THE IMPACT OF DEVICE ORIENTATION ON SMALL GROUP COLLABORATION DURING WHOLE CLASS GAME-BASED SIMULATIONS

BY

LITONG ZENG

THESIS

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Master's Committee:

Assistant Professor Michael Tissenbaum, Adviser
Associate Professor Robb Lindgren
Associate Professor Emma Mercier

ABSTRACT

This paper evaluated how students collaborated when using a tablet as a shared interface during group activities that required collaborative decision making within complex system ecological simulation. The simulation was a whole class city management game called *City Settlers*, which supports young students to better understand interdependent systems including environmental sustainability, civics, economics, and history.

While tablets are widely used in today's K12 classrooms, their impact on collaboration when they are shared among students has not been thoroughly studied. In response, this work examines the challenges surrounding students' collaboration using shared tablets. The use of tablets as the shared interface for the game critically influences students' collaborative decision-making and impacts students' learning and gaming experience. The researcher looked at a small group, three students, collaboratively playing the game *City Settlers*, and how they use the shared tablet.

The finding shows that the orientation of the shared tablet has an impact on students' engagement and collaborative learning process. For the student who is seating at the edge of the shared workspace of the tablet, the visibility can be low hence it creates friction for this student's participation in the game.

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CHAPTER 1: INTRODUCTION

Negotiation during collaborative decision making in a complex system encourages students to reason about their goals with each other, which can help them generate deep understanding and active engagement in learning the concepts related to the system (Antle et al., 2014). In *City Settlers* - a collaborative simulation game for the complex understanding of sustainability – effective communication and collaboration are key for students to better comprehend the learning content.

Tablets are widely used in today's classrooms, but collaboration on tablets is not thoroughly studied (Fleck et al., 2021). There are some challenges for collaboration on shared devices. Many researchers have found that with proper design, tablets have a positive impact on students' learning (Haßler, et al., 2016). But poor design of the mobile learning experience can result in inefficient communication in collaborative group work. Even though there is evidence of learning for students using handheld devices like tablets, their use may result in students not giving each other enough attention, which can prevent them from effectively communicating (Liu & Kao, 2007). Since tablets as learning devices are increasingly being adopted by schools and summer camps, it is important to thoroughly understand their use and design to better assist with learning and collaboration.

In the current version of *City Settlers*, it is not yet clear how handheld shared devices, and their orientation, impact collaboration, decision-making processes, and students' engagement in terms of their emergent dialogues about sustainability. To this end, within the context of *City Settlers*, this research aimed to answer the following research questions: (RQ1) What is the influence of a shared tablet's orientation on students' collaborative decision-making process during group interactions? (RQ2) What effect does device visibility and intractability have on students' engagement in collaborative actions?

CHAPTER 2: LITERATURE REVIEW

Collaborative Decision-Making

According to Roschelle and Teasley, "Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995, p.70). Based on social constructivism theory (Duit, 1998) and constructivism learning theory (Olusegun, 2015), knowledge is constructed by learners during their interactions with each other. However, not all interactions help learners generate knowledge nor can they be called collaborative learning. Based on Dillenbourg (1999), collaborative learning means the type of interactions that might generate learning mechanisms, but it is not guaranteed; as such, it is important to understand and design situations well to help generate more learning-related interactions.

Collaborative learning has long been considered an effective way of learning (Alavi, 1994; Dillenbourg, 1996). Previous studies have shown that collaborative learning can help students reach better conceptual understanding and skill learning (Lai, 2011). In the group decision-making game and energy management learning project *Youtopia*, Antle et al. (2014) revealed that gaming collaboratively in a complex system and making decisions together will encourage students to talk and reasoning their decisions with each other which help them generate a deep understanding of the content and engage actively in learning of the complex system. Through an undergraduate collaborative engineering activity, Shehab and Mercier (2010) studied students' verbal interactions and their scores on a collaborative problem-solving task. They found that performance on the task was positive related to students' engagement in causal elaborated statements and metacognitive turns.

Even though collaborative learning is known to have positive effects on learning, with Computer Supported Collaborative Learning (CSCL) (Jeong & Hmelo-Silver, 2016), there is more to examine in terms of how to scaffold learning with digital technologies' assistance. When students collaboratively learn together, the collaboration should have a relatively symmetrical structure, and students should be equipped with the same level of abilities or knowledge to perform the same tasks, and have shared and negotiable goals (Dillenbourg, 1999; Lai, 2011). When learners make decisions together, their interactions should mirror those of effective collaborative learning, which can assist them in sense making, push them to elaborate their thoughts in words, and to communicate with their peers. However, when studying collaboration, it is important to look closely at students' interactions to understand the role the scaffolding plays (particularly any computer-supported scaffolding).

To better understand the collaborative interactions that aid in learning, have researchers also developed well-established analysis frameworks. Chen and Andrews et al., (2019) developed a coding scheme framework for Computer Supported Collaborative Learning. The project *OurSpace* classroom examined the process of how students collaborate toward the same goal around tabletops and proposed a CLM (Collaborative Learning Mechanisms) framework for investigating similar activities (Fleck et al., 2009). *Oztoc* helped people at a museum to engage in hands-on learning electrical engineering content collaboratively using tabletop simulation, and the researchers developed the DCLM framework (Divergent Collaboration Learning Mechanisms) based on the CLM framework to investigate how learners collaborate when they have open-ended and divergent goals for learning (Tissenbaum et. al., 2017). To study collaborative interactions, and especially to design technologies to better assist collaboration and interactions, it is important to understand and adjust the analysis accordingly to the type of learning activities (Tissenbaum et al., 2017). When investigating collaborative games, understanding the type of activities learners engage in can be interpreted in terms of the game itself and the game's mechanisms.

Collaborative Simulation Games

Studies have found that as a highly interactive learning experience, games with well-designed learning content have a positive impact on students' learning outcomes as well as significantly improve engagement (Ke & Xie, 2016). Nowadays, serious games are being studied extensively in the learning sciences, and the term mostly refers to digital game-based learning (Anastasiadis et al. 2018), which is proven to be effective in learning, especially for content understanding and sense making (Hussein et al., 2019).

An important part of digital games in the learning sciences are simulation-based games. Simulation games enable students to interact with complex systems that they cannot change in the real world (Wu & Lee, 2015). For instance, in the simulation game project Rainbow Agents, students can manipulate plants' growth through a unique programming mechanic, which combines gardening with computational literacy together, which can only happen in the virtual simulation world (Pellicone et al., 2019). When students interact with a simulation, they can act as either a part of the system to influence the direction of the simulation or to directly manipulate the system. While students are manipulating the system, they can directly observe the impact of their actions, allowing them to make sense of different factors in the system as well as their own actions' impacts. The game mechanisms boost their motivation for sense making, as they are looking to perform well in the game (Ryan & Rigby, 2015).

Sustainable development education through simulation games is increasingly being studied by researchers (Gatti et al., 2019). For instance, Gatti et al. (2019) have studied college students playing a business simulation game for sustainable development, and found it is effective in proving students' critical thinking about sustainability. Another example is the game *Climate Interactive*, which presented a complex system in which students manipulate factors in a city that can affect the environment status. The game helped students effectively understand and change their own mental models of how human activity is affecting our environment based on the game system (Sterman et al., 2012; Sterman et al., 2014).

Students' motivation through the desire for achievement, social interactions, and immersion are well promoted during game-based learning (Yee, 2006). Researchers have found that collaborative game-based learning with simulations, or participatory simulations, can effectively promote the learning performance due to learners co-constructing knowledge together during the process (Chen et al., 2015, Chen & Law, 2016).

D'Angelo et al. (2015) have developed the collaborative game *Fishing with Friends*, the visitors in the local aquarium were able to play together to compete for finishing to gain more money. The competition for more fish gathering as a key component in the game, allowed players to experience the ecosystem's reaction for overfishing. They have found it is effective for promoting people's awareness of environmental issues with the game. Researchers studying the collaborative programming game Bots and (Main) Frame, found that collaboration helps students decrease anxiety when learning to code (Melcer & Isbister, 2018). In another example, Antle et al. (2013) developed Youtopia, a multiplayer land use planning tabletop game. In Youtopia, the researchers were focused on the interface design to facilitate collaboration. They studied how students collaboratively learn sustainability when using an interface designed to require two or more students to collaborate in order to complete tasks in the game. Their interface allowed more complex collaboration to happen in the shared simulation (Antle et al., 2013). Similarly, Kreitmayer et al. (2012) designed a climate simulation game with a classroom display and tablets called 4Decades. Students play collaboratively in groups to manage their CO2 rate and development. From this work, the researchers proposed the concept of Contributory Simulations, which refers to a scaffolding instruction model that can facilitate students better collaborate and make critical decisions together in group settings.

Based on previous research, collaborative simulation games are effective for learning, and immersive collaborative simulation games support the collaborative learning experience with even more connectivity between the learner and the gaming environment. Immersive simulation games for classrooms, refers to simulations that include the whole room as the gaming environment. Immersive simulations are effective for constantly engaging students in the activities (Liu & Slotta, 2014; Liu et al., 2020) which is the goal that *City Settlers* is aiming for. Whole class simulations as a type of immersive simulation are also studied by researchers. Researchers have compared whole class simulations and small group computer simulations and found that even though both kinds of simulations are effective in terms of the learning outcome, students in the whole class simulation tend to generate more meaningful interactions (Smetana & Bell, 2013).

How students collaborate in learning is one of the most important aspect for designing collaborative gaming and learning experiences. When using digital simulation games as a tool to assist collaborative learning, the gaming device and interface which structure the collaboration can directly influence the learning process.

Tablet and Territoriality in Collaboration

The choice of which devices to use and the design of their interfaces have a big impact on students' behavior, decision making and sense making during gameplay (Nussbaum et al., 2009). Students' interaction is structured by the design of device and interface, which will influence the quality of the communication, is more evident for shared devices (Liu & Kao, 2007). Good designs of tablet display and interface can positively impact students' learning (Haßler et al., 2016). When multiple students share the same tablet in a group setting, the design of the interface is essential to the quality of learning, especially considering territorial behaviors and territoriality aspects of collaboration (Scott et al., 2004).

Dillenbourg (1999) explained that in collaborative learning, learners need both their personal workspace to digest the information and collective workspace to collaborate with others. Depending on the task and group activities, students may have their own space for working and thinking in a certain location of the shared table, in which they have access to resources and information that they prefer not to share with the public (Scott et al., 2004).

The game *City Settlers* is a tablet game, but like the collaborative tabletop designs, there are also personal and shared workspaces that appear naturally during the gameplay. These territories exist with even clearer boundaries than with tabletop games, as the tablet does not lay flat on the table surface but usually facing one direction, which means students seated in a certain range outside of the tablet will be excluded from the shared workspace.

Previous research exploring territoriality have focused mostly on tabletop activities. Scott et al. studied learners' physical and tabletop territoriality and found that in tabletop games, there are three kinds of territory: personal territory, shared territory, and storage territory (Scott et al., 2004). Students gather information in the shared workspace, and they tend to work and process information in their personal space first and then work collaboratively in the shared space. Even though all the spaces are shared space in the game initially, students still tend to create a personal space to maintain their personal belonging to set boundaries for their territory, between the personal and the shared (Scott et al., 2004).

Researchers have also indicated that the physical environment and initial seating area will highly influence how personal territories are placed (Tang, 1991; Kruger et al., 2003; Scott et al., 2004). Rick et al. (2009) researched an *OurSpace* application and found that during tabletop collaborative tasks, students take more responsibility to the area in front of them, which can loosely be considered as their personal territory. Marty et al. (2016) researched multi device game-based learning collaborative activities with both individual and group tasks. They used an interactive tabletop as a shared workspace and perceptible individual workspace, and a tablet as an individual workspace. The inter-territory actions can help with managing information in a multi-device collaborative learning environment. Fleck et al. (2021) conducted research on how two students collaborated during single player games on single touch tablets. They observed territorial behaviors in which students tried to dominate the tablet during the collaborative task. This research suggests that there is a need to further investigate and consider territoriality in tablet-only collaborative activities, and shared display and shared workspaces that use multiple devices (including personal tablet computers).

Tablets as shared displays have been used in schools to assist with students' collaborative learning (Fleck et al., 2021). Researchers indicating that tabletops support collaborative learning is vastly examined in the research, but tablets are not fully explored even though they are increasingly used in the classroom (Fleck et al., 2021; Falcão & Price, 2009; Clark & Luckin, 2013; Haßler et al., 2015). To this end, it is important to gain a thorough understanding of how tablets can facilitate collaborative game-based learning.

In collaborative games, the shared device can also directly influence information distribution, which has been shown to play an important role in group decision-making processes (Gruenfeld et al., 1996). When the collaborative activity is taking place in Single Display

Groupware (SDG) (Stewart et al., 1999), all students can input information or action to interact with the system, the output of the information will be a shared display, for example, a tablet screen. In this setting, equal access to the shared display is significant to the co-presented collaboration (Falcão & Price, 2009). If not, interference can become a problem where people might bother each other during the coordination of finishing tasks (Tse et al., 2004). To support students' collaborative decision making with their embodied action playing in a complex simulation game, there is a need to use a shared tablet to support more interaction between group members. But it is important to design the tablet interfaces properly, including what content should be on the shared tablet, a what should be on the personal device. To this end, when students use a multitouch shared tablet, and especially when key information is on the shared display, it will be valuable to see how students interact with these collaborative and personal devices and arrange them in their "workspace," and how this impacts the quality of groups' sense making and decision making.

CHAPTER 3: METHODS

Gameplay and Setting

City Settlers is a collaborative decision-making participatory simulation (Wilensky & Stroup, 1999) game aimed at cultivating young students' understanding of sustainability. The game is played out over multiple rounds (each round approximating roughly a year), with when the game ends decided by the teacher. For each round of the game, within their groups, students need to decide which building to attempt to buy (through a whole-class auction/bidding system), which of their existing buildings to run or not, and make decisions and strategies about trading resources with other cities (see Figure 1). During this process, students need to interact with their personal tablet for trading, and a main shared group tablet to manage their city (see Figure 2) including searching city data about resources, their city's metrics (e.g., happiness, pollution, etc.), and bidding for and placing buildings. There is a large central classroom display that shows the entire class all the cities' public data. All three screens have their specific function and display design (see Figure 3). In this research, I will mainly look at how students interacted with their group city management tablet, and how it influences the decision making listed below.

As mentioned above, the current version of the game is played on tablets. One group of students share one main tablet for their city view, and each student has their personal tablet for trading with other cities. Research has shown that the medium used in the game will influence students' behavior, decision making and sense making (Nussbaum et al., 2009). As such, having a deeper understanding of how students interact with the tablets, will give future studies a greater understanding of how to design a better digital environment to assist students' learning.

Participants

The research participants were local upper elementary and middle school students who signed up to play the game as part of a summer camp. There were total of 11 students recruited. All participants and their parents consented to the students participating in the experiment and for them to be audio and video recorded. For the gameplay data collected, there were four groups of students in the game, three groups had 3 students, one group has 2 students (see Figure 4).

Because this study is not targeted toward a specific race, sex, or socioeconomic status, in this paper these factors are not considered as the research focus.

Activity Design

At the beginning of the session, students were introduced to the game and its rules. They were then separated randomly into groups. Students were placed in their respective cities across the room in a way that approximated where their respective cities were positioned in the game environment (see Figure 4). During gameplay, the researchers and the summer camp teacher were around to help with the orchestration for each round of the game and assisted students when they have questions about the game rules. The total experiment lasted one 3-hour session. The students played about 10 rounds of the game. All 3 hours of gameplay were captured through video and audio recording for further analysis.

Figure 1

Process of Each Round of the Game

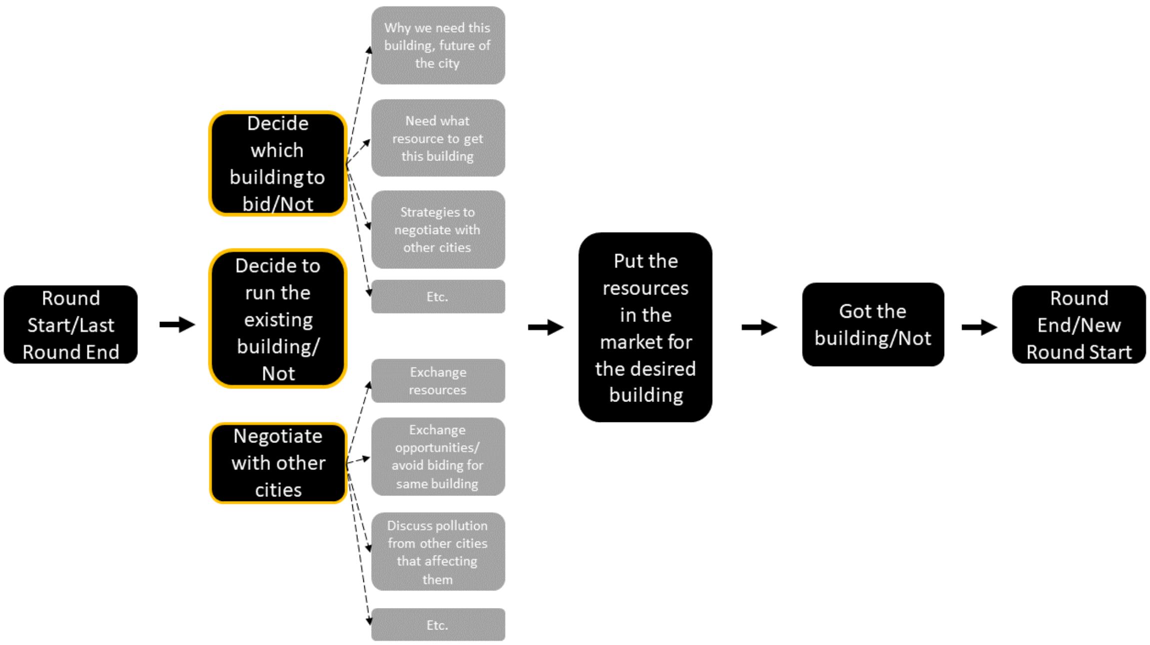


Figure 2

Shared Surface Tablet Display Content Screenshot

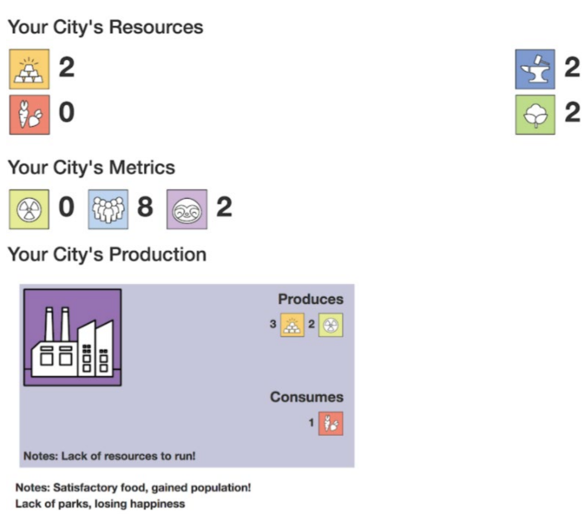
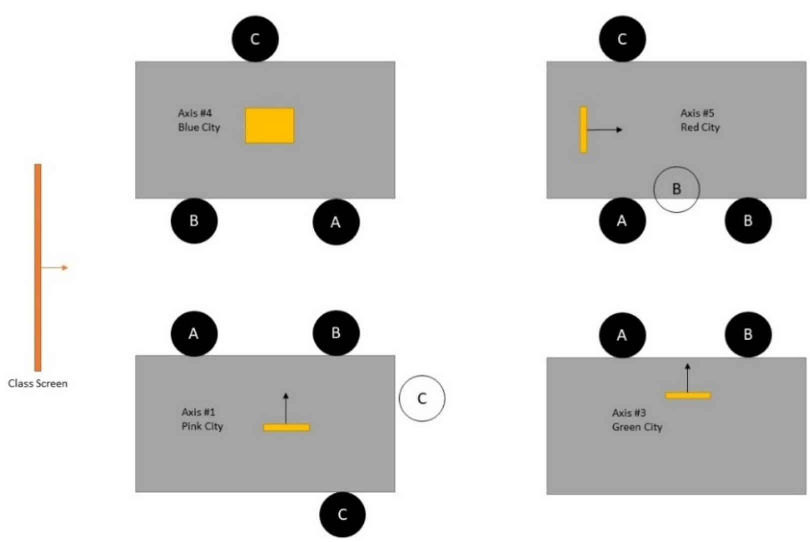


Figure 3

Classroom Display Personal Tablet Display and Shared Tablet Display Device

Figure 4

Arrangement of the Gameplay Environment and Initial Screen Facing of the Main Shared Tablets for Each Group/City



Data Collection

The research data was collected by Professor Tissenbaum and his research team in June 2019. There were total of five video cameras, four cameras facing four tables, and one camera for the overall 360-degree classroom view to capture cross-group interactions. There were also four audio recording devices, one on each table to capture the discourse during the gameplay. The experiment was collected at the College of Education building's digital research lab, with the summer camp teacher on-site with students while playing.

Analytic Approach

The study is informed by qualitative video analysis framework (Goldman & McDermott, 2007). To find out how students interacted with tablets in the decision-making process, and how this interface affected students' communication, this study analyzed the videos from the run of the game on June 14th, 2019.

The research involved two cycles of analysis. The opening analysis was based on the video content logging (Goldman & McDermott, 2007). This was used to select important episodes of the video to conduct the second cycle of analysis which using microgenetic learning analysis (MLA) to help reveal the underneath relation of the devices and collaborative learning (Parnafes & diSessa, 2013).

The first cycle of analysis is fully grounded in the video data with the aim to provide themes and highlight gameplay episodes for the second round of analysis. Orientation of the shared display emerged as a major factor based on content cataloging and notes. Factors under investigation included who contributed to the decision, who interacted with the shared display, who had the clearest view of the shared display, and what is the shared workspace in territoriality (where and to whom the shared display was facing). The first phase of this analysis revealed the need to understand what the relationship was between these three factors, and what verbal interactions indicated what happened during the process of engagement.

Based on my interaction logging at the tables, another finding from the first round of analysis was that in the early rounds of the game, three students who sat at the opposite side of the table from their peers (referred herein as the “single student side,” see Figure 4, where Student C from each group are seating at), two actively engaged in and contributed to the biding decisions which required information from the main tablet. However, in the later rounds, students at the single student side (Student C at each table) became less active in engaging in group conversations about the bidding decisions. To this end, it is worth further focusing more on Student C’s collaboration and interaction and its relationship to device orientation and interactions.

Also, based on the initial analysis of multiple rounds and multiple cities in the game from primarily the whole classroom video, I selected Pink City’s (see Figure 4) gameplay to further analyze for interactions among group members and with the tablets as it was most representational of how we designed the game. Green City (see Figure 4) only had two students, which is not our future aim for interaction studies, so is less valuable to look at it in this research. Red City’s Student C used a small personal screen for interaction, and her less active behavior might be influenced by her personal device’s screen size. In Pink City, all students were equally active at the beginning and tended to indicate clearly their needs during the group. This is very helpful for better understanding the situations for the shared display influencing decision and collaboration process.

Analysis and Coding Scheme

CLM framework

The *City Settlers* simulation game draws many of its design features from the Divergent Collaborative Learning Mechanisms framework (DCLM) (Tissenbaum et al., 2017). This framework focuses on when learners are more open-ended toward their respective goals during collaborative learning, which means, learners may or may not share the same tasks or learning goals within or across groups when collaborating with each other, even when they can still collaboratively learn or engage using the same content. For example, in the game *City Settlers*, different groups of students might make the same decision of trading with each other, but they do not share the same goal of why to trade this resource, the reasoning process, and production of knowledge behind the task can be different. However, my coding of *City Settlers* does not solely reference the DCLM framework, as my analysis focuses more on within group communication and collaboration, in which students typically do not have divergent collaborative learning processes. For this reason, my research references mainly the Collaborative Learning Mechanisms (CLM) framework, for both the underlying theory and research method (Fleck et al., 2009) – from which DCLM itself was developed.

The CLM framework was developed based on collaborative learning theories (Dillenbourg, 1999). Within collaborative learning theory, the CCC (Convergent Conceptual Change) is the underlying model for the CLM, that the learners together co-construct knowledge concepts (Roschelle & Jeremy, 1992). The knowledge is constructed on site by learners when they constantly elaborate and negotiate with each other. And the learner's knowledge will converge toward similar concepts after the collaboration (Tissenbaum et al., 2017). The CLM framework considers that the most important knowledge building process lays in the discourse and students' interaction with each other. There are two mechanisms in the CLM framework for further investigation, Mechanism of collaborative discussion and mechanisms for coordinating collaboration (Fleck et al., 2009).

This research used the collaborative discussion mechanism to investigate how students making and accepting suggestion during the process of making decisions together, and the negotiation when different interest appears. There are two layers within the collaborative discussion which are the game content for learning discussion and device display related discussion. The accessibility of information may be a major issue for coordination during group negotiation. The second layer of the collaborative discussion is also highly related to the coordinating collaboration mechanism, which is more emphasis on the behaviors of interaction between group members. This research used the coordinating collaboration mechanism to investigate joint attention and awareness. The analysis based on the two mechanisms and the device related interactions allows the researcher to understand the process of decision making and the device's influence on collaboration and coordination.

For this second cycle analysis, Student A, Student B, and Student C mentioned from this point beyond are all from the Pink City. Student Seating and orientation see Figure. 5.

Figure 5

Student A, Student B, and Student C's seating in Pink City

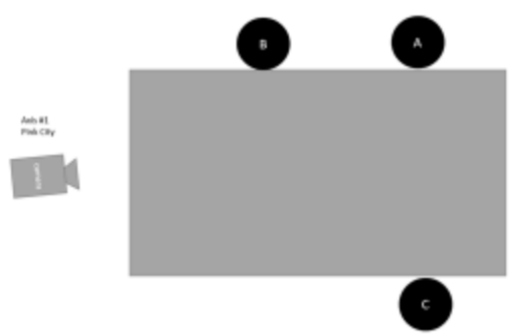


Table 1

Collaboration and Coordination Coding Scheme, Adjusted Based on the CLM Framework

Code	Definition	Example
Making suggestion MS (Collaboration Coding Scheme)	A student brings up a new idea that is not introduced before, the ideas can be major decisions that are going to affect the city's development. For example, when the decisions are about: biding on which building, bid on how many of a resource, trading with which cities, trade for how many of what resource.	Student C: "I want to do a factory and a Park."
Accepting suggestion AS (Collaboration Coding Scheme)	A student first time shows clear verbal agreement with an idea.	
Clarification C (Collaboration Coding Scheme)	Conversations that clarify an ambiguous part the student does not clear about. For example, a student is not sure about how the game works, an idea another student suggested, a city decision made by others, etc.	Student B: "Did we get it?"

Table 1 (continued)

Negotiation <u>N</u> (Collaboration Coding Scheme)	When students have different goals in the game and talking about them. Either they had different suggestions for the city development decisions or wanting to use different ways to achieve the same interest. The negotiation may include reasoning why she/he/they are wanting to make such a decision to convince teammates, to debate about others' ideas is not good enough, and trying to reach a common ground for different people's interests.	Student A: "No, we can't afford this."
Narration <u>R</u> (Coordination Coding Scheme)	Students giving a description of what they are thinking or doing. Other students can track their behavior and thoughts when students narrating. Narration usually does not seek other's responses. Sometimes other students respond to a narration, sometimes they do not.	Student A: "Our city is depressing". (A is commenting on their city)
Stopped Joint awareness and attention <u>J</u> (Coordination Coding Scheme)	When students start to work on their own, and not giving others attention. Does not count when students went off for trading and working on the execution of a decision.	[Student C staring at the table and zoning out while A and B are talking about the city development]

Table 1 (continued)

Off-task talk and behavior T	Talks/self-talks that do not relate to the game content, or the game display and environment.	Student C: "Does anyone want sushi?"
Execution E	Students executed the decision (bid the building, trade with another city, etc.)	

This coding ignores interaction with instructors and other group's members and only considered the interactions within the group (we did not code anything if there's other group's members are in the conversation)

Device related discords and interactions

The game *City Settlers* is a tablet game, but similar to tabletop collaboration, there are also personal and shared workspaces that appear naturally without predefined during the gameplay. On tablets, the territories will appear with even more clear boundaries than the tabletop game since the tablet does not lay flat on the table surface but usually facing one direction, which means students seated in a certain range outside of the tablet will be excluded from the shared workspace. For this reason, in the coding scheme, defining the shared workspace based on the tablet's orientation very important. Figure 7 shows the defined shared workspace and its relationship with the shared display facing the colored area is considered the shared workspace.

The shared workspace for tablets needs to be the space in front of the screen and within a range where people can see and interact with the content in the device, based on the action visibility and transparency rule by (Scott et al., 2004). Based on the device in this version of the gameplay which is Lenovo Surface Pro 4, the "20/20 Vision Distance where Pixels or Sub-Pixels are not resolved" based on Lenovo's official records, "Individual Pixels are Not Resolved at 12.9 inches or more." And the viewing angle shift to 180 degrees will affect slight color shifts (Surface Pro, n.d.). "For 20/20 vision the minimum Viewing Distance where the screen appears perfectly sharp to the eye." (Surface Pro, n.d.) 20/20 is known as what is called a Snellen fraction which is the ability to see or identify a letter or some image of a certain height at a certain distance (Gregori et al., 2010). After transcribing the 20/20 vision angle of minute of angle to digital text size and the viewing distance referencing the ISO standard for electronic visual display (ISO9241-303:2011) (minimum Latin character height shall be 16 arcmin), the result of a shared display area for shared workspace is 100 cm distance and the angle is 180 degrees of the tablet surface (Ko et al., 2012).

My research question for this phase of analysis concerns how students' engagement and contribution to the collaborative decision-making process changes over time with the current interface display. As such, the coding themes were focused on where and to whom the shared display device was facing; students' interaction with the display device; which decisions influenced the city growth in the game; how the decision was made; how and how much each student is involved in making/accepting suggestions in the discussion, including clarification and off-task talks; any device related conversation during the gameplay; and how the device assisted with the group collaboration and influenced each decision. By closely analyzing the physical interaction students have with the device, combined with their discourse, it is easy to see how the display influenced the group decision. For example, who is contributing more to the decision making, or which students are struggling more with figuring out the game content, and thus is not able to make suggestions toward the decision, need more clarification, or engage in off-task talk, and how any of these factors might be influenced by the current orientation of the shared display.

Table 2

Display and Device Interaction Coding Scheme

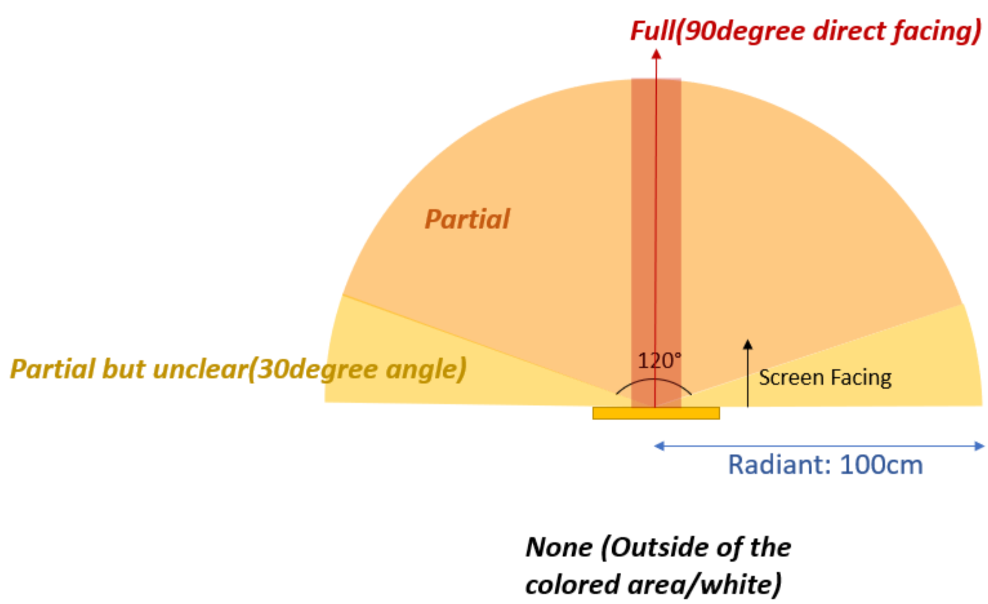
Code	Definition	Example
Display Facing related conversation D	When students are talking about the shared device, shared display, or display facing.	Student C: "I can't see anything." (Student C is indicating she cannot see the shared display screen)
Interaction and Control I	The students who are interacting or orienting the shared city device, may change the orientation, hold the device in hand, clicking or scrolling to search information, put in the bid, place buildings, enable buildings, etc. 5s if they stop interacting, the duration code stop.	[Student B clicking on the shared display screen]
Shared Display Facing Full/Partial/Obstracted F/P/O	See Figure 6 (Radiant: 100cm or 40inch) When the students are not facing the screen, but the screen is facing their direction, it is still considered facing (P or F). But when the students' position/location has changed, the Screen facing might change too. The FPO is based on if the display is available to them, i.e., if they are at the shared workspace defined by the shared display.	

Table 2 (continued)

	When there are objects in the middle between the student and the screen, mark as obstructed if the object is the same size as the device or larger. If out of the radiant but the angle is facing full, code as Partial, if out of the radiant but the angle is facing partial, marked as Obstructed (reference of radiant: the table is about 200cm long) If at the edge, mark as when students not out of the radiant"

Figure 6

Screen facing: Partial, Full, Obstructed



In Table 2, *Display Facing Related Conversation* is point code and is coded based on students' verbal communication. There are three codes within *Shared Display Facing*, describing the spatial orientation and relation of each student with the tablet.

To establish interrater reliability, the author coded with a second rater. The two raters coded 10% of the video, with a percent agreement of 92.3%. The two raters resolved all disagreements through discussion. The author then coded the remaining events.

CHAPTER 4: FINDINGS

After analyzing the video of Pink City's Student conversation and behaviors based on the codes in Table 1 and Table 2, the results are as shown in Figure 7, Figure 8, Figure 9, Figure 10 and Table 3.

Table 3

Student A, Student B, and Student C Conversation and Action Occurrences

Code	**Total**	Student A	Student B	Student C
Making Suggestion	48	19	18	11
Accepting Suggestion	23	7	11	5
Narration	142	68	26	48
Clarification	71	35	19	17
Negotiation	43	18	14	11
Stopped Joint Awareness and Attention	8	0	3	5
Off-task Talk and Behavior	27	3	10	14
Execution	17	12	5	0
Narration	142	68	26	48
Device Related Conversation	9	1	2	6
Interaction and Control	134	75	48	11
Shared Display Full	19	14	3	2
Shared Display Partial	40	9	24	7
Shared Display Obstructed	39	9	21	9

Figure 7

Duration of State Events for Student A

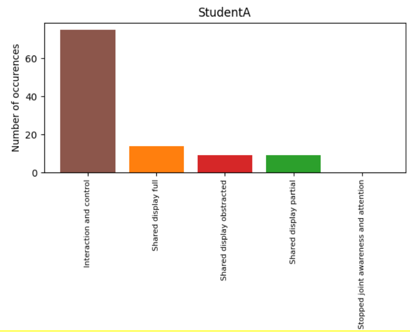


Figure 8

Duration of State Events for Student B

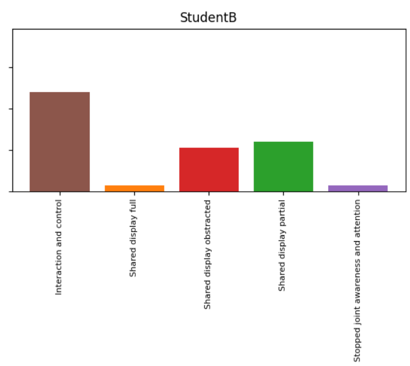


Figure 9

Duration of State Events for Student C

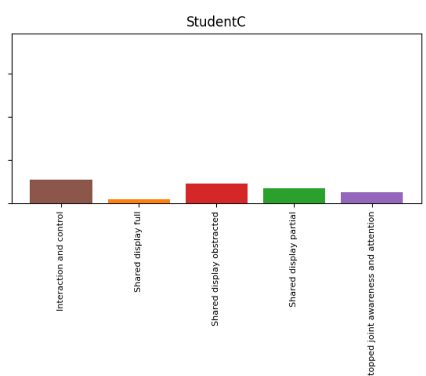
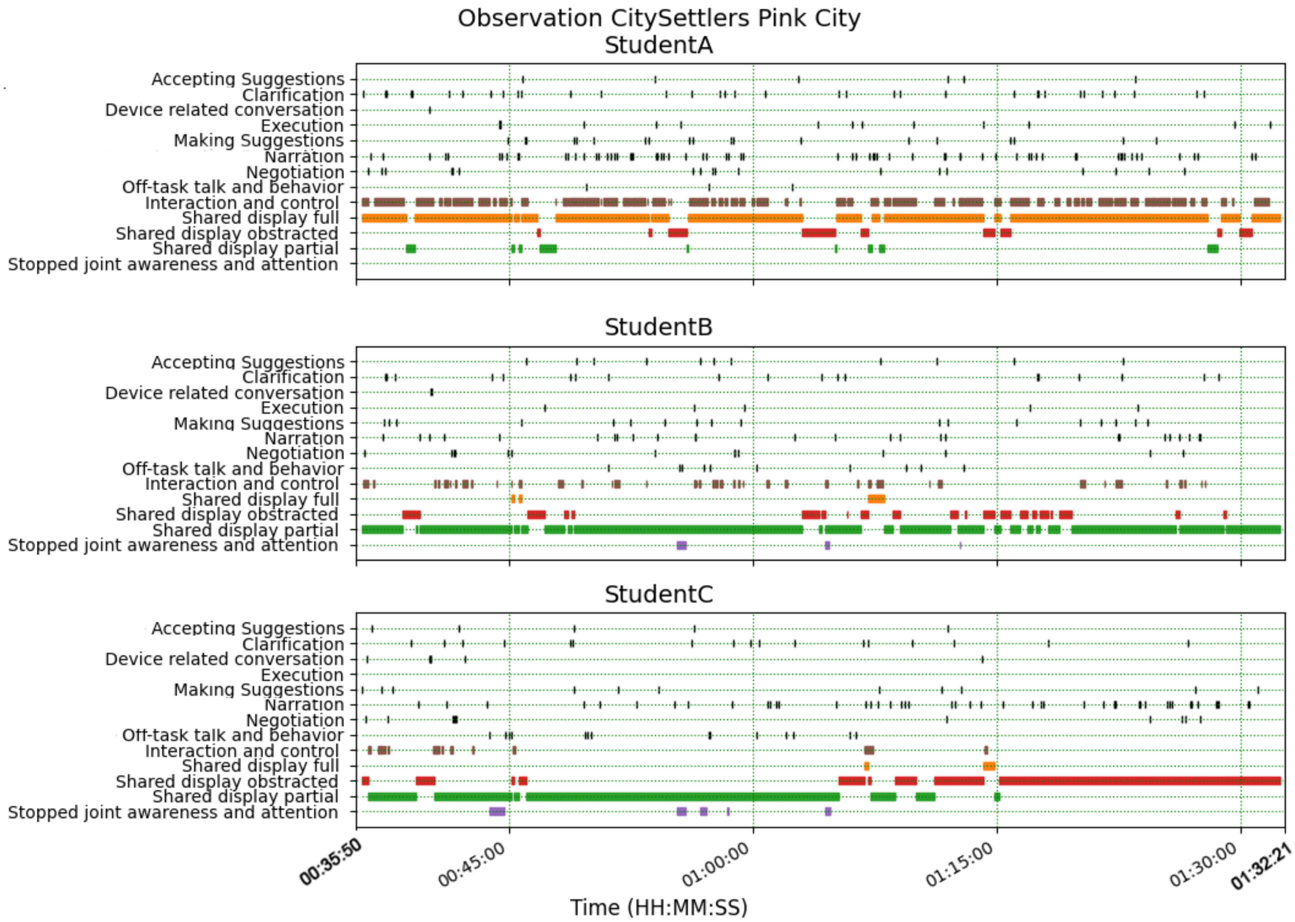


Figure 10

Time Plot of the Pink City Student A, Student B and Student C Gameplay Collaboration Event



Collaboration and Coordination

For the collaboration and coordination coding scheme, Student A had the most occurrences of *Making Suggestion* with 19 instances, Student B had almost the same number of occurrences as with 18 instances, and Student C has the least with only 11 instances.

Similarly, for *Clarification,* Student A has the most occurrences (35), Student B had 19 and Student C has the least at 17 instances. For *Negotiation*, the occurrences are Student A 18, Student B 14, and Student C 11. For *Execution*, the occurrences are Student A 12, Student B 5, and Student C 0.

In terms of *Accepting Suggestion*, Student B had the most occurrences with 11, Student A has less with 7 instances, and Student C had the least with only 5 instances.

It is worth noting that for *Narration*, even though Student A has the most *Narration* (68), Student C also has many occurrences (48), more than Student B (26). Most of the *Narration* for Student C happened in the second half of the gameplay. For all three students, *Narration* has the greatest number of occurrences comparing to other collaboration and coordination events.

Student A has a total of 159 behavior events in this gameplay section for Collaboration and Coordination, not including *Stopped Joint Awareness and Attention* and *Off-task Talk and Behavior*. Student A has the greatest number of *Narration* (68), *Clarification* (35), *Negotiation* (18), and *Execution* (12). In terms of the purely quantitative occurrences, she is considered the most active of the three students. It is also worth noticing that Student A had no *Stopped Joint Awareness and Attention*.

Collaboration and Coordination, Student B has 93 behavior events. Student B is less active when compared to Student A for the Collaboration and Coordination behaviors such as Narration (26), *Clarification* (19), *Negotiation* (14), and *Execution* (5).

Student C has a total of 92 events for Collaboration and Coordination, not including *Stopped Joint Awarenes*s and *Off-task Talk and Behavior*. Comparing to Student A and Student B, Student C has the least amount of Collaboration and Coordination behavior. Even though she has almost the same number as Student B (93), Student C has the greatest number of *Off-task and Behavior* events with 14 occurrences.

Display Orientation and Interaction

As for the display and device interaction, in a total of 4355.960 seconds were observed. Student A had the longest duration of *Interaction and Control* with the tablet of 1731.230 seconds. She also had the most occurrences of *Interaction and Control* with the device 75 times. Student B has less amount (267.986 seconds, 48 occurrences), Student C has the least amount (120.737 seconds, 11 occurrences).

Student A also has the longest duration of *Shared Display Full* for a total of 2831.912 seconds. Student B and Student C both had only a little amount of *Shared Display Full*, Student B has slightly more than Student C. Student C has the lowest duration for *Shared Display Full* for only 58 seconds.

In terms of *Shared Display Partial,* Student B has the longest duration for a total of 2770.438 seconds, as well as the most occurrences at 24 times.

Student C has the longest duration of *Shared Display Obstructed* for a total of 1518.814 seconds.

It is worth noticing that the *Interaction and Control* and *Shared display full* was evenly distributed throughout the gameplay for Student A. And the *Shared Display Partial* is distributed relatively evenly for Student B in the overall gameplay. For Student C, the Shared display facing is not evenly distributed. During the first half of gameplay, Student C spent most of the time in the state of *Shared Display Partial*, which means she can see the display and had access to the city data. It is also worth noticing that Student C's *Interaction and Control* is less in duration for the second half of the game than the first half of the game. Student C also has the most *Device Related Conversation.*

Summary

Based on the result from the coding, Student A and Student B are relatively evenly engaged in the city development collaborative decision making throughout the whole game. Student C has a slow shift from more collaboration behavior to fewer collaboration behaviors at the later part of the gameplay, except for the code *Narration*, which has a shift from the lower amount to the higher amount. How exactly did some students slowly lose engagement in the game or decision-making process, and was it caused by the orientation of the display? This shift will be addressed in later detailed analysis.

Figure 11

Device Related Conversation During the Gameplay (Detailed Analysis Interaction Selection)

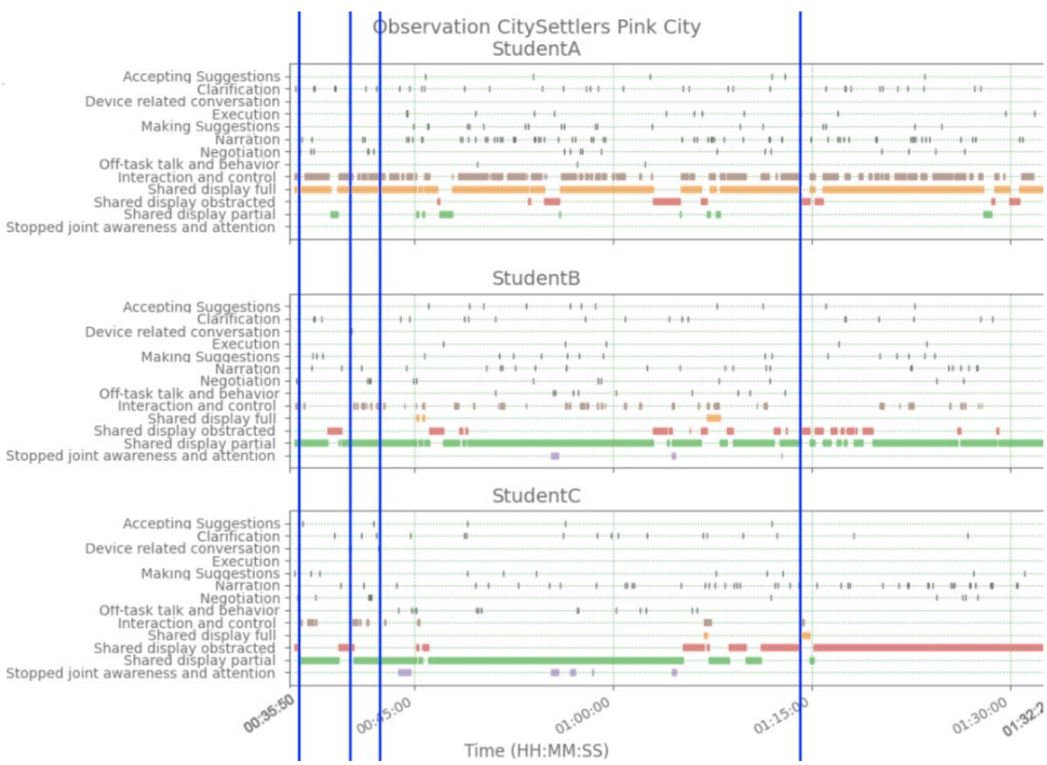
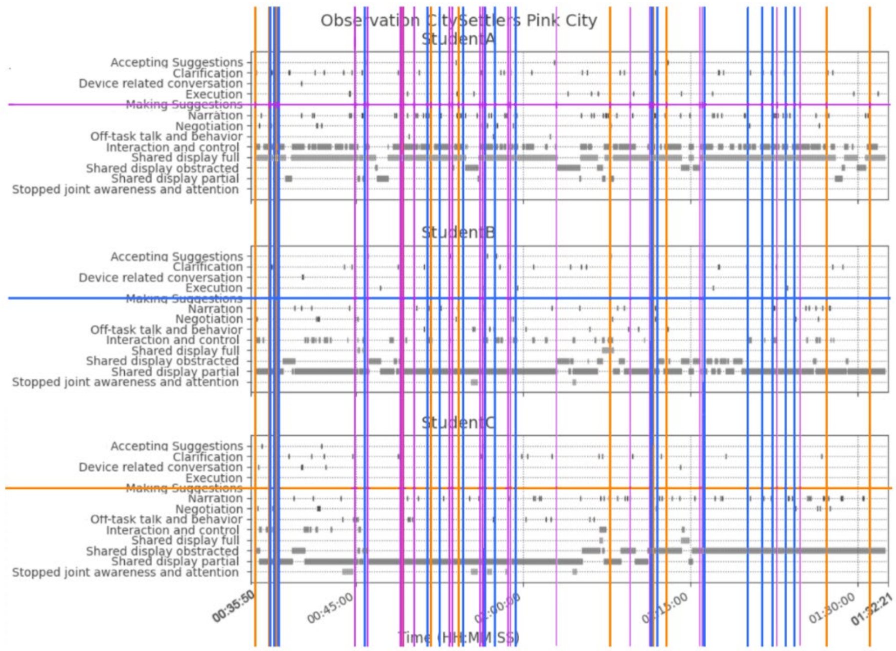


Figure 12

Time Plot of the Pink City Decision Episodes



The sections between each new suggestion (based on the code Making Suggestion's definition: students bring up a new idea), is considered a decision episode. Figure. 12 coded the decision episodes in three colors representing each suggestion made by the student and the episodes that were dominated by this student. Pink represents a Student A suggestion, blue represents Student B's suggestions, orange represents Student C's suggestions.

The suggestions coded in this graph are not necessarily the ideas executed or accepted by all group members. But segmenting the gameplay in this detailed way can help the researcher understand when the students' conversation shifted, which allows the researcher to look in-depth at how the conversation and group decisions change over time in later analysis. The important episodes are selected for further analysis based on the analysis of Figure 11 and the comments during the coding analysis. See Figure 11 for the device-focused conversation during the gameplay.

Detailed Analysis

There are a few sets of episodes of the interaction that are important and worth further exploration. The episode selection is based on where the *Device Related Conversation* happened in the collaborative gameplay (Figure 11). The detailed analysis aims to elaborate on how displays have impacted the collaboration.

Because all the *Device Related Conversation* was initiated by Student C, the case selection is also highly related to Student C's participation and collaboration in the game. Based on the previous analysis, Student C's behavior is not evenly distributed throughout the game and distinctly changed in the middle of the game. The group decision-making process also changed as student C changed her interaction with the other two group members. Thus, the detailed analysis studies how the display facing impacted student C, which also impacted the group's decision-making process.

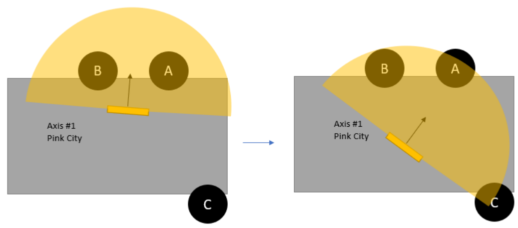
Table 4

Interaction Episode 1

Student	Transcript	Code
C	Everybody want to do a farm and a park, I don't want to do that, I want to do a factory and a park	MS
A	Factory and a park?	C
B	You can do a farm and a park.	N
C	Wait why don't we do a factory?	N
B	audio lost	
C	I can't see anything, can we probably put where it was before?	D
B	We need a park	N
A	Yeah, we need to make a park	AS
A	Our city is depressing.	N
C	Yeah we should do a park.	AS

Figure 13

Display Facing Changed Back to its Original Place



The first interaction, see Table 4, is from 00:35:55-00:36:31. In this interaction episode, Student A grabbed the tablet from its original space to right in front of her for her to interact with it. For Student A, it is coded as *Shared Display Full* for this episode. For Student B it is *Shared Display Partial*, and for Student C, the first half before she had the *Device Related Conversation*, is *Shared Display Obstructed*. Student C grabbed the tablet and put it where it was before, then the display becomes *Shared Display Partial* (see Figure 13 for display facing change). Student A and B were too focused on the content in the interface and the discussion about the decision between themselves and did not pay attention to Student C's *Device Related Conversation*.

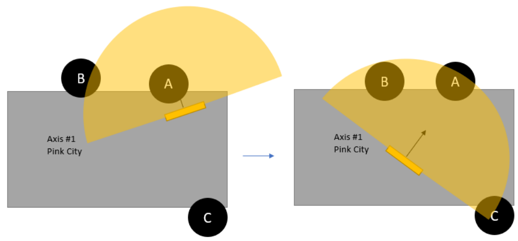
Table 5

Interaction Episode 2

Student	Transcript	Code
C	Can you put it (Shared device) here?	D
B	But we need to type on it.	D
C	I can't see anything	D
C	We can put it here	D
A	Wait what?	D
C	I'll put it here, give it to me, I'll put it here.	D

Figure 14

Display Facing Changed Back to its Original Place



This interaction, see Table 5, is from 00:40:05-00:40:14. This episode of interaction is about where the device display was facing and was the only device related conversation that involved all three students. Student C started this conversation because prior to this interaction, Student A had placed the tablet back to where it was obstructed for Student C in order to interact (see Figure 14 for device facing change during this interaction).

It might be hard to interact with a small screen from a far distance. This might be a negative impact of using the tablet as the shared collaborative display. In the later part of the game, Student A at one point was aware of Student C's need for the tablet to be put at the original place. At around 1:09:58, she looked at Student C and moved the tablet back after interacting with it. But because interactions with the tablet can be hard when it is far away from the student, Student A had to move her whole body and reach far to the screen to interact with it (at its original position which allowed all students can it). This resulted in Student A grabbing the shared display device when she wanted to interact and forgot to put the device back.

Table 6

Interaction Episode 3

Student	Transcript	Code
C	Why can't we bid for something else?	N
B	No, cause the people in our city are sad, we have to have a park.	N

Table 6 (Continued)

A	That's where they living, we got to have a park.	N
C	Well, we need home too.	N
A	We can't play home.	N
C	Don't we want a factory?	N
B	No	N
C	Then how are we gonna feed our people?	N
B	Look, literally right here.	N
C	Yeah I know, but we'll need food as well.	N
A	We'll deal with that later, because it says we're lack of park, so we should deal with that first and then worry about others	N
C	Ok	AS
A	I'm still confused. audio lost.	C
C	Don't worry about it.	C
C	I can see nothing.	D

Figure 15

Interaction 3 Students' Spatial Orientation

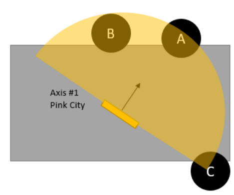
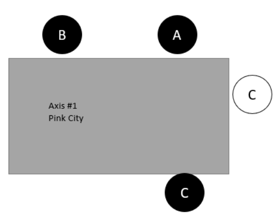


Figure 16

Student C Changed Seating



This interaction episode, see Table 6, is from 00:41:20-00:42:15. During this episode, there is no verbal communication for *Making Suggestion.* But based on later interactions, Student A and Student B decided on the tablet by interacting with the device. Throughout this episode, Student

A remained *Shared display full*, Student B and Student C remained *Shared Display Partial*. Student A and Student B were in *Interaction and Control* the majority of the time, Student C interacted with the display one time when she was negotiating C: "We need home too."

In this decision episode, Student C was still actively engaged in the collaborative decision-making process. It is worth noticing that Student C's seating position is partial, but her position is at the edge of the shared workspace. Even though she can both see and interact with the tablet, she still said "I can see nothing." This indicates that it is hard for her to see and interact with the tablet (see Figure 15 for students seating). This may be the reason Student C changed her seating after a while of this *Device Related Conversation* occurring. Student C changed seating twice in total during the gameplay, see Figure 16. The first time she changed from her original seating to the side of the table next to Student A, after the second occurrence of *Device Related Conversation*. The second time she changed back to where she originally sat, this happened after the third occurrence of the *Device Related Conversation*.

Students sometimes make suggestions but do not narrate their thinking. If all three students share a clear view of the tablet, without verbalizing the suggestion and decision, the group members can still be on the same page (due to a shared visual reference). However, if one student does not have a clear view, this can create a scaffolding problem. In the later part of the game, not knowing the exact city data, Student C was often unsure of the exact decisions happening around their city, Student A and Student B did not narrate out loud every time they had an idea for the city development, because Student A and Student B shared a mutual understanding of the idea when they were looking at the same display content. There are several times, Student C had misconceptions surrounding the group's decision and talked with other groups for trading but for the wrong item, only finding out later their city (i.e., Student A or Student B) had decided to trade for something different. For example, at 1:05:36, 42:57, and another at 43:36, similar situation had happened.

This observation suggests that, for collaboration around tablets, if the student's position is at the edge of the shared workspace, it can still be hard for this student to see and interact with the display content, even though in theory the student can see and interact with the device.

Table 7

Interaction Episode 4

Student	Transcript	Code
C	We have 7 people though	R
C	We have so much pollution.	R
C	Wait, let me see this, no.	D
A	I will get it for trading.	R

This interaction, see Table 7, is from 1:13:16- 1:14:05, where the last *Display Related Conversation* happened. The interaction is unique not only as this is the last time Student C had the *Device Related Conversation*, but also because Student C is at the table by herself during this episode. Student A and Student B both left the table to trade with other cities. Student A brought the shared display tablet with her and left the table. She came back at the end of this episode to change the tablet from the shared tablet to the trading personal tablet.

Student C engaged in *Narration* twice regarding the content she saw on the large classroom display (which has the general city data of each city). Student C was paying more attention to the large classroom display and what was happening in the classroom in the later parts of the game. This allowed her to use the limited information on the classroom display to make sense of what was happening in their city, even though she did not have access to the shared display city data. Because Student C paid more attention to the large classroom display, she understood how pollution works in the game before others, and her attention to other cities ‘activities became useful to the group in the later part of the game.

It is noticeable that, in the later part of the game, Student C is *Narrating* a lot of what she is thinking, regardless of if it is off task talk or information that might not be correct, she also narrating when her group mates are not at the table. The narration happens more when she does not have the access to shared display facing. As a way for coordination during the collaborative process, *Narration* helped her to re-engage in the conversation several times successfully. Especially when she is narrating, sometimes Student A and Student B will respond with *Clarification*. This gave Student C more information about their city’s status. For example, at 1:17:54 and 1:22:11. C: “our happiness is low” N A: “it's been like that for a while.” C. The *Clarification* is not initiated with a question but started with Student C’s narration. Sometimes, off-task talk has a similar effect for Student C. Student A and Student B stopped the gameplay and joined with Student C in her off-task conversation.

Without their group members' help, students are not able to execute trading in their personal tablet as the game originally designed. This is because it takes more effort for the student to understand the group conversation of the collaborative decision, making it hard for them to know what to trade. For example, in Pink City, Student C had very little access to the interaction and control of the city tablet, and thus less access to the shared display city data, and she was not able to fully participate in the decision-making conversation. Also, Student A and Student B were not intentionally letting Student C trade, therefore Student C did not use her personal tablet to trade for the whole game. All trading was completed by Student A and student B.

CHAPTER 5: DISCUSSION

The work above helps us to understand the influence of shared device orientation on students' collaborative decision-making process during group interaction (RQ1). The position of the students seemed to cause some friction in the collaboration process, the size of the tablet and the single-sided screen display made it hard to allow more than two students to interact with the content. This demonstrated that it is hard to maintain a large enough shared workspace to include everyone in the group, which can make some students less engaged in the activity and created friction for the collaborative learning experience. Because interaction with the tablet cannot be done from a long distance, due to its small screen size, the most comfortable way for students to interact with it is to grab the tablet, interact with it, and put it back. It is therefore not surprising that when students got excited about figuring out the system or a made decisions for the city, they tended to forget the main screen was a shared workspace. It seems that the small screen size and mobility of the tablet created friction in the collaboration process, especially for the students who were not located at the center of the workspace. A slight move of the tablet can result in students being obstructed and out of the shared workspace. The distribution of the information can be uneven when this happened.

Another major finding is about visibility and students' collaboration process (RQ2). Sense-making of the system usually happens after or while students looked at the displays that contained the most city information (i.e., either the shared city display or the large classroom display). As such, it is key to have an even amount the information distributed to each student, even if it is not the same content. It is hard for the student who is not able to see the content to process information and sense-making of the system, which also makes it hard for this student to engage and contribute to the decision-making process. Considering the size and mobility of the tablet, the challenge for collaboration with this device is to carefully design which information is displayed at which screen, with the consideration of each screen's accessibility for each student.

To resolve this issue, one option is to pay attention to the physical environment that in which the activity is going to take place. Concerning the starting seating arrangement of the students, it would be better for them to be placed such that they can all reach the tablet easily. It might be better if they are at one side of the table, as tablets only have one side for viewing and interacting. But the limitation of this solution is that the size of the tablet cannot allow too many students to collaborate even though they are all seating at the same side of the tablet.

Another solution is to use Active Learning Classrooms (ALCs) designs which have already been proved of positive impact on students' learning (Chiu & Cheng, 2017). ALCs is a space in which small groups of students work together and interact with the same screen on the wall, see Figure 17 (Texas McCombs, n.d.). This method allows each student to see clearly the information being displayed. However, which student is in control and interacting with the screen using the mouse can still create conflicts, as it can still be hard for all the students in the group to have equal access to the display.

Figure 17

ALCs Space

One other way is to have all the students interacting with the data together using multiple-mice platform. Multiple-mice platforms allows students to simultaneously interact with the content and access the information. This is proven to be effective for students' collaborative learning (Echeverría et al., 2012). However, the productive dynamics around face-to-face interaction and communication might be reduced. With the *City Settlers* project, in later research work, the researchers further explored the possibility of using multi-access point and multi-screen design which allows each student to interact with the city content from their own device, placing all the city information and trading function all the team's tablets to give each student one such device.

The use of augmented reality to display information and students' interaction for shared workspace is considered another possibility. Researchers have suggested that even though augmented reality can be expensive and might not be significantly more effective than multiple mice platforms, it is still worth further exploring, as it can "provide experience that no traditional computer can achieve" (Echeverría et al., 2012, p.1177). AR may also alleviate many of the orientation issues found with tablets and tabletops, as the visual information, controls, and prompts can all easily be oriented to each individual user. AR can also give learners customized views of a simulation or physical space, allowing groups to see space (in this case their city) differently than their peers. This would allow designers to carefully consider what information they wish to make available at different classroom granularities without worrying about "unauthorized" access (e.g., students from one city looking at the screen of another city without permission).

Limitations

This study is limited by the amount of data being analyzed, which was only one group of students. Even though the first round of analysis included three other groups of students, the results cannot be generalized to a larger audience. Because this study only aimed at exploring possibilities in tablet collaboration with a specific game *City Settlers*, different kinds of games or activities might not apply to the findings of this research. It is possible that different game mechanisms will result in different interactions and collaborations.

Future Work

In future research about tablet collaboration, it will be useful to discover how other kinds of collaborative learning activities are performed using the similar device and interface configurations.

In the future design of the *City Settlers*, it is worth trying iterations of the game that are more immersive. Based on previous research about immersive simulations, the immersion aspect has a profound positive effect on student's active engagement in the learning process (Dunleavy et al., 2008). There is room to improve the current version of *City Settlers* in terms of its immersion aspect. Even though during the gameplay, the whole classroom is involved in the game and the physical classroom is set as the gaming environment, the visual effect on a flat screen is not able to give students a strong impression that they are in another world.

Also, the current immersive simulation's limitation is partly because of the limited shared workspace, due to the nature of the traditional design use of the tablet. It is hard for students to gain access and understanding of the content if they are at the edge of the shared workspace. If we were to consider using augmented reality as the interface, even while still using tablets as an interface tool, the shared workspace would be dramatically changed (see Figure 18).

Figure 18

Shared Workspace Changing When Using the Device Differently

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