Gender-Related Differences in Collaborative Learning in a 3D Virtual Reality Environment by Elementary School Students

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ABSTRACT

This study aimed to understand how children collaborated to create their own stories in a 3D virtual reality (VR) environment and to explore whether there were any gender-related differences in this learning setting. A total of 65 students (38 females and 27 males) of grades 4-5 participated in this study. A qualitative methodology was adopted in this research to answer three research questions about how the participants work collaboratively, whether a gender difference exists in the process of 3D construction and how they think about learning in a 3D virtual environment. Based on the behavior patterns of these participants in a 3D world, the research findings revealed two types of collaboration: a team either with or a team without a strong leader. In addition, gender-related differences in this learning environment were also depicted in this study.

Keywords

3D virtual environment, Collaborative learning, Gender-related differences

Introduction

Traditional teaching and learning approaches and learning theories have been challenged for decades. It has been claimed that game-based learning suits learners of the new generation (Hsieh, Lin, & Hou, 2015; Rankin & Edwards, 2017; Reinders & Wattana, 2014; Watson & Yang, 2016). The advantage of game-based learning has been recognized (Charsky, 2010; Jarvin, 2015), which is that learning and entertainment occur at the same time. Additionally, several researchers have been using technology to enhance learning performance or to increase learning motivation through collaborative learning over the last two decades (Ding, Bosker, & Harskamp, 2011; Ludvigsen, 2016; Oliveira, Tinoca, & Pereira, 2011; Pellas, Kazanidis, Konstantinou, & Georgiou, 2016; Vogel, Vogel, & Cannon-Bowers, 2006; Warschauer, 1997). It was found that gender difference existed in the behaviors of the students who played a mini-game in school (Hsieh et al., 2015) and the behaviors of those who played lego blocking creations (Kato & Morita, 2009). Apart from the setting of game-learning, sex difference was also found in the art creations (Ahlawat & Budhiraja, 2016; Huynh, Doherty, & Sharpe, 2010). The nature differences between the two genders had an impact on their teacher-student relationship and academic performance (Hajovsky, Mason, & McCune, 2017), which teachers should be aware of. Although gender differences in the computer-supported collaborative learning (CSCL) and 3D virtual learning settings have been investigated, the results are mostly based on the analysis of verbal contents (Prinsen, Volman, & Terwel, 2007) and the results mostly include a framework for evaluating collaborative learning interactions (Daradoumis, Martínez-Monés, & Xhafa, 2006). The importance of gender sensitivity toward educational games has been strongly recognized by Robertson (2012). Furthermore, gender differences in game preferences and game playing habits have been explored (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Hayes, 2008). The findings of the previous research on CSCL and 3D VR worlds, however, did not seem to have depicted gender differences particularly in learner collaboration for the creation of their own works in a 3D VR world. This issue may impact how teachers develop their pedagogy. Therefore, the purpose of this research is to explore, based on video observation and their thoughts of this learning experience, the gender differences in the context where children created their own films in a 3D VR world.

Literature review

Siemens (2005a) claimed that learning theories should be reevaluated because learning nowadays has been greatly influenced by technology. Learners may nowadays be more likely to rely on computers to store and retrieve information. The focus of learning, rather than simply mugging up knowledge, should be placed on locating appropriate resources and wisely determining whether the information is valuable to be processed. Therefore, the connectivism theory (Siemens, 2005b) was proposed to explain several new learning phenomena. This learning theory states that learning could be defined as an ability to access online resources and to interact with others. The connectivism theory concerned a variety of learning approaches, including "through communities of practice, personal networks, and through completion of work-related tasks" (Siemens, 2005a, p.

1). This theory was similar to situated learning (Lave & Wenger, 1991), which takes knowledge as constructed through the participation in the social practices of communities. Felix (2002) provided a more educational explanation for situated learning: "Skills and knowledge are best acquired within realistic contexts and authentic settings, where students are engaged in experiential learning tasks" (p. 3). These learning theories suggest that researchers should explore diverse concepts of learning, such as social interactions in a learning process and also the complexity of learning contexts.

Although the connectivism theory pointed out the impact of new technology on learning, further significant learning theories, including constructivism, social constructivism, and situated learning, are still needed to understand learning in a 3D virtual reality environment. These learning theories have been remarked by some studies (Glancy & Moore, 2013; Pellas et al., 2016). According to Mikropoulos and Natsis (2011), constructivism is the current theoretical model most of the computer-supported educational setting is based on. Pellas and his colleagues (2016) explained that "learning is a subjective and internal process of building meanings and it is considered as the result of organization and adaption of new information into the existing knowledge that students already have to enhance their experiences" (p. 4). This definition is similar to the one generated from social constructivism (Vygotsky, 1978). These theories suggest that learning is an individual and internal changing process, by the stimulus of interaction, either with people or environments. Given that the collaborative learning approach has potential for encouraging learners to express their own ideas and to critique others' opinions during the process of collaborative problem-solving, collaborative learning has been supported by social constructivism as a research focus for two decades (Cuseo, 1992; Ludvigsen, 2016; Stahl, Koschmann, & Suthers, 2006). According to Stahl and his colleagues (2006), the history of group learning could be traced back to 1960. Ludvigsen (2016) approached this concept from a cognitive level. Based on his literature review, he stated that shared understanding and mutual modeling were crucial to building common ground for action, which is important to collaborative learning. Additionally, while investigating the ideas about collaborative learning, more should be explored from the perspectives of personal positioning in the group, in-group interaction to find out whether the shared value exists among members.

Interaction in an authentic context, in addition to the collaboration among peers described above, is also a key component of social constructivism. 3D virtual reality has been recognized as a potential technology capable of providing learners with authentic contexts and immersive experience for them to carry out collaborative tasks (Lan, Kan, Sung, & Chang, 2016). Additionally, from the practical perspective, the advantages of learning in a 3D learning environment have been identified by several researchers (Chang, Gütl, Kopeinik, & Williams, 2009; Hansen, 2008). These benefits include encouraging students to actively interact with learning contexts, reducing the anxiety of learning, and providing a relatively authentic learning experience. Theoretically, a 3D virtual reality environment is a friendly platform for researchers to explore the concepts of collaborative learning (Andreas, Tsiatsos, Terzidou, & Pomportsis, 2010; Cen, Ruta, Powell, Hirsch, & Ng, 2016; Lee, 2009; Roschelle & Teasley, 1995; Sutcliffe & Alrayes, 2012). With the technology of text- and voice-based chat and online voice recorder, researchers can collect data of social interactions easier. However, Lee (2009) mentioned that some of those studies which have addressed collaborative learning simply presented the perspectives of the users rather than the concepts of collaborative learning. For example, Chang, Gütl, Kopeinik, and Williams's research (2009) aimed to evaluate collaborative learning settings in 3D VR worlds. The focus of the research findings is mainly related to the opinions of the participating students. Furthermore, although the users can freely access this virtual world without the limitation of time and space so they could "meet" people from different countries, Jarmon (2009) and Whitelock, Romano, Jelfs, and Brna (2000) were concerned that the cognitive load of mastering this new technology may distract students from learning the target subject.

Regarding the possible challenge for learners as they used 3D virtual worlds as a learning platform, Dickey (2005) found that the identity of avatars may help students reduce their learning anxiety because the learners may be too engaged in role-playing to associate their past unpleasant learning experiences with new ones. This finding was consistent with Lan's research finding (Lan & Lin, 2016). Finally, this platform allows students to put their ideas into practice, which could strongly motivate them and allow them to learn from errors (Beard, Wilson, Morra, & Keelan, 2009). Furthermore, practice in a 3D virtual environment could help learners to transfer their experience in the virtual environment into the real life (Hansen, 2008).

In contrast with the aforementioned positive effects of 3D virtual reality on collaborative learning, the issue of gender differences in the process of collaborative learning in 3D virtual reality seems to have not obtained consistent results. Some researchers believed that gender differences existed in personality traits (Schultheiss & Brunstein, 2001) and emotional responses (Osborne, 2001), while some thought that sexual differences were shaped by social and cultural influences (Putrevu, 2001). There were biological and developmental differences between hemispheres and lateralization of a human brain, which affected both spatial and verbal skills (Geary,

1996). Boys may perform better in spatial tasks, while girls may have greater verbal skills (González-Gómez, Guardiola, Martín Rodríguez, & Montero Alonso, 2012). Li and Kirkup (2007) found that male students in China and the UK showed higher self-confidence in computer skills. Cuadrado-García and Ruiz-Molina (2010) pointed out that women used computers for social purposes and paid more attention to communicative activities, while men considered computers as machines and focused more on operating systems and functions. Additionally, boys spent more time playing computer games, which may extend boys' technical knowledge (Adamus, Kerres, & Getto, 2009). Whether the aforementioned difference between male and female computer learners can be also identified when boys and girls collaboratively construct their 3D virtual contexts as well as create their own stories is still an issue insufficiently investigated. Based on the aims of this research mentioned in the introduction and the literature review, the research questions were proposed as follows:

- How did students work collaboratively in a 3D VR environment?
- Were there any gender-related differences in collaborative creations in this learning setting?
- What were their perceptions of learning through collaboration in a 3D VR world?

Method

Participants

Sixty-five students who studied in grades 4-5 in an elementary school in Taipei, Taiwan participated in this study. They were 38 females and 27 males. The participants were divided by genders into groups of 4-6 depending on the class size, forming 5 groups of boys and 5 groups of girls. All the participants had been learning basic computer skills such as typing, drawing and surfing the web for one or two years. Thirty-eight per cent of the participants had prior experiences in 3D construction and role-playing in a 3D virtual environment, such as *Minecraft*.

Research design

A qualitative research was adopted in the current study. In order to explore the potential gender differences during the process of 3D construction, all the students' group creations, including 3D contexts, story scripts, and role-play screen videos, were collected. How they collaboratively worked with group members will be described in the section of Procedure. All the students were interviewed to understand their perceptions of using Build and Show (B&S), which will be described in the section of Instruments. All the collected data were then analyzed by two researchers to confirm the concerned gender differences.

Instruments

Build and Show (B&S)

The platform used in this study, Build and Show (B&S), was developed by the authors. It was programmed by OpenSim. B&S is user-friendly. The users, hence, were not required to have prior knowledge in programming or 3D modeling for mastering the functions of B&S. Additionally, B&S can be installed in most of the computer, which means that there is almost no extra cost to set it up. Challenge of obtaining the technique was an obstacle to hinder teachers' willingness to incorporate games into their teaching (Watson & Yang, 2016). B&S can be a possible solution to this concern. As shown in Figure 1, students had their own avatars and created their story scenes by selecting "build." Next, they could choose what they wanted to build and adjust the locations of the objects. When they were collaboratively building up their scenes, they could communicate through either voice- or text-based chat tools. In this study, establishing an airport was the main task for the class. This 3D setting involved five scenes, namely a safety check area, a fast food shop, a duty-free shop, a customs checking area, and a toilet. Each group of students was assigned to one scene of the airport, and then they had to make a real-life story using their assigned area as the setting. One student of each group was responsible for screen recording of the whole process of their group discussion and their scene establishment. The data from this platform were collected in the form of videos and were analyzed to answer research questions one and two.

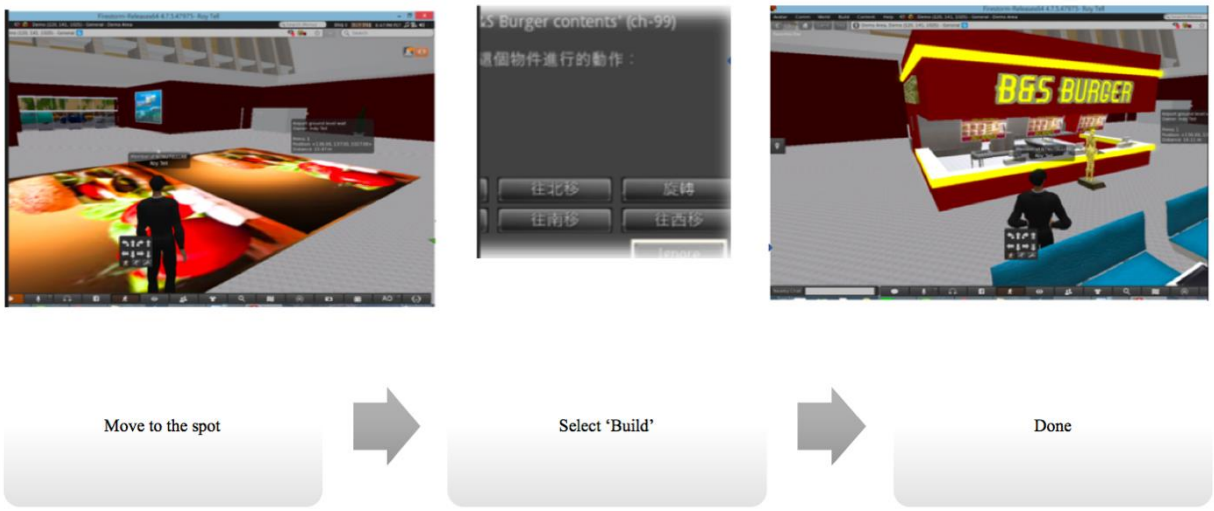

Figure 1. The three steps of construction in B&S

Figure 2. Students collaboratively created their own scene

The interview questionnaire

The researchers adopted the usability questionnaire (Lewis, 1992) and then adjusted the questions according to the current research context. The aim of this questionnaire was to understand participants' perceptions, as well as their prior experience of playing VR games. In order to collect students' active responses, the participants were interviewed in groups. Two advantages of this interview method were considered here. Firstly, the researchers could explore students' perceptions in details to overcome the limitations of short answers in a paper-pencil questionnaire. Secondly, the participants might be more comfortable with the way of speaking in groups where peers may provide emotional support. Furthermore, in order to probe deeply into individual's ideas about this learning experience, the participating students were also asked to write down their opinions in the final week of this study. The written feedback and the results of the interviews were interwoven to answer the third research question.

Procedure

This research lasted for 5 weeks from April to May 2015. Figure 3 shows the timeline and the weekly learning goals. The students worked on the platform, B&S, in the first four weeks, and were interviewed and completed the questionnaire in the fifth week.

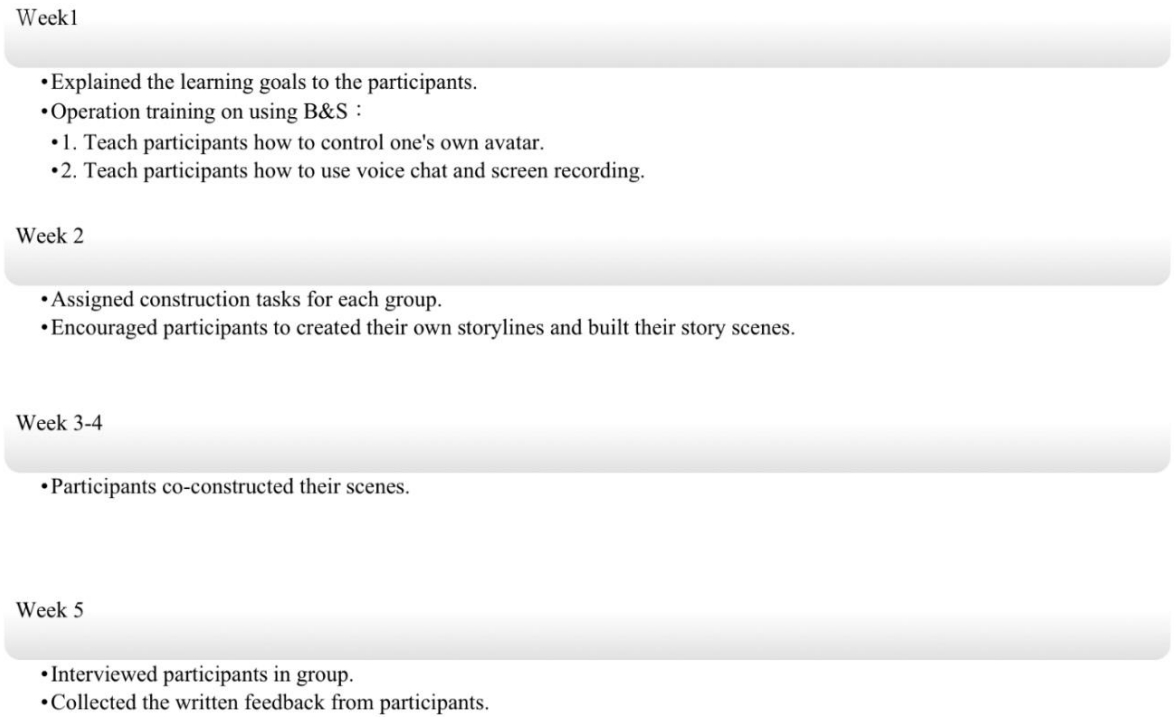

Figure 3. Research timeline and weekly goal

Theoretical framework and data analysis

According to Creswell (2012), "qualitative research collects data in a natural setting sensitive to the people and place under study" (p. 37). Furthermore, the current research aimed to understand the gender differences in collaborative learning and to explore students' learning experience and their ideas about this learning activity. A qualitative methodology was therefore adopted in this study to reach the research goals. More specifically, the interpretivism was the philosophical position underpinning the data analysis. Considering the age of the participating students, the authors mainly adopted the narrative analysis, which paid more attention to what people responded, rather than how they responded (Riessman, 2005). Having this research assumption in mind, the researchers carefully chose the relevant articles in the literature review in order to clarify the definitions of concepts involved in this study. The comparative matrix for the analysis was based on the research addressing collaborative learning in three main topics: characteristics of communication (Oliveira et al., 2011), process-solution analysis (Bravo, Redondo, Verdejo, & Ortega, 2008), and group functioning (Daradoumis et al., 2006).

Three analysis stages were involved in this study. The first round of analysis was to analyze screen videos whose total length was around 6 hours to reveal the significance within the raw data. Those screen videos lasting less than ten seconds and were mistakenly recorded were removed. The open-coding scheme, field notes, and the transcripts of student's last week of discussion were generated in this stage. The initial coding scheme was emerged in this stage based on the three broader concepts: communication, process-solution, and group functioning. In the following stage, the two coders watched and evaluated the videos based on the coding scheme and completed their own coding separately. Next, the two coders and the researchers discussed whether the codes should be deleted or added when there were discrepancies in the coding result. The differences in the coding results were mainly caused by different interpretations of certain concepts or judgments of how long a behavior lasted. The kappa coefficient of agreement of the coding scheme obtained from the two coders was .86 ($p < .01$), indicating that the inter-rater agreement reaches a substantial level. As for the analysis of the interview questionnaire, the data were analyzed in two ways. First, with regard to their previous experience which was categorized by multiple choices, the results were presented in a numerical way. Second, the oral data from the interview were transcribed and coded. The procedure of the coding of this data was similar to the how the visual data were coded. The kappa coefficient of agreement of the coding scheme of this questionnaire was .88 ($p < .01$). The final stage was to interpret and explain the findings obtained from the first two analysis stages.

Table 1 lists the relations between the final analysis and the research questions and also displays the different types of research evidence used to answer the research questions. The codes emerged from the raw data and then were aggregated into meaningful units. Based on this coding scheme, we could identify the real situation of

students' behaviors while exploring and collaboration in the 3D VR environment. In order to explore the gender-related differences, the frequencies of the codes in the genders were analyzed. One limitation in data analysis should be noted here. The analyzed screen videos were recorded by one student of each group, so the observation of avatars in the screen was mainly limited to a certain angle in the 3D setting. However, with the help of the soundtrack, the verbal interactions could be researched. Additionally, the numbers of codes were not significantly great based on the nearly-6-hour video observation because the occurrences of certain behaviors lasted a long time. For example, the discussion of the female group (toilet) about the storyline lasted for almost 13 minutes.

Table 1. Types of data analysis

	Analysis of the behaviors of avatars	Analysis of participants' group discussion	Researchers' field notes	Students' written feedback and verbal answers
RQ1	Codes	Codes	Reference	
RQ2	The frequency of codes of two genders	The frequency of codes of two genders	Reference	
RQ3				Codes and their frequency

Results

Based on the process-solution analysis (Bravo, Redondo, Verdejo, & Ortega, 2008), the results of students' collaboration were presented in two main domains: the process of their collaboration and the characteristics of their final co-creations. Moreover, in order to answer the research questions effectively, the results will be presented in three aspects. The first is the question related to how the students work collaboratively in the B & S. The participating students mainly worked together by controlling their own avatars and communicated by their headsets and microphones, rather than face to face. Therefore, the results of the first question were based on the screen videos to present the analysis of the avatars' behaviors and the content of their verbal expressions. The second question concerned the gender differences of the collaborative creations which include the students' skills learned in this experience and also their final video works in this study. Finally, the feedback from the participants was presented.

The gender differences in avatars' behaviors and the levels of verbal expressions

An example of the structure of the analysis is shown in Table 2. In the following paragraphs, the gender differences will be explored according to this coding scheme. All participating students were very excited when they logged in to B&S. A few classes needed stronger class management to assure that the students clearly understand their learning task. The most striking behavior observed in the first lesson was that almost all the students attempted to fly and explore the VR world. This could be seen frequently in almost all the screen videos, and "tell me how to fly" was the most frequently asked question during this program. The first gender difference lay in the way the students explored the 3D VR world by flying. The boys in this study tended to spend longer time exploring the environment. Based on the analysis of the video, the area where the boys explored seemed to be wider and higher than that explored by the girls. Additionally, the boys mastered the techniques of flying their avatars and changing the perspectives of their avatars quicker than the girls did, while the girls tended to be easily confused between their avatars' perspectives and their own perspectives.

Verbal data included two levels, namely individuals and interactions. More verbal data were collected from the female groups than from the male groups. There were two explanations for this. One was related to the technical error of the recording software. Five soundtracks of twenty-one screen videos from male groups were missing. This may influence the coding result in terms of verbal expression, while the behaviors of avatars were still recorded. However, even so, according to the rest of the sixteen videos from the male groups, the gender-related differences were still clearly observed. First, the boys tended to verbally check the condition of the instruments, such as screens or headsets. After checking, they spent more time on creating and controlling their avatars and seldom on verbally discussing anything with the team members. On the other hand, the girls raised more murmurs of discontent, including the noise from their headsets, or wondered what they should do. This result could be seen in the categories of checking and complaining in Table 2 (male: female = 9:20). Almost all the verbalization of actions of an avatar, for example, "I am falling," was found in the female groups. In addition, the frequency of interaction between the members was found to be higher in the female groups (male: female = 6:25). The girls showed more instances of asking questions, communication, squabbles and impolite language.

Table 2. The coding scheme of screen videos of students' creation and frequency of each code in genders

Categories	Sub-categories	Codes	Boys	Girls
Behaviors of avatars	Exploration	Walking or flying around in the 3D setting	10	10
Levels of verbal expressions	Individuals	Checking the condition of the instruments	3	8
		Complaining about the noise from the headset	6	12
		Squabbles and impolite attitudes	2	16
		Verbalizing the actions of an avatar	1	6
		Asking how to fly	7	8
		Wondering what should be done	0	6
	Interactions	Communicating verbally with members	6	25
Collaboration	Preparation	Looking for members	10	25
		Organizing the teamwork	8	12
		Discussion	2	6
	Off-task	Chatting with others	9	10

In terms of collaboration, the girls demonstrated a stronger sense of collaboration. It was more often observed in the female groups that they were looking for members and also reminding group members of their roles in the learning task. Additionally, when most avatars of each group gathered in the assigned working area, the girls tended to verbally discuss how they should create their own story collaboratively (4 of 5 female groups), while the boys demonstrated a higher tendency towards finer scene creations and object adjustment in the working area individually. In other words, girls seemed to have participated via more talks, and boys via more actions. However, off-task behaviors could be seen in both genders.

Two types of collaboration were identified in this study: the groups with a strong leader and the groups without a strong leader but peer discussion. In the former type, the group with a strong leader, the occurrence of conversation, discussion, and the quarrel was much less frequent than that of in the latter type, the group with peer discussion. Most members of the group with a leader followed the requests of their leaders without much questioning. On the other hand, the peer discussion groups demonstrated different characteristics, involving more off-task chats and focused discussion. One example from the focused discussion group (working in the virtual toilet area) is shown below.

S1: How to record our performance?
S2: We should practice before recording!
S3: Shall we start the rehearsal?
S1: That's right! Let's practice. Raise your hand if you agree!
S2: Ok, let's practice. Don't video-record yet! Ready? 321, go. I want to be the narrator!
S3: Stop! Are you sure you want to continue typing? (Some members argued by text-chat about the best timing to start recording.)
S2: It's the director's responsibility to control the recording software!
S1: Be quiet! Shall we restart?
[They took turn narrating the story of Little Red Riding Hood. All their avatars were in a toilet.]
S3: Is it appropriate to film this story in a toilet?
S2: But we will need to reassign the roles (if we change our story)
S1: Stop arguing. I know it is difficult to create a story in a toilet.
S2: How is it possible to film a story in a toilet? Teacher! (Shouted loudly)
[Some students from the other groups provided their ideas for this group]

From the excerpt, each member in this group had an equal amount of responsibility and they created a friendly atmosphere to allow themselves to express their own ideas. They created a story about sexual harassment, which was an appropriate storyline for their assigned area.

The characteristics of collaborative creations between female students and male students

Two categories were considered as the learning outcome in this section: the mastery of computer techniques and the short films created by the students. The boys could smoothly adjust between avatar's perspectives, camera angles and their own perspectives in a shorter time. Additionally, the following computer skill was only demonstrated by boys: checking all the details of their assigned areas, such as to what extent could they change the sets of buildings and objects. Some of the boys attempted to hide or delete the objects. For example, a boy flew around the whole airport and landed on a building outside their assigned area. The boy smoothly adjusted

between the perspective of the avatar and the user himself. His avatar looked down and then the boy tried to hide the building. The building disappeared and the avatar fell on the ground. In general, the boys tended to test as many functions in a 3D world as they could use, while the girls tended to work collaboratively mainly by verbal communications rather than by creations of new objects for their scenes.

Additionally, it could be seen in almost all the screen videos that one avatar in a different color from the color of the nearby avatars appeared among the small groups, and it was usually in blue or green (the colors assigned to boys). Interestingly, the boys did not mind that there was an avatar from the other groups in their working areas, while an avatar from the other groups would trigger females' strong actions. The female students would chase the avatar away verbally and push off the avatar, seen as an intruder, physically in the virtual environment. On the contrary, the skill observed in both genders was to simultaneously communicate by text- and verbal-chat. However, the purpose of using the two communication tools was different. The boys only used the text-chat for fun to show naughty language, but the girls created another line of conversation which was different to their verbal communication. For example, when the female group (toilet) verbally rehearsed for their story through their headsets, some of the team members discussed whether they needed to record the process of their rehearsal by text-chat.

As for students' co-construction screen videos, in both genders, 4 of 5 groups completed their tasks in time. The students' artifacts stretched their imagination by involving a great sense of humor in their stories. One of the male groups (assigned area: the hamburger store) did not simply demonstrate the transaction process but also embroider the story with the latest news which was about cooking oil made from recycled restaurant waste. One female group (assigned area: customs control) developed their story based on the reality, including checking the passport and asking for some details of the journey. However, the customs officer recognized her long-lost daughter and son while inspecting them, which created a dramatic ending. Interestingly, one boy groups held a very different mindset of creation in this VR environment. These boys paid more attention to the details of how they arranged their objects, such as adjusting the angles of a computer on the x-ray machine. In their final work, they spent a long time having their avatars queue in front of the machine without saying a word, like a show of an army march. These research data demonstrated the diversity of students' ideas towards creations in a 3D VR world.

Students' perceptions of this learning experience

Almost all the participating students considered this learning experience special and interesting; 92% of the male students and 98% of the female students expressed that they enjoyed creating in this platform. That was their first experience of exploring in a 3D VR world in school and they enjoyed the freedom to work collaboratively with little intervention by teachers. Gender differences also exist in their feedback on this learning experience. According to the group interview, 99% of the female participants believed that this experience enhanced their creativity, while 74% of the male students thought so. Based on their written feedback, some of the male students showed their motivation to learn English in order to use this platform more efficiently, and almost all male students were happy to learn more computer skills. Only one male student mentioned that he enjoyed working with others, while 8 female students evaluated this experience as a good opportunity for learning to work as a team and also recognized the importance of collaboration. One example of these responses was "This program encouraged us to develop our sense of responsibility and creativity. I believe that both are important for our future. The sense of responsibility is the key to building up trust in a relationship." It was revealed that they still grasped certain key aspects of collaboration in the four weeks. In addition, as more girls encountered technical difficulties in this setting, these girls obtained the sense of achievement by mastering the skills. One of these female students even underwent a change in her learning attitude. She wrote, "When we were asked to complete some tasks, I sometimes found the tasks difficult. I knew that I have to conquer these difficulties. It was all about my attitude. If I keep trying, it means that I am successful." In brief, the focus of the internal process of building meaning of this learning experience was also different between genders. The male students focused on what they could do, while female students reflected on what they could learn from this experience and expressed their personal feelings.

Discussion and conclusion

Gender-related differences in the social interactions in the process of co-construction in a 3D VR world

Geary (1996) found that boys were more interested in spatial exploration and putting their own ideas into practice, while girls were more comfortable with verbal skills, which was also revealed in the coding results in Table 2. In this study, boys tended to be more flexible with the detailed changes made by the other members. According to the video observation, male students were more likely to negotiate by directly changing the objects, while females preferred to reach a common ground through verbal interactions, including asking, chatting, and quarreling. As for quarreling, the result of this study contradicted the statement of Prinsen, Volman, and Tercel (2007), who believed that tension and abusive language were commonly observed in male groups. However, in this study, it was much more often found in the female groups than in the males' (see the code of squabbles and impolite attitudes in Table 2). Interestingly, quarreling or impolite language seemed to be an acceptable communicative style in these female groups. These girls were not obsessive about the form of language or their naughty attitude. Therefore, they still could continue discussing their ideas about the creations. It should be noted here that we need more research on whether this phenomenon only appears in the process of their co-construction or this style is a part of their daily talking habits. This finding implies that teachers can set a clear learning target without much intervention during their collaboration and also allow students to negotiate in their own ways, rather than limiting their speaking manners at that moment. Moreover, as the previous and current studies have recognized the gender differences in the collaboration both in a real world and in a 3D VR world, teachers should provide different types of learning tasks to encourage students to develop multiple skills, especially in a 3D VR world. For example, one type of learning task should be designed to guide male students to verbally evaluate their actions after their co-construction, thereby developing their communication skills (Oliveira et al., 2011), while another type of learning task should be provided to encourage female students to develop their spatial exploration.

Gender-related differences in the style of collaboration

Although gender-related differences in CSCL have been explored by Prinsen and his colleagues (2007), the focus of their research was more concerned with the verbal interactions and they found that males and females tended to adopt different ways of expressing their own ideas. This finding was also confirmed by the findings mentioned in the previous section, suggesting that teachers and researchers need to mix both genders in the future, which may provide a richer learning climate for students to develop their skills of collaboration by working with others with different mindsets. Based on the different definitions of discussion and collaboration (Dillenbourg, 1999), this study found that both gender groups involved different degrees of discussion. Instances of collaboration in boys' and girls' groups were also identified. Based on the video observation, the boys individually interacted with the 3D environment and felt free to modify some details of their assigned areas during the whole process. On the other hand, verbal negotiation and reaching a common ground before taking actions seemed to be more emphasized in the female groups. Once the girls had plans fixed, it seemed that fewer adjustments could be made. In this study, male students tended to mix two working styles together. They put their ideas into practice first and then negotiated by directly changing the objects or through further verbal discussion. Female students tended to verbally collaborate in the beginning and then completed their task cooperatively.

It should be noted here that the gender-related differences described in the previous paragraph were based on peer discussion with groups. There were two limitations of this study. One concern was the age of the participants. They were 9 or 10 years old and might have fewer experiences of negotiating in groups. The other limitation relates to the research methods. It was difficult to identify how students negotiated and built their common ground in the groups with a strong leader without exploring the metacognition of their learning experience. Theoretically, more research is needed to explore how young students learn to work collaboratively in different ways, such as well-balanced group distribution (Daradoumis et al., 2006). From the practical perspective, teachers can guide students to reflect on the process of their co-creation, especially the process of their collaboration including their verbal communication and actions of their avatars, which could be recorded and reviewed. This metacognition may effectively develop students' collaboration skills.

The possibility of collaborative learning in a 3D VR world

In this study, the participating students had to construct virtual contexts and create their own stories together. Most of them stated that they learned how to collaborate with others from this experience, for example how to express their own ideas, and to negotiate with someone who held a different idea. These important social skills are not commonly addressed in academic subjects in the education system in Taiwan, which is more teacher-centered. In this study, students were only taught how to create their own contexts in Build & Show and were told to make a short film as the learning outcomes. Although some heated arguments and unfocused behaviors were identified during the process, this study proved that students could learn to collaboratively create their own works even without teachers' guidance. However, in order to enhance students' social skills, teachers can set up some events such as an emergency in a 3D VR world and then encourage students to solve the issues while providing certain communication skills. Therefore, students could formulate their concepts of collaboration. With the aid of a 3D VR platform, learning an abstract concept and playing could be done at the same time.

Chang (2009) argued that learning in 3D virtual worlds may increase the workload of learners, in that they need to be familiar with the new techniques and complete learning tasks. However, this was not clearly observed in this study as some researchers (Harasim, 2017; Tapscott & Williams, 2008) identified that the new technology is integrated into the new generations' life. In this study, more than half of the participating students had experience of playing 3D online games, which means that students could develop their computer skills based on their previous experience. Although the gender differences existed in their creating behaviors and working styles, the female students enjoyed more and were more engaged with their creations in a 3D VR world. This result echoed Robertson's research (2012). Based on these two studies, it is suggested that teachers should be aware of their unconscious preconceptions of gender bias when deciding whether to incorporate games into their teaching plans. However, according to this study, girls may need more time or more guidance to master operational skills in the beginning. Therefore, the findings suggest that teachers may provide more support for female groups and also guide students on how to deal with the learning difference between members. Although the participating students nowadays are often surrounded by new technology, they still spend a long time trying to control their excitement to focus on their learning tasks. It is suggested that teachers need to carefully develop learning plans with new teaching aids and wisely guide students to the best usage of new technology to enhance their learning, instead of allowing technology to distract them from learning purposes. For researchers, it should be expected that it may take more time to spot participants' target learning behaviors because it is likely that participants are too excited to stay focused on completing the main tasks. Finally, the sample size was small in this study, so there is a need that a more long-term study dedicating to how a 3D VR world can enhance students' competency should be done.

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