knowledge Elaboration Pattern and Gender

We constructed Model 4, adding the number of divergent patterns as the predictor, to examine whether the relatively low performance of females in the mixed-gender dyads was related with different knowledge elaboration patterns. The reduction of deviance was highly significant ($\chi^2(1)=51.71$, $p<.05$), and moreover the number of divergent patterns uniquely accounted for 58% of the total variance in posttest scores, and for 86% of the between dyads differences in posttest scores. This indicates that those who engaged in one more divergent pattern scored 7.21 lower. The effect of the number of divergent patterns was significant ($t=-9.61$, $p<.05$). But the effects of the number of cross as well as parallel patterns were not significant.

As aforementioned, there were significantly more divergent patterns in the mixed-gender dyads than in the single-gender dyads. But the analyses of the individual learning performance and counting the frequency of the patterns alone seemed inadequate to explicate why females were at a relative disadvantage in mixed-gender dyads. Therefore, with a consideration of the hierarchical structure of the data, we continued with the multilevel analyses to answer the third research question.

Therefore, we explored the interaction effect of gender and the number of divergent patterns (Model 5), and of group gender and the number of divergent patterns (Model 6). The reduction of deviance of Model 5 was not significant ($\chi^2(1)=3.25$, $p>.05$). Yet, Model 6 showed a significant interaction effect of the group gender and the number of divergent patterns on students' posttest performance ($\chi^2(1)=7.83$, $p<.05$). In mixed-gender dyads, the more divergent patterns, the lower students scored on the posttest.

As for the question, whether the divergent patterns could explain the females' relative disadvantage in mixed-gender dyads, we constructed Model 7. In this model, we looked into the interaction effect of students' gender, group gender and the number of *divergent patterns*. The results showed a significant reduction of deviance in comparison with Model 6 ($\chi^2(1)=6.93$, $p<.05$). For females in the mixed-gender dyads, the involvement in one more divergent pattern resulted in that they scored 7.08 lower on the posttest. To put it another way, the more divergent patterns in the mixed-gender dyads, the lower female students in this condition scored on the posttest.

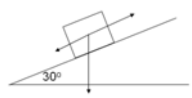
Table 7.8 shows the results of the multilevel analysis in a different way, by predicting posttest scores for 12 types of students using the multilevel model parameters. The most salient finding is that the posttest scores of female students in single gender dyads - unlike the other combinations - are not moderated by the number of divergent patterns. In all other cases learning achievement is negatively related to the number of divergent patterns.

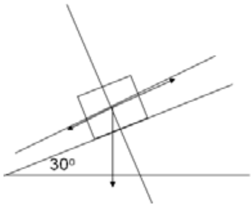
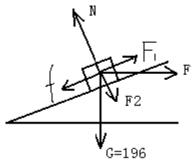
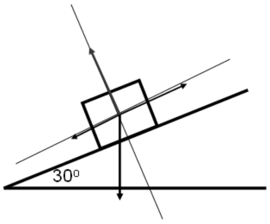
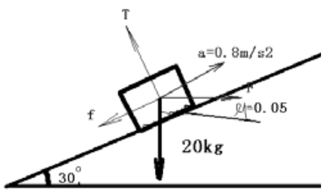
Table 7.8 Results of multilevel analysis for students' learning achievement

Gender	Group Composition	Divergent Patterns		
		Low (-1 SD)	Average	High (+1 SD)
Female	Mixed-gender dyads	86	74	62
	Single-gender dyads	80	78	77
Male	Mixed-gender dyads	88	76	64
	Single-gender dyads	77	65	52

In order to find out what happened in mixed-gender dyads, we chose an extract of a mixed-gender dyad's CSCL script. It was based on the third problem that was shown in Table 7.1. Table 7.9 describes the knowledge elaboration process of the mixed-gender dyad. It was translated from Chinese into English. As previously mentioned, all messages were coded as, -1, 0 or +1. The right column of Table 7.9 lists the elaboration values. Then we plotted the sums of these values for each individual along the timeline. Doing so helped us to visualize the elaboration process of individual students within one dyad (Figure 5). We found two divergent curves representing the female and the male student respectively.

Table 7.9. Extract of a mixed-gender dyad's CSCL script

Line	Time	Gender	Transcripts	Elaboration Values	Sum of Elaboration Values
1	05:32	Female	How many forces?	1	1
2	05:56	Male	wait	0	0
3	06:04	Female	I feel tired	-1	0
4	06:12	Female	& u?	-1	-1
5	07:03	Male	three	1	1
6	07:06	Male	forces	0	1
7	07:23	Female	gravity, pushing, friction?	1	0
8	07:58	Male	yep	0	1
9	08:46	Female	r u sure?	0	0
10	09:03	Male	wait, draw 4 u	0	1
11	09:05	Female	ok	0	0
12	10:12	Male		1	2
13	10:15	Female	en	0	0
14	10:27	Male	then, construct a coordinate	1	3
15	10:35	Female	en	0	0
16	10:46	Female	but, on which direction?	0	0
17	10:52	Male	like this	0	3

18	11:26	Male		1	4
					
19	11:53	Male	G=196	1	5
20	11:55	Female	?	0	0
21	12:01	Male		1	6
					
22	12:06	Female	ok	0	0
23	12:09	Male	then, go to Force_push	1	7
24	12:16	Female	Wait wait	0	0
25	12:32	Male	?	0	7
26	12:59	Female	Is it complete? I think…	1	1
27	13:25	Female		1	2
					
28	14:18	Male	O, yeah. the bouncing force	0	7
29	14:26	Male	X-axis	1	8
30	14:39	Male	F*Cos30-196*Sin30-umgCos30	1	9
31	15:07	Male	Y axis -> G*Cos30+F_push*Sin30	0	9
32	16:11	Female	!! 2 fast	0	2
33	17:25	Male	answer=136.48	0	9
34	17:36	Female	sure?	0	2
35	18:04	Male		1	10
					
36	18:06	Male	*submitted the answer for the first time with agreement of the female*		

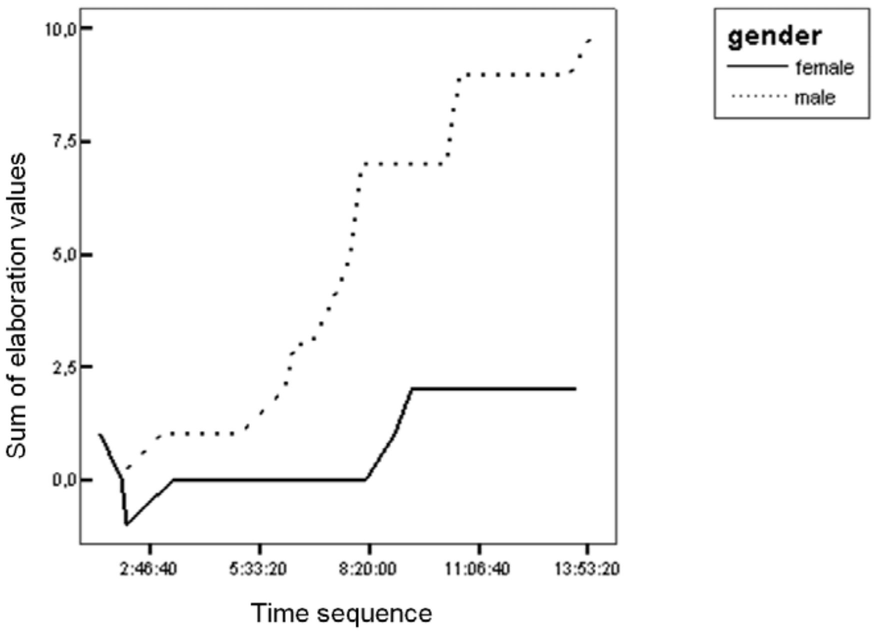


Figure 7.5 Divergent Pattern of Knowledge Elaboration in CSCL

In the pretest, the female had the same score as the male with 78, suggesting that there was no significant difference of physics knowledge between them at the outset. This dyad spent around 27 minutes on problem solving. They submitted their answers twice. The second time they succeeded. From the extract, we found a certain amount of “teen lingo”, the expressions frequently used by teenagers in online interaction. For example, “u” represents “you’ (L.4), “4 u” is “for you” (L.10), “r u sure” is “Are you sure?” (L.9), and “2 fast” means “too fast” (L.32).

The interactions between the two students reflected a high proportion of on-task talk. But there was a noticeable imbalance of visual and verbal representations between students. The male student presented three visual representations (Line 12, 18, 21, 35) to illustrate the problem information while the female student only added two axes on the work of the male (Line 27). Taking a close look at their interaction, we found a dominance of the male student in the discourse and hitchhiking behavior of the female student.

At the beginning, the female student seemed to be actively engage in problem solving. She raised the question relevant to the solution (Line 1). The dramatic change occurred at 14”26 when the male student proposed to use axes for analysis (Line 29) and calculated it rashly (line 30, 31). The female tried to catch up with the male by complaining that her partner moved too fast (Line 32). However, this was ignored by the male student. He continued with his calculation and reached the answer soon (Line 33). It seemed that the female student was not clear how the male student got to the answer. Instead of asking for a direct explanation, she asked whether he was sure about the solution (Line 34). The male student gave a detailed visual representation delineating the solution clearly, but no verbal explanation (Line 35). Then, he filled in the answer into the answer box and sent it to her. With her permission, this (Line 36) was soon sent to the server computer for check.

If we focused on the quantity of students' online participation, we may say that the interaction between them was well balanced. But if we look into the process of knowledge elaboration, we notice a cognitive discrepancy between the students.

A "close-up" view of students' knowledge elaboration process uncovered several possible factors that resulted in the discrepancy of knowledge elaboration of the mixed-gender dyad. Firstly, responding to the female's question, the male student gave a detailed visual representation delineating the solution clearly (L.12, 18, 21, 35), rather than verbal explanation. In our previous study (Ding, 2008a), we found that female students preferred using verbal-based messages to represent knowledge in physics problem solving. The different ways of knowledge representation may impede the female's knowledge elaboration.

Secondly, due to the CSCL properties, both students' messages tended to be simple and incoherent. This caused problems for the female student to understand the male student's explanations (L.9, 20). In addition, lack of shared contextual factors, students worked on the problem in different tempo. When the female student was still stuck on the force analysis, the male student had already gone on with calculation (L.19, 28-31).

Thirdly, when the male student ignored his female partner's question, the female complained that her partner moved too fast (L.32). However, this complaint was ignored. The male student went on with his calculation and reached the answer soon. At this moment, the female student also gave up her question. After the male student sent his first solution to the female student for agreement, the female student had not proposed any opposition, but accepted it. The male student's *no-explanation* and the female student's *giving up asking* led to an increasingly larger gap between them. Therefore, although at the outset the female student was eager to get involved into the problem solving, the male student dominated the discourse and excluded the female student in problem solving by being ignorant of her complaint and question. Gradually the female student withdrew from the discussion.

7.7 Conclusion and Discussion

The aim of the study is two-fold. First, it focuses on the gender difference in learning performance and explores whether the single- and mixed-gender dyads present different pictures of knowledge elaboration in CSCL. Second, it investigates whether students' gender, group gender, and knowledge elaboration process have an effect on students' learning achievement. The study was conducted in a synchronous CSCL setting that was designed to facilitate physics problem solving.

For the first research question, whether female and male students' learning performance is sensitive to their partner gender, our study showed that, within the mixed-gender dyads, males outscored female students, although this effect was not significant. Females in the single-gender dyads outperformed females in the mixed-gender dyads significantly. But this was not the case for male students. This result indicates that the female students' learning performance was sensitive to their partner gender and the gender problems that we are familiar with in the face-to-face collaborative learning appear to carry over into the CSCL setting.

The second research question centered on the knowledge elaboration process that could be visualized with the help of "elaboration values". Based on the rationale that individual contributions as data points are interdependent and can be interpreted additively, we plotted the sums of the values along the timeline and got the patterns: divergent, cross and parallel. A small number of patterns were defined as "ambiguous". Our study found a proportionally much higher frequency of divergent patterns than cross or parallel patterns in the mixed-gender dyads than what was found in the female-female and male-male dyads.

With respect to the question, whether females' relatively poorer performance in the mixed-gender dyads was correlated with the knowledge elaboration patterns, applying traditional ANCOVA and ANOVA test only would be inadequate. CSCL research should take the interdependency of individuals and their learning processes into consideration (Cress, 2008). Individual students were nested in different dyads, and their learning was influenced by their partner. This dependency in this case is quite obvious, because the knowledge elaboration patterns were formed at the group level, based on a co-construction and elaboration of the knowledge. We thus resorted to multilevel analyses to answer the third research question. The multilevel analyses showed that, in the mixed-gender dyads, the frequency of divergent patterns may explain the relatively low performance of female students in the posttest. The more divergent patterns, the lower females in the mixed-gender dyads scored on the posttest. This finding potentially taps into an explanation why female students performed worse in mixed-gender dyads than in single-gender dyads. Underwood and Underwood (1999) have found that learning is at its best when the learners talk constructively together, introducing and elaborating knowledge mutually. But this style is more frequently found in single-gender collaboration, rather than in the mixed-gender one. Breedlove, Burkett and Winfied (2007) have stressed the positive correlation between students' learning performance and some interactions such as helping the partner to understand. However, the characteristics of mixed-gender collaboration are individualistic, constrained and verbally controlled by the male students. Facing an interaction break-down, the mixed-gender dyad runs the risk that one member dominates while the partner gives up and withdraws. The high frequency of divergent elaboration patterns is indicative of the problem of mixed-gender collaboration. When we used the "elaboration values" to visualize the process, we noted an increasing gap between the female and the male student. Zooming in on the episodes of their collaborative problem-solving, we found some likely causes such as different ways of knowledge representation and the male's ignoring of female partner's complaints and questions. As for the mediational role of the computer, we found the incoherent and fragmented interactions featured in CSCL impeded students' knowledge elaboration process. Fitzpatrick and Hardman (2000) claimed that the role of the computer is more clearly seen in the mixed-gender dyads when the collaboration breaks down. In our study, when the female student was still stuck on the first part of the male's message, the male student had already sent the next part to her and moved to the next episode of problem solving. This echoes Weisband's (1992) claim that computer-mediated communication reduces conformity and convergence.

There have also been studies that have found no support for difference in learning performance concerning group gender (Howe & Tolmie, 1999; Pheasey & Underwood, 1994). Fitzpatrick and Hardman (2000) have proposed several possible explanations for the differing results, for example, the task feature, the computer-based learning environment, and the way of the performance is assessed, etc. They further proposed "classroom interventions" to encourage effective collaboration for mixed-gender collaboration. For instance, the education practitioners may enhance students' awareness of how they talk together and develop the problem solving strategy together. They may heed on female students' confidence with computer-based learning and support their positive attitudes. In our study, during the experiment sessions, we have observed that the female students were more likely to use the hints and read them more carefully than the male students. But the majority of the hints used in the experiment were text-based. In order to achieve a better balance of knowledge elaboration and construction, we suggest providing the female students more visually-designed hints. This may help the female students to understand the problem information better. Having the visual hints at hand may enhance females' confidence in physics problem solving as well.

Henderson and Dancy (2004) claim that the best evidence of problem solving skills (as well as an understanding of problem principles) is a student's ability to solve novel problems in real life. Thus, a delayed post-test seems crucial when we are really interested in sustained problem-solving skills of the learners. In addition, for CSCL research, a broad research agenda is required to explore the mechanisms that result in divergent patterns, and a comparison between the mechanisms that result in cross or parallel patterns with those that result in divergent patterns may help us find a way out to reduce achievement gaps between students.

We believe that the current study begins to fill in the evidence gap regarding gender and CSCL. It may lead to a better understanding of how collaborative learning works via computers, and can equip practitioners for better applying CSCL in physics education.