The Impact of Device Orientation on Small Group Collaboration During Whole Class Game-Based Simulations

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Abstract: This paper evaluated students' collaboration when using a tablet as a shared interface during group decision making in *City Settlers*, an ecological simulation that supports students' learning of interdependent systems including environmental sustainability, civics, economics, and history. While tablets are widely used in today's K-12 classrooms, their impact on collaboration when shared among students has not been thoroughly studied. This work showed how the use of tablets as a shared game interface critically influenced students' collaborative decision-making. By examining one group of players in the game and how they used shared displays, this work highlights the impact of the shared tablet's orientation on students' engagement and collaborative learning processes. Of particular importance is how obstructed access to shared displays can negatively impact students' engagement and discourse over time.

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). Similarly, previous studies have shown that collaborative learning can help students reach better conceptual understanding and skill learning (Antle et al, 2014; Shehab & Mercier, 2010). However, even though collaborative learning is broadly accepted to have positive effects on learning, there is a need within Computer Supported Collaborative Learning (CSCL) to further consider how the design and use of supportive technologies might actually hinder effective student collaboration, particularly around device orientation.

Serious games - instructional content combined with entertaining elements - have been shown to be effective for learning, especially for content understanding and sense making (Hussein et al. 2019). Simulation games, which enable students to interact with complex systems that they cannot change in the real world, can positively impact students' motivation through the desire for achievement, social interactions, and immersion (Chen et al., 2015). Researchers have found that collaborative game-based learning with simulations, or participatory simulations, can effectively promote learning outcomes by allowing learners to co-construct knowledge together (Chen et al., 2015).

However, choosing which devices to use, and the design of the interfaces on these devices, have a big impact on students' behavior, decision making and sense making during gameplay (Nussbaum et al., 2009). Students' interactions are structured by the design of devices and their interfaces, which influence the quality of the communication, and this impact is even larger for shared devices (Liu & Kao, 2007). When multiple students share the same device 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). Scott et al. (2004) 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.

Researchers have also indicated that the physical environment and initial seating area influence how personal territories are established (Scott et al., 2004). For example, Rick et al. (2009) researched an OurSpace application and found that during tabletop collaborative tasks, students take more responsibility for 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 were shown to help with managing information in the multi-device collaborative learning environment. However, much of this shared display work has focused on tabletops, with limited research being conducted on tablets. In a rare example, Fleck et al. (2021) examined how two students collaborated during single-player games on single touch tablets. They observed students tried to dominate the tablet during the collaborative task. This suggests that there is a need to further understand shared workspace in tablet-only or tablet-focused collaborative activities.

Similarly, in collaborative games, a shared device can directly influence information distribution, which can play an important role in group decision-making processes (Gruenfeld, et al., 1996). When the collaboration takes place using a Single Display Groupware, all students can interact with the system independently, with the output of the information shown on the shared device. In these cases, equal access to the shared display is critical to ensure collaboration. If not, interference between participants around the interface can become a problem (Tse et al., 2004). To support students' collaborative decision making in these spaces, a combination of individual and shared tablets is one way to support more equitable interaction between group members. However, the design decisions for the tablet interfaces need to carefully consider what content should be on shared versus personal devices. To this end, when students use a combination of shared and personal tablets, important questions arise as to how students interact across these devices, how they arrange the devices in their "workspaces", and how these orientations impact the quality of groups' sense making and decision making.

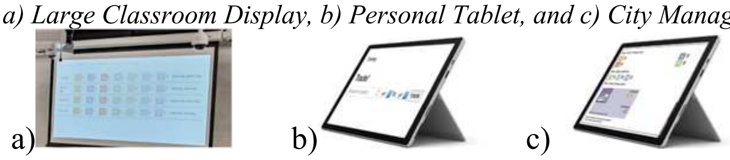
To investigate these issues, we present *City Settlers*, a multi-device collaborative learning game that, unlike collaborative tabletop designs, promotes collaboration across personal and shared devices. This provides students with different kinds of territory distribution compared to tabletop games - as most of the time the shared tablets do not lay flat on the table surface, but must face one direction, meaning students seated in a certain range outside of the tablet may get excluded from the shared workspace. In the context of *City Settlers*, we wanted to understand how the orientation of shared tablet devices might impact collaboration, decision-making processes, and students' engagement in terms of their emergent dialogues about sustainability. To this end, 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 collaboration?

Methods

Gameplay and setting

City Settlers is a collaborative decision-making participatory simulation game aimed at cultivating young students' understanding of sustainability (Kumar et. al*, in press*). The game is played out over multiple rounds (each round approximating roughly a year). 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 strategic decisions around trading resources with other cities. There are three different kind of displays that students interact with in *City Settlers*, each with their own specific function and display design (see Figure 1): a) Large Classroom Display showing the world and a subset of each cities' data that allows players to compare some data across cities; b) Personal Tablets, which mainly enable students to trade resources; c) City Management Tablet, which shows the team their detailed city metrics (e.g., happiness, pollution, etc.), and handles much of the city's management (e.g., bidding for and running buildings). 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 and across these tablets, will give future studies a greater understanding of how to design more effective digital environments to aid in students' learning and collaboration.

Figure 1
a) Large Classroom Display, b) Personal Tablet, and c) City Management Tablet.



Participants

Participants were 11 local upper elementary and middle school students who signed up as part of a summer camp. All participants and their parents consented to the student's participation and for them to be audio and video recorded. For this session, there were four groups of students, three groups had 3 students, one group had 2 students. Each group had a ceiling camera and voice recorder directed at their table to capture their actions and discourse. Because this study is not targeted toward a specific race, sex, or socioeconomic status, these factors are not considered in this paper.

Activity Design

At the beginning of the session, students were introduced to the game and its rules, and placed into random teams. Students were placed in their respective cities across the room in a way that mirrored where their respective cities were positioned in the game environment. During gameplay, the researchers and the summer camp teacher were around to help with the orchestration of each round of the game and assisted students when they had 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.

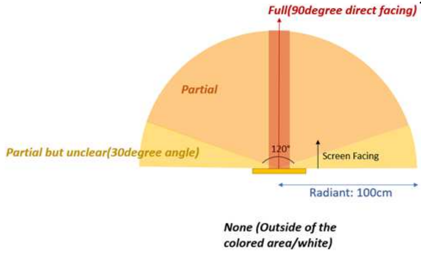
Data Analysis

To find out how students interacted with tablets in the decision-making process, and how this interface affected students' communication, this study analyzed the video captured from a single run of the game. The analysis involved two cycles of analysis. The opening analysis was based on video content logging (Goldman, 2007) to select important episodes of the video to conduct the second cycle of analysis using micro genetic learning analysis (MLA) to help reveal underlying relationship between the devices and the collaborative learning (Parnafes & diSessa, 2013). The first cycle of analysis was fully grounded in the video data 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 groups decisions, who interacted with the shared display, who had the clearest view of the shared display, and the territory of the shared workspace (where and to whom the shared display was facing). The first phase of this analysis revealed the need to understand the relationship between these three factors, and what verbal interactions indicated what happened during the process of engagement.

Table 1
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 indicating she cannot see the shared display screen)
Interaction and Control *(I)*	The students who are interacting or orienting the shared city device.	[Student B clicking on the shared display screen]
Shared Display Facing: Full/Partial/ Obstructed (*F/P/O*) Visual angles and radiant (See Figure 2)	When the screen is facing towards students, it is considered **Full *(F)*** or **Partial (*P*)**, regardless of the students are facing it or not. If the student cannot see the screen at all, it is **Obstructed *(O)***. If the student was more than 40 inches away from the tablet (the maximum visible distance for such devices as described by Ko et. al, [2012]), but they are directly facing the device, this was coded as **Partial**. If the student is beyond the visible distance and the viewing angle is coded as partial, this was coded as **Obstructed**.	

Figure 2
Student Orientation Towards the Tablet for Coding Visible Range.



Based on the initial analysis of multiple rounds and multiple cities, we selected Pink City's gameplay to further analyze the interactions among group members as it was the most representative of the range of players' interactions in the game. Analysis of this data was done by adapting the collaborative device coding schemes by Fleck et al. (CLM - 2009), Tissenbaum et al. (DCLM - 2017), and the problem-solving coding scheme developed by Shehab and Mercier (2020). From Fleck et al. (2009), we used the following codes: Making Suggestions *(MS)*; Accepting Suggestions *(AS)*; Negotiation *(N);* Narration *(R)*. We also adapted the code Joint Awareness and Attention *(J)* by adding the concept of when students *stopped their joint awareness* (e.g., when students start to work on their own, and stop paying attention to other members). From Tissenbaum et al. (2017), we added the code: Clarification *(C):* for conversations that clarify an unclear element in the simulation for students. Drawing from Mercier & Shehab (2020), we adapted and added Off-task talk and behavior *(T)*: verbalizations and behaviors that do not relate to the game content, or the game display and environment. Through our initial rounds of watching the videos we added the code Execution *(E):* where students executed the decision (e.g., bidding on buildings, trading with another city). For this analysis, we ignored interactions with instructors and other groups and only considered within group interactions.

While students' interactions in *City Settlers* take place with tablets instead of tabletops (in contrast to Fleck et al. 2009 and Tissenbaum et al. 2017), these frameworks are still applicable in revealing how students interacted with, and ultimately collaborated around, shared surfaces. On tablets, territories have clearer boundaries than on tabletops, as the tablet does not lay flat on the table surface but faces a single direction. This means students seated at some angles/distances from the tablet will be excluded from the shared workspace. For this reason, defining the shared workspace based on the tablet's orientation is critical. Based on visible barriers (Scott, 2004), Figure 2 shows the defined workspace area. The visibility angles were based on Microsoft's own viewing angle specifications for the Surface Pro tablets (Surface Pro, n.d.). For this reason, using a grounded approach, we also developed a coding scheme that focused on the students' orientation around the tablet (See Table 1). 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.

Findings

Collaboration and coordination

Figure 3
Time plot of Pink City's Student A, Student B and Student C collaborations

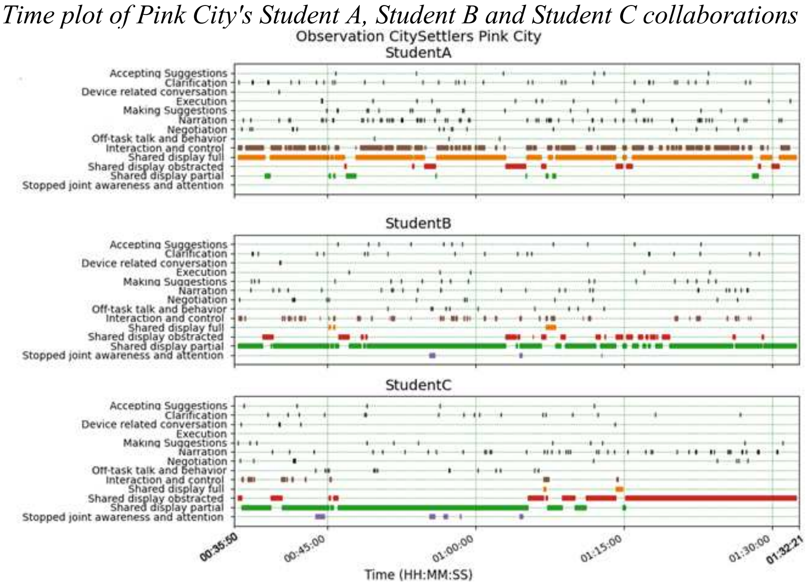


Figure 3 shows a temporal coding of students in Pink City's conversations and behaviors. Student A had the most occurrences of *Making Suggestion* with 19, Student B had 18, and Student C had the least with 11. Similarly, for *Clarification*, Student A with 35 has the most occurrences, Student B has 19, and Student C had the least at 17. 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 had less with 7, and Student C had the least with only 5. It is worth noting that for *Narration*, even though Student A has the most *Narration* (68), Student C had more occurrences (48), than Student B (26), most of Student C's narration happened in the second half of the gameplay. For all three students, *Narration* has the greatest number of occurrences compared to other collaboration and coordination events.

Student A has a total of 159 behavior events 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, Student A 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 Awareness* and *Off-task Talk and Behavior*. Compared 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 and device interaction

A total of 4356 seconds were observed. Student A had the most *Interaction and Control* with the tablet with 1731 seconds (s). They also had the most instances of *Interaction and Control* (75 times). Student B had less (268s, 48 times), and Student C had the least (121s, 11 times). Student A also had the longest duration of *Shared Display Full* (2832s. Student B and Student C both had limited *Shared Display Full*, with Student B having slightly more than Student C. Student C had the lowest duration for *Shared Display Full* (58s). In terms of *Shared Display Partial*, Student B had the longest duration (2770s), as well as the most occurrences at 24 times. Student C had the longest duration of *Shared Display Obstructed* (1519s). It is worth noticing that the *Interaction and Control* and *Shared display full* were evenly distributed throughout the gameplay for Student A. *Shared Display Partial* was distributed relatively evenly for Student B. For Student C, *Shared display facing* was 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 could partially see the display and had less access to the city data. It is also worth noticing that Student C's *Interaction and Control* was less in duration for the second half of the game than the first half of the game. Student C also had the most *Device Related Conversation*.

From Figure 3, Student A and Student B were relatively evenly engaged in the city development collaborative decision making throughout the whole game. In contrast, Student C had a slow shift from more collaborative behavior to fewer collaborative behaviors, with the exception of *Narration*, in which they moved from the less instance to more frequent instances. We were curious what caused some students (like Student C) to slowly decrease their engagement in the game and the decision-making processes, and the potential role the orientation of the display played in this. Below, we unpack the possible causation for this in more detail.

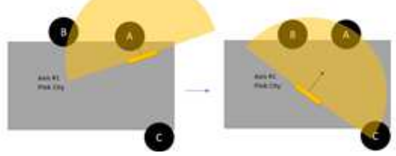
Episodic Analysis of Device Orientation and Collaboration

To understand these changes, we examined student discourse around new ideas being brought up by the group (indicated by the *Making Suggestion* code). Below, we highlight the role the shared device played in these collaborative conversations, through two specific Interactions. This focused discourse analysis aims to elaborate on how displays impacted the collaboration.

Table 2
Interaction 1 Conversation

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 4
Interaction 1 Display Facing Changing



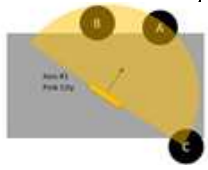
Interaction 1 begins about 5 minutes into the game and concerns where the device display was facing. This was the only device related conversation that involved all three students. Student C started this conversation because prior to this interaction, Student A had placed the tablet such that it was obstructed for Student C (see Figure 4 for changes in where the device was facing across this interaction). After their conversation the tablet was reoriented so that everyone could see it. However, from our understanding of the focal length of display distances (Figure 2) it is difficult to interact with a small screen from a distance, Student A had to move her whole body and reach the screen to interact with it. This resulted in Student A eventually grabbing the shared display device when she wanted to interact with it and did not put the device back, once again isolating Student C from seeing the screen and collaboration.

Interaction 2 begins almost immediately after Interaction 1. During this interaction, there was no verbal communication for *Making Suggestion.* But based on later interactions, it was clear that Student A and Student B made a decision on the tablet by interacting with the device. Throughout this interaction, 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* most of the time, Student C interacted with the display one time when she was negotiating stating “We need home too”. It was worth noting that, at first, even when Student C was at *Shared display partial*, she was 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, given her positioning, it was difficult for her to see and interact with the tablet (see Figure 5 for students seating). For collaboration around tablets, if the student’s position is at the edge of the shared workspace, it can challenge for the student to see and interact with the display content, even though in theory the student should be able to see and interact with the device. While outside of this interaction, about 5 minutes later, Student C changed their position at the table to be more centrally located in front of the device.

Table 3
Interaction 2 Conversation

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*
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 [*inaudible*]	*C*
C	Don't worry about it.	*C*
C	I can see nothing.	*D*

Figure 5
Interaction 2 Display Facing



Additional Impacts of Device Orientation on Collaboration

It is also notable that, later in the game, Student C was *Narrating* a lot of what she was thinking, regardless of whether it was off task talk or incorrect information. She was also narrating when her group members were not at the table. The narration happened more when she did not have access to the shared display. As a way of coordination during the collaborative process, *Narration* helped her to re-engage in the conversation several times successfully. When she was narrating, sometimes Student A and Student B responded with *Clarification*. This gave Student C more information about their city’s status. For example, at 42 minutes the following exchange occurred: C: “our happiness is low” *(N)* A: “it's been like that for a while” (*C*). Student A’s *Clarification* started with Student C’s *Narration*.

We noted in later interactions that students sometimes made suggestions but did not narrate their thinking. If all three students had a clear view of the display, without verbalizing the suggestion and decision, the group members were still on the same page (due to a shared visual reference). However, if one student did not have a clear view, this created 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 ideas based on their shared view. Several times, Student C had misconceptions surrounding the group's decisions 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. Similarly, we noticed that when not being able to fully engage with the city data resources decisions or their group members, students were less likely to execute trading on their personal tablet. This points to the fact that it took more effort for the student to understand the group's rationale for the collaborative decision, making it hard for them to follow what their next step should be or what to trade to achieve it.

Discussion & Conclusion

This work helps us understand the influence of shared device orientation on students' collaborative decision-making process during group interaction (RQ1). The position of the students in relation to the tablet clearly impacted the collaboration process. The size of the tablet and the single-sided screen display made it hard to allow multiple students to interact with the content, especially when students were not on the same side of the table. As such, it was hard to maintain a large enough shared workspace to include everyone in the group, which made some students less engaged in the activity and created friction in the collaborative learning process. Because students could not interact with the tablet at a distance, due to its small screen size, they often interacted with it by grabbing the tablet, interacting with it, and putting it back. It is therefore not surprising that when students got excited about figuring out the system or making decisions for the city, they tended to forget the space in front of the main screen was a shared workspace. It seems that the small screen size and mobility of the tablet inhibited the collaboration process, especially for the students who were not located at the center of the workspace. Even a slight move of the tablet can result in students being obstructed and out of the shared workspace, and as a result, access to information can end up being inequitable.

Another major finding concerned visibility and students' collaboration process (RQ2). Sense-making of the system usually happened while, or after, 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 equitable amount of the information distributed to each student, even if it is not the same content. It is hard for students who are not able to see specific content to process information and make sense of the system, making it difficult for them to engage and contribute to the decision-making process. Considering the size and mobility of the tablet, supporting effective collaboration with it requires us to carefully consider which information is displayed on which screen, and to consider their accessibility for each student. To resolve this issue, one option is to pay attention to the physical environment in which the activity takes place. For instance, it might be better for students to be situated so they can all reach the tablet easily (e.g., on the same side of the table, or lay the tablet flat). However, the limitation of this solution is that the size of the tablet cannot enable multiple students to collaborate even though they are all seated close together. Another solution might be to design these spaces similar to other Active Learning Classrooms (ALCs) designs, in which small groups of students work together and interact with a large, shared screen, and have already been shown to have a positive impact on students' learning (Chiu & Cheng, 2016). This method may allow each student to clearly see the information being displayed and could be coupled with approaches that allow students to all control the screen simultaneously. Future iterations of *City Settlers* project aim to investigate the potential of using multi-access point and multi-screen designs which allows each student to interact with the city content from their own device.

The use of mixed reality (MR) or augmented reality (AR) in *City Settlers* to display information and support students' interactions is another possibility. MR or AR may alleviate many of the orientation issues found in this study, as the visual information, controls, and prompts can all easily be oriented to each individual user. MR and AR can also give learners customized views of a simulation or physical space, allowing groups to see information (in this case their city) differently than their peers. This would allow designers to consider what information they wish to make available at different classroom granularities without worrying about students from one city looking at the screen of another city without permission. AR and MR could also more deeply immerse students in the simulation, which could also provide new opportunities for collaboration.

A limitation of this study is that it only focuses on one group of students. Even though the first round of analysis included three other groups of students, the results may not be generalizable 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.

References

Author(s)

Antle, A. N., Wise, A. F., Hall, A., Nowroozi, S., Tan, P., Warren, J., Eckersley, R., & Fan, M. (2013, June). Youtopia: a collaborative, tangible, multi-touch, sustainability learning activity. *Proceedings of the 12th International Conference on Interaction Design and Children*, 565–568.

Chen, C. H., Wang, K. C., & Lin, Y. H. (2015). The comparison of solitary and collaborative modes of game-based learning on students' science learning and motivation. *Journal of Educational Technology & Society*, *18*(2), 237-248.

Chiu, P. H. P., & Cheng, S. H. (2017). Effects of active learning classrooms on student learning: a two-year empirical investigation on student perceptions and academic performance. *Higher Education Research & Development*, *36*(2), 269-279.

Fleck, R., Rogers, Y., Yuill, N., Marshall, P., Carr, A., Rick, J., & Bonnett, V. (2009, November). Actions speak loudly with words: Unpacking collaboration around the table. *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces - ITS '09*, 189–196.

Fleck, R., Vasalou, A., & Stasinou, K. (2021). Tablet for two: How do children collaborate around single player tablet games?. *International Journal of Human-Computer Studies*, *145*, 102539.

Gruenfeld, D. H., Mannix, E. A., Williams, K. Y., & Neale, M. A. (1996). Group composition and decision making: How member familiarity and information distribution affect process and performance. *Organizational behavior and human decision processes*, *67*(1), 1-15.

Goldman, R. (2007). Video representations and the perspectivity framework. In *Video research in the learning sciences* (1st ed., pp. 3–38). Routledge.

Hussein, M. H., Ow, S. H., Cheong, L. S., Thong, M. K., & Ale Ebrahim, N. (2019). Effects of Digital Game-Based Learning on Elementary Science Learning: A Systematic Review. *IEEE Access*, 62465–62478.

Ko, P., Mohapatra, A., Bailey, I., Sheedy, J., & Rempel, D. (2012, September). Effects of font size and reflective glare on Text-Based task performance and postural change behavior of presbyopic and nonpresbyopic computer users. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2378–2382.

Kumar, V., Tissenbaum, M. B., & Kim, T. (2021). Procedural Collaboration in Educational Games: Supporting Complex System Understandings in Immersive Whole Class Simulations. *Communication Studies*, 1-23.

Liu, C. C., & Kao, L. C. (2007). Do handheld devices facilitate face-to-face collaboration? Handheld devices with large shared display groupware to facilitate group interactions. *Journal of Computer Assisted Learning*, *23*(4), 285-299.

Marty, J. C., Serna, A., Carron, T., Pernelle, P., & Wayntal, D. (2016). Multi-device Territoriality to Support Collaborative Activities. *Adaptive and Adaptable Learning*, 152–164.

Microsoft surface pro 4 display technology Shoot-Out. (n.d.). Microsoft Surface Pro 4 Display Technology Shoot-Out. Retrieved July 18, 2021, from https://www.displaymate.com/Surface_Pro4_ShootOut_1.htm

Nussbaum, M., Alvarez, C., McFarlane, A., Gomez, F., Claro, S., & Radovic, D. (2009). Technology as small group face-to-face Collaborative Scaffolding. *Computers & Education*, *52*(1), 147-153.

Rick, J., Harris, A., Marshall, P., Fleck, R., Yuill, N., & Rogers, Y. (2009, June). Children designing together on a multi-touch tabletop: An analysis of spatial orientation and user interactions. *Proceedings of the 8th International Conference on Interaction Design and Children - IDC '09*, 106–114.

Scott, S. D., Sheelagh, M., Carpendale, T., & Inkpen, K. M. (2004, November). Territoriality in collaborative tabletop workspaces. *2004 ACM Conference on Computer Supported Cooperative Work - CSCW '04*, 294–303.

Shehab, S. & Mercier, E. (2020). Exploring the Relationship Between the Types of Interactions and Progress on a Task during Collaborative Problem Solving. In Gresalfi, M. and Horn, I. S. (Eds.), The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS) 2020, Volume 3 (pp. 1285-1292). Nashville, Tennessee: International Society of the Learning Sciences.

Tissenbaum, M., Berland, M., & Lyons, L. (2017). DCLM framework: understanding collaboration in open-ended tabletop learning environments. International Journal of Computer-Supported Collaborative Learning, 12(1), 35-64.

Tse, E., Histon, J., Scott, S. D., & Greenberg, S. (2004, November). Avoiding interference: How people use spatial separation and partitioning in SDG workspaces. *The 2004 ACM Conference on Computer Supported Cooperative Work - CSCW '04*, 252–261.