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Playing in the Virtual Sandbox:
Students' Collaborative Practices in Minecraft

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ABSTRACT

Researchers, teachers, and the news media have touted Minecraft as an effective, engaging way to promote students' 21st century skills, including collaboration. However, little is known about what collaboration looks like in Minecraft, including what factors support and undermine high quality collaboration. The current exploratory study investigated this question through an analysis of middle school students' collaborative processes while playing Minecraft in small groups of 2-4 players. Analyses of the discourse functions used by players during gameplay revealed a number of factors affecting the success of their collaboration, such as prior social ties, gaming experience, and responsiveness to other players. The findings contribute new insight into the nature of more and less effective collaborations in multiplayer video games. These insights will be useful to educators who are interested in using Minecraft and other multiplayer games to promote collaboration among their students.

KEYWORDS

Collaboration, Game-Based Learning, Joint Attention, Middle School, Minecraft, Multiplayer Games

INTRODUCTION

Minecraft is one of the most popular video games ever, having sold over 100 million copies since its release in 2009 (Huddleston, 2016). This sandbox game, in which players explore, build, and find ways to survive in virtual landscapes, is particularly popular among young people (Thompson, 2016). Educators are taking note, and many are exploring ways to incorporate Minecraft into their teaching (Timoner, 2014). In the classroom, Minecraft is being used to teach subjects and skills such as physics, math, computational thinking, creativity, art, history, digital citizenship, and collaboration (e.g., Cipollone, Schifter, & Moffat, 2014; Craft, 2016; Hill, 2015; Overby & Jones, 2015; Short, 2012). There is even a *Minecraft: Education Edition* that is geared toward helping teachers use Minecraft with their students. Outside the classroom, Minecraft camps and workshops have become popular in informal learning environments such as libraries (e.g., Cilauro, 2015; Gauquier & Schneider, 2013). Educators' interest in Minecraft is part of a broader trend in game-based learning (Gee, 2007, 2008; Plass, Homer, & Kinzer, 2015; Squire, 2006, 2008). These efforts are based on a constructivist approach

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to education in which learners actively construct knowledge by engaging in open-ended activities that involve problem solving, decision-making, and following one's interests (Plass et al., 2015).

Despite the widespread enthusiasm for using Minecraft to support learning, there is scant research investigating its effectiveness. We lack empirical evidence documenting the learning benefits, if any, associated with using Minecraft to teach specific skills, as well as the conditions under which such benefits arise. Until such evidence is available, efforts to incorporate Minecraft and other multiplayer games into teaching and learning will be based on hunches and best guesses instead of empirically supported best practices.

The current study seeks to address this gap in knowledge through an exploratory investigation of middle school students' collaborative interactions while playing Minecraft in small groups of 2-4 players. We chose to focus on collaboration due to its centrality in learning (Johnson & Johnson, 1989; Rogoff, 1998; Roschelle, 1992), and because multiplayer games are particularly suited to collaboration (Gee, 2007, 2008; Plass et al., 2015; Squire, 2006, 2008; Steinkuehler, 2004). Although we acknowledge that collaboration is typically used in conjunction with other pedagogical aims, this study intentionally isolates collaboration as a focus of investigation. Prior research shows that students often struggle to collaborate effectively with each other, with negative consequences for the learning outcomes associated with their collaborative tasks (e.g., Barron, 2003). Thus, collaboration is itself a skill that students must develop in order to experience the benefits of collaborative learning, and therefore warrants specific investigation.

We focused our analysis on the types of discourse functions that participants employed while playing the game, such as Questioning, Responding, Instructing, and Encouraging (Bluemink, Hamalainen, Manninen, & Jarvela, 2010). The findings provide new insight into factors that support and undermine high quality collaboration in Minecraft. These insights will be useful to educators who are interested in using Minecraft and other multiplayer games to promote collaboration among their students.

LITERATURE REVIEW

Collaboration's Role in Cognition and Learning

We define collaboration as a process involving two or more people coming together to share their focus of attention and achieve a shared understanding of the problem and its solution (Dillenbourg, 1999; Rogoff, 1998; Roschelle & Teasley, 1995). Existing research demonstrates the learning benefits associated with working collaboratively to solve a problem (e.g., Barron, 2003; Johnson & Johnson, 1989; Rogoff, 1998; Roschelle, 1992). Johnson and Johnson (1989) found in their meta-analysis that working collaboratively led to an increased frequency of idea generation and promoted higher quality cognitive reasoning and metacognitive strategies compared to individual learning. For instance, Okada and Simon (1997) found that pairs of students were more successful in tasks involving discovering scientific laws than students working individually. Compared to students working alone, those working in pairs were more likely to engage in activities such as entertaining hypotheses and considering alternative ideas.

Not all instances of collaboration are equally effective (Barron, 2003; Matusov, Bell, & Rogoff, 2002; Rogat & Linnenbrink-Garcia, 2011; Rogoff, 1998 Sfard & Kieran, 2001). In her investigation of sixth-grade students collaborating on a problem-solving task, Barron (2003) found considerable variation in performance across groups despite the fact that all students came into the task as similarly high-achieving math students. Her analysis of the microinteractional processes that took place within the groups uncovered patterns of interaction that separated the more successful groups from the less successful groups. In particular, successful groups demonstrated effective strategies for recruiting and maintaining joint attention among members of the group. They were more likely to respond to each other's suggestions, engage in nonverbal synchronized movements, and maintain a respectful

conversational tone. In contrast, the less successful groups were more likely to ignore or interrupt each other, demonstrating resistance to negotiating a shared space. Barron's (2003) work highlights the importance of joint attention to the success of collaborative groups. Indeed, developing an "intersubjective attitude" (Crook, 1994) has more bearing on a group's success than the individual characteristics (e.g., age, skill level) that each member brings to the collaborative activity. In the current study, we define joint attention as a form of coordination among group members in which attention is jointly focused on a task and its solution (Barron, 2000). Jointly focused attention does not require group members to be looking at the same object, but rather working toward the same goal.

Establishing joint attention can be challenging for elementary and secondary school students (Rogoff, 1998; Socha & Socha, 1994). Play represents an important context for children to develop and practice their collaborative skills (Piaget, 1959, 1977; Rogoff, 1998). In play, children learn to clarify meaning, negotiate conflict, explain, persuade, and coordinate ideas. They also learn to engage in social regulation, a key aspect of successful collaboration (Jarvela & Hadwin, 2013; Rogat & Linnenbrink-Garcia, 2011; Wertsch, 1985). The similarity of status among peers enables these interactional processes to result in shared thinking and, ultimately, a change in individuals' perspectives (Piaget, 1959, 1977).

Video Games as Contexts for Collaboration

Games have emerged as a fruitful context for studying informal collaborative processes (Gee, 2007, 2008; Plass et al., 2015; Squire, 2006, 2008; Steinkuehler, 2004). This work recognizes the opportunities that games provide for social interaction in the pursuit of a shared goal (Plass et al., 2015; Squire, 2006). Like other contexts of play, video games encourage players to negotiate conflict, explain and persuade, and coordinate ideas with other players. These collaborative processes occur within the context of a community of practice where experts support novices (Lave and Wenger, 1991), and all participants gather around a common interest (Gee, 2007).

Multiplayer video games are particularly suited to fostering collaboration among players (Chen, 2008; Dieterle & Clarke, 2006; Plass et al., 2015; Steinkuehler, 2004). They typically feature game mechanics that require coordinated action (e.g., quests) in order to meet specific goals within the game. In addition, the user-generated content that typically emerges around these games, such as cheat sheets, online discussion forums, and footage of players' gameplay, further supports collaborative activities among players (Plass et al., 2015). In her cognitive ethnography of the MMOG *Lineage*, Steinkuehler (2004) described how novice players learned the game's discourses through apprenticeship in a community of practice. This apprenticeship involved genuine gameplay alongside more experienced players. In this way, Steinkuehler demonstrated how learning in the game occurred in the context of social practice and coordinated action.

In a more structured investigation of collaboration in multiplayer games, Bluemink and colleagues (2010) conducted a design experiment in which small groups of university students played a social action adventure game. The researchers analyzed players' conversations during gameplay in order to gain insight into the nature of their collaborative processes. Their analysis showed that the most frequently used discourse functions were Question, Content Statement, Instruction or Order, and Response. They also found that players' prior gaming experience and prior social ties affected the nature of their social interaction and the outcome of their collaboration. In another study with younger children (ages 6-10), Ballagas and colleagues (2013) showed how in-room collaboration between siblings was promoted by a multiplayer game that used augmented reality on mobile phones. The findings from these studies point to the promise of using multiplayer games to facilitate collaborative activity among students.

Minecraft is a specific type of multiplayer game that holds potential for promoting collaboration among students (Wernholm & Vigmo, 2015). The virtual landscape of Minecraft is composed of blocks that resemble Lego bricks. Players manipulate these blocks as they explore, build, fight monsters, and collect resources to survive in the world. The game can be played individually or,

more popularly, with other people through public or private servers. In addition to the coordinated activity that occurs within the game world, players contribute and interact with user-generated content outside the game, such as modifications (mods) that extend gameplay, custom maps, tutorials, and videos of people playing Minecraft. In this way, Minecraft presents many opportunities for players to collaborate with one another.

There is considerable enthusiasm among educators for exploring ways to incorporate Minecraft into the classroom to augment teaching in a variety of subjects, such as science and math (Short, 2012), literature (Cipollone et al., 2014), art (Overby & Jones, 2015), and history and foreign languages (Craft, 2016). However, because the game is still fairly new, published research on the learning potentials of Minecraft remains scarce. To our knowledge, there are no published studies explicitly focused on documenting and analyzing children's collaborative processes in Minecraft, though a few studies do address social and collaborative practices more broadly (e.g., Dezuanni, O'Mara, & Beavis, 2015; French, Stone, Nysetvold, Hepworth, & Edward, 2016; Niemeyer & Gerber, 2015; Wernholm & Vigmo, 2015). In their investigation of 8- and 9-year-old girls' use of Minecraft, for instance, Dezuanni and colleagues (2015) characterized Minecraft as an affinity space that supports social processes of play, learning, and identity construction. In another study, Niemeyer and Gerber (2015) examined Minecraft players who created virtual world walkthroughs and commentaries and posted them on YouTube. They described how this online environment became a "collaborative learning community" in which the video creator and viewers engaged in rich conversation about the content of the video.

The Current Study

To explore the potential of using Minecraft to support students' collaborative processes, we invited three groups of 2-4 middle school students (8 boys, 2 girls, mean age = 12 years) to build a summer camp together in Minecraft for approximately one hour in a game-testing lab set up as a living room. Following Roschelle (1992), we examined collaboration from the point of view of the conversational interactions among study participants. Prior research involving Minecraft demonstrated the importance of analyzing children's language in order to achieve a deep understanding of their collaborative processes during gameplay (Wernholm & Vigmo, 2015). To that end, we focused our analysis on the types of discourse functions that participants employed while playing the game, such as Questioning, Responding, Instructing, and Encouraging (Bluemink et al., 2010).

The current study contributes new insight into children's collaborative processes in Minecraft by exploring the following research questions:

Research Question #1: What discourse functions did middle school students employ while playing Minecraft in small groups of 2-4 players?

Research Question #2: Which patterns of discourse functions were associated with more and less successful collaborations?

METHOD

Participants

As an exploratory study aimed at uncovering initial themes, our sample was deliberately small. Participants were 10 middle school students (8 boys, 2 girls) aged 11-13 years (M = 12 years) attending the same school in a suburban area located in the Northwest United States. They were put into three separate groups according to their scheduling availability. Table 1 summarizes the individual characteristics of each participant, their experience with Minecraft, and prior relationships to each other. We have used pseudonyms to protect participants' privacy.

Group 1 included three 12-year-old boys and one 12-year-old girl, all in 6th grade. Neil and Derek had been friends since pre-school and were both experienced Minecraft players who were comfortable

Table 1. Profiles of study participants, including their Minecraft experience and prior relationship to each other

Pseudonym	Group	Gender	Grade	Age	Minecraft experience	Prior relationship to each other	Other notes
Neil	1	Male	6	12	Experienced player; familiar w/ Xbox	Friends w/ Derek since pre-school	
Derek	1	Male	6	12	Experienced player; familiar w/ Xbox	Friends w/ Neil since pre-school	
Rachael	1	Female	6	12	Some experience but never on Xbox	Didn't know anyone in her group	
Peter	1	Male	6	12	Experienced player; never played on Xbox	Knew who Neil and Derek were, but not friends with them	High functioning autism
Frederick	2	Male	6	12	Experienced player; plays mostly on PC	Knew Edward and Ken	
Denise	2	Female	7	13	Experienced player; familiar w/ Xbox	Didn't know anyone in her group	
Edward	2	Male	6	11	Experienced player; plays mostly on computer or iPad	Good friends w/ Ken	
Ken	2	Male	6	12	Experienced player; familiar w/ Xbox	Good friends w/ Edward	Arrived ~20 minutes late
Noah	3	Male	7	13	Experienced player; familiar w/ Xbox	Good friends w/ Aaron	
Aaron	3	Male	7	13	Experienced player; familiar w/ Xbox	Good friends w/ Noah	

playing the game on Xbox. Rachael was the least experienced Minecraft player in the entire sample. She had played the game a few times, but never on Xbox. In addition, she did not know anyone in her group. Peter was an experienced Minecraft player, but had never played on Xbox. He knew who Neil and Derek were, but he was not friends with them at school. In addition, Peter's mother informed the researchers that he had high functioning autism.

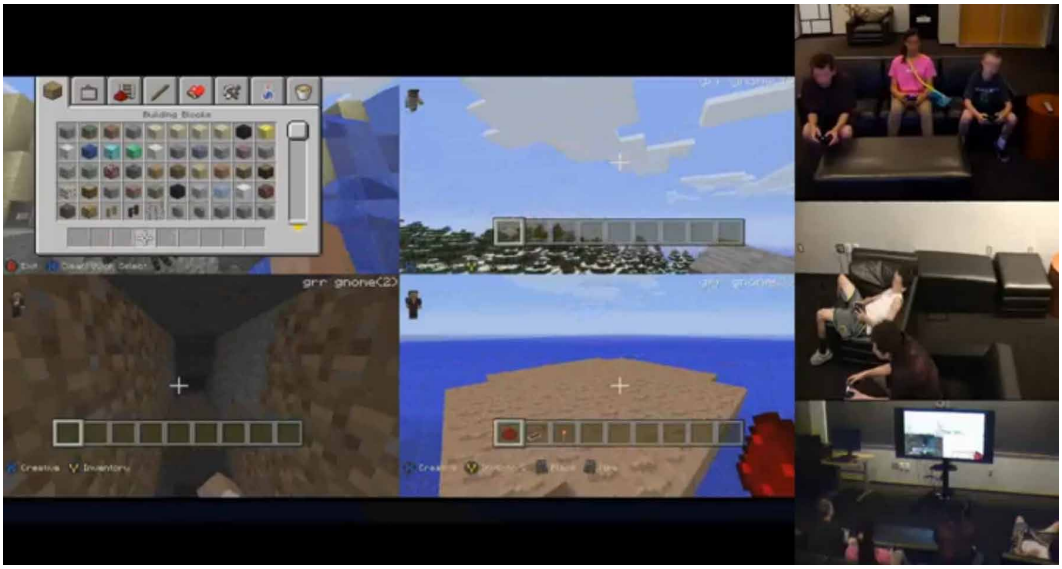
Group 2 included two 12-year-old boys in 6th grade, one 11-year-old boy in 6th grade, and one 13-year-old girl in 7th grade. All four participants were experienced Minecraft players, though Frederick and Edward did not usually play the game on Xbox. Edward and Ken were good friends and knew Frederick. Denise did not know anyone in her group. She was the most skilled player in Group 2. Frederick was late to the study, joining approximately 20 minutes into the session.

Group 3 included two 13-year-old boys in the 7th grade. They were good friends and both were experienced Minecraft players who were comfortable playing the game on Xbox.

Procedure

Participants were invited to a game-testing lab to play Minecraft in a small group for approximately one hour. The room was set up as a living room with a comfortable couch and chair (Figure 1). Participants entered the lab with an adult guardian and were invited to choose a seat and game controller. A researcher explained that the purpose of the study was to understand how middle school students play Minecraft in small groups. She explained that participants would be observed behind a one-way mirror and their gameplay would be video recorded. She also explained that their identities would be kept confidential and they were free to stop playing and leave the study at any time. Consent

Figure 1. Screenshot of Group 1 during gameplay



was obtained from participants' adult guardians, and participants were asked to describe their prior Minecraft experience (see Table 1).

The researcher invited participants to work together to create a summer camp in Minecraft. A brief discussion followed to ensure that all participants knew what a summer camp was. They were told that they would be playing in creative mode (as opposed to survival mode), which meant they would not have to worry about dying or obtaining resources. Group 1 played in a biomes world that contained a swamp and forest landscape. Group 2 and Group 3 played in a superflat world. All three groups played on Xbox (due to the availability of equipment in the game-testing lab), which posed challenges for the four students (Rachael, Peter, Frederick, and Edward) who primarily played Minecraft on a computer or iPad at home. The researchers observed the groups behind the one-way mirror and took detailed field notes during each session.

At the end of the study, the researcher returned to the room and asked participants to describe what they created and how they experienced the session. They were given $10 in appreciation of their time and escorted out of the room to join their guardians.

Data Analysis

Written transcripts of the video data were produced and used to code participants' utterances. We adapted the coding scheme that Bluemink et al. (2010) created for their investigation of small-group collaboration in a virtual multiplayer game. The researchers developed this coding scheme based on their review of prior work on the role of conversational interaction patterns in establishing joint attention and constructing a shared meaning of a task (Barron, 2000; Dillenbourg, 1999, 2006). These interaction patterns are composed of individual utterances, or discourse functions. A term from the field of linguistics, a discourse function represents the specific role played by an individual contribution in oral conversation (Greenbaum & Quirk, 1990). Examples of discourse functions include Questions, Responses, Content Statements, and Instructions.

Although the study conducted by Bluemink et al. (2010) involved university students playing a game other than Minecraft, the study conditions were similar to the extent that players spoke to each other in the same room as they manipulated their avatars in the game world. Further, both studies involved approximately 60 minutes of goal-oriented gameplay that involved some measure of player

collaboration. Therefore, the types of utterance, or discourse function, produced in each study were similar, even if their specific content was different. Nevertheless, we were mindful that the nature of university and middle school students' utterances could differ in some respects. Consequently, we began our analysis by reviewing one of the transcripts to ascertain whether any of the utterances could not be captured by the codes used by Bluemink et al. (2010). This review did not result in the identification of any new codes, though our subsequent analysis of the remaining transcripts did produce a new code, as detailed below. Table 2 includes the complete list of codes used in the current study, including definitions and examples from the transcripts. Each example represents a single utterance, or one line of transcribed conversation (Chi, 1997).

Our small sample size allowed us to provide an in-depth thematic analysis (Boyatzis, 1998) of all utterances in the written transcripts. Two researchers served as the primary coders, with a third researcher participating in consensus building conversations (Smagorinsky, 2008). The process of establishing inter rater reliability (IRR) began with the two primary coders applying the coding scheme separately to the first five minutes of a single transcript. They discussed areas of agreement and disagreement with the third researcher and came to consensus on the applicable codes. This process was repeated a second time in order for all researchers to become familiar with the coding scheme in the context of the current study. Consistent with Bluemink et al. (2010), only one code was applied to a single utterance. The purpose for this decision was to maintain analytic clarity by focusing on the primary function of an utterance in the context of the conversation.

Following this preliminary consensus building work, the two primary coders engaged in four rounds of coding until they reached satisfactory IRR levels. For each round, the two coders independently coded a 10-minute segment of one transcript, calculated IRR statistics, and then met with the third researcher to discuss areas of disagreement until consensus was achieved. By the fourth round of coding, kappa statistics were strong, ranging from 0.73-1.00 (Landis & Koch, 1977) (see Appendix).

The two primary coders divided the remaining transcripts and coded all utterances. Throughout the coding process, the researchers referred repeatedly to the original video data in order to understand the original context in which an utterance was made. This triangulation further ensured that utterances were coded accurately.

During the process of establishing IRR, we noted that the code Encouragement did not occur with enough frequency to calculate IRR accurately. Therefore, each time a researcher applied this code after the IRR process it was brought to the research team for discussion to ensure correct application. In addition, we identified a new code not reflected in Bluemink et al.'s original coding scheme: Discouragement/Sarcastic Comment (Table 2). Because this code was identified after IRR was established, and because it occurred so infrequently, each instance of the code was also discussed among the three researchers to ensure it was applied correctly.

Informed by previous work examining collaborative processes (e.g., Barron, 2003; Rae, 2010; Stevens, 2000; Whittaker, 2003), we used our review of video data in conjunction with researchers' detailed field notes to characterize the quality of the collaborations observed in each group as they worked on their summer camp. Specifically, we considered the final product of their collaborations (i.e., progress made on building a summer camp) and looked for evidence of joint attention (i.e., players working towards a common goal) (Barron, 2000). We considered this review alongside the results of the thematic analysis of discourse functions in order to identify patterns of discourse functions that distinguished each group and appeared to contribute to the unique quality of their collaboration. In the Findings, we follow our summary of the discourse function patterns across and within groups with in-depth summaries of each group. These summaries include descriptions of the groups' gameplay drawn from our review of the video data and field notes. Similar to prior studies (e.g., Stevens, Satwicz, & McCarthy, 2008), we include illustrative vignettes from the session transcripts that highlight results from the thematic analysis that distinguish one group from another and provide insight into the quality of their collaborations.

Table 2. Code names, definitions, and examples from transcripts

Code Name	Definition	Examples
1. Question	Student asks a question from the others or thinks aloud in the form of a question.	"Where are you guys at?" "I need to get wood, okay?"
2. Social Statement	Social statements can be described as 'small talk' which is not directly content specific. There are three different types of social statements. 1. Greetings and jokes 2. Short comments showing that the person is present in the conversation or action 3. Comments on one's own or others' behavior	"He's called like forty times today. I'm busy." "No, well, I mean I did in a James Bond movie." "I am a cat."
3. Content Statement	Content statements can be described as notifications that the players make about the others, the environment and the events of the game. The content statements can be statements related to the game or the task at hand, to inform others; they can also include repeating, reading or commenting on the game's instructions in ways not directly meant as orders to the other players.	"I'm making a TNT house." "I'm trying to find you people." "Oh, I'm going the wrong way!"
4. Suggestion	Suggestions are content statements and questions, which propose an activity or predict how things might work. They are not direct instructions or orders. 1. If the player suggests to the others to do something and includes him or herself in the action, the utterance is categorized as suggestion (note the different from the category 'Instruction or Order'). 2. Expectations and insights concerning the logic of the game may also fall in this category.	"Let's go, let's go to the sea." "You guys, we should go to bed." "We need to get that horse."
5. Instruction or Order	The Instruction or Order category consists of two different types of utterances: 1. Student is giving instructions or help to other(s) or giving an order to do something. 2. Player is reading or explaining instructions provided by the game.	"I'm making stuff, be quiet." "Neil, stop blowing up TNT." "All right, watch this!" "Look up, press A, and dig."
6. Encouragement	Utterances, in which the student is encouraging other players in their actions or ideas, are categorized as encouragement. Encouragements are directly aimed at a person or the group.	"Oh, good idea!" "Dude, that's pretty good."
7. Discouragement, Sarcastic Encouragement	Snarky, sarcastic comment made to another player	"Neil, you dummy!" "You're soooo funny."
8. Response	This category consists of the students' responses to previous utterances. Responses are general acknowledgements, and the previous utterance can belong to any one of the other categories. It is typical to this category that the utterance can only be understood in context since the utterances do not usually have an understandable meaning as single utterances. Only responses that are clearly related to the previous utterance(s) and are rather short without particular new content, are coded as responses, otherwise they are coded in one of the other categories.	"That sounds pretty expensive." "Yeah." "Must be fun." "You click it." "No problem."
9. Incoherent Utterance	Utterances that could not be interpreted by the transcriber or researchers	"Neil, Yeah, I'm, whoo."

FINDINGS

Discourse Functions Across Groups

In total, 3,098 utterances were made across all three groups and all ten participants. Group 1 (4 participants) had a total of 1,281 utterances; Group 2 (4 participants) had a total of 1,036 utterances; and Group 3 (2 participants) had a total of 781 utterances. The three most frequently used discourse functions were Content Statements (36.7% of total utterances), Responses (30.8%), and Questions (18.8%). The remaining discourse functions each accounted for less than 10% of total utterances, with Encouragements and Sarcastic Comments each representing less than 1% of all utterances (0.3% and 0.4%, respectively). *Figure 2* shows the frequency with which each type of discourse function was used across all groups.

Figure 3 shows the frequencies of discourse functions within each group. Content Statements, Responses, and Questions remained the most frequently used discourse functions for each group, although the order of frequency was slightly different. For instance, Content Statements were the most popular discourse function in Group 1 and Group 2, whereas Responses were the most popular discourse function in Group 3. Overall, Group 1 had the lowest proportion of Responses, possibly suggesting a lower level of reciprocity among the players. Group 1 also had the most Content Statements and Snarky Comments and the fewest Social Statements. Group 3 had the most Suggestions and Instructions. We explore these differences among the three groups in greater detail in the following section.

Group 1: A Failure to Connect

Overview of Group 1's Gameplay

Group 1 never discussed the task of building a summer camp with each other, and appeared to have either disregarded or forgotten about it as soon as they started to play the game. The two friends, Derek and Neil, broke away from the others early in the session, and did not do anything to help Rachael and Peter find them, even though both were trying to do so. Rachael was the first to find Derek and

Figure 2. Discourse function as a % of total utterances (N = 3,090) across all groups

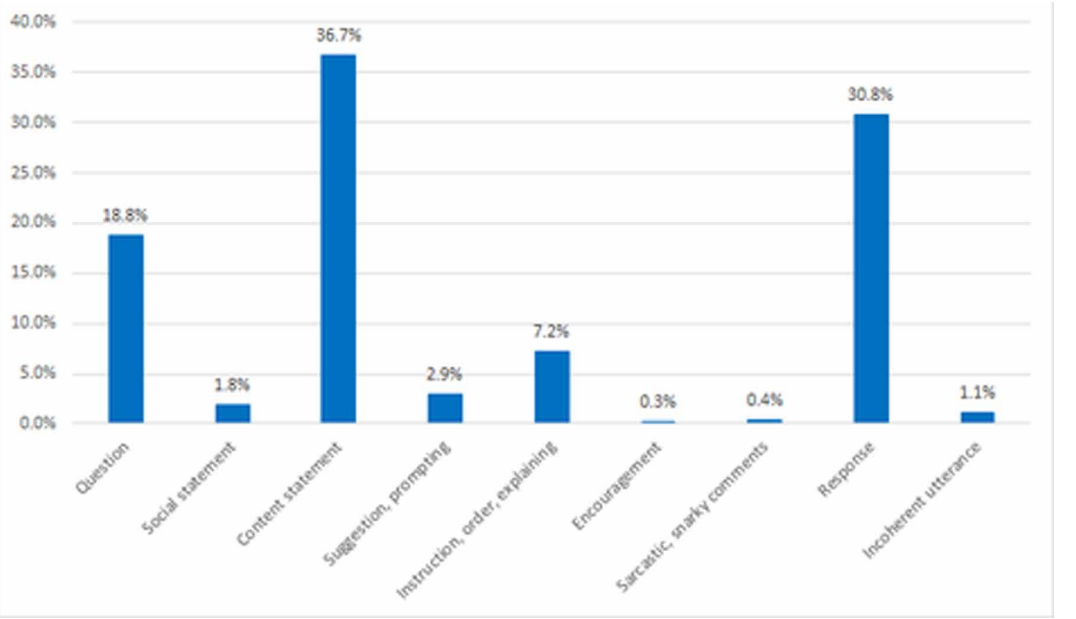
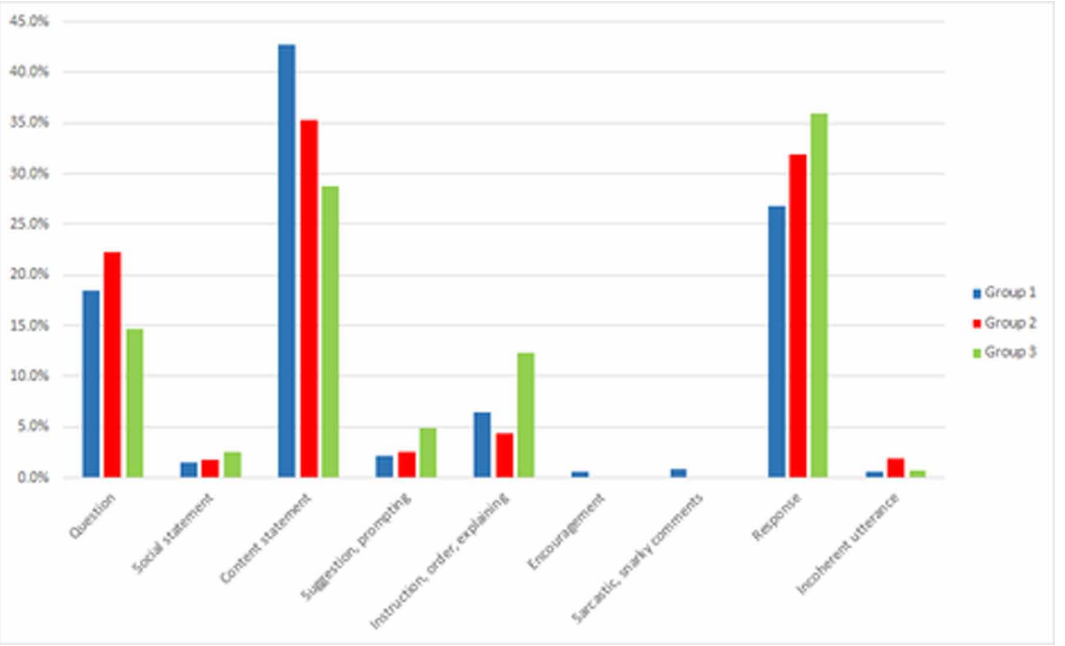


Figure 3. Discourse function as a % of total utterances in each group



Neil after considerable struggle with her controller and minimal assistance from the other players. Subsequently, she gave Peter her controller to help him find the rest of the group, but he would not give it back to her.

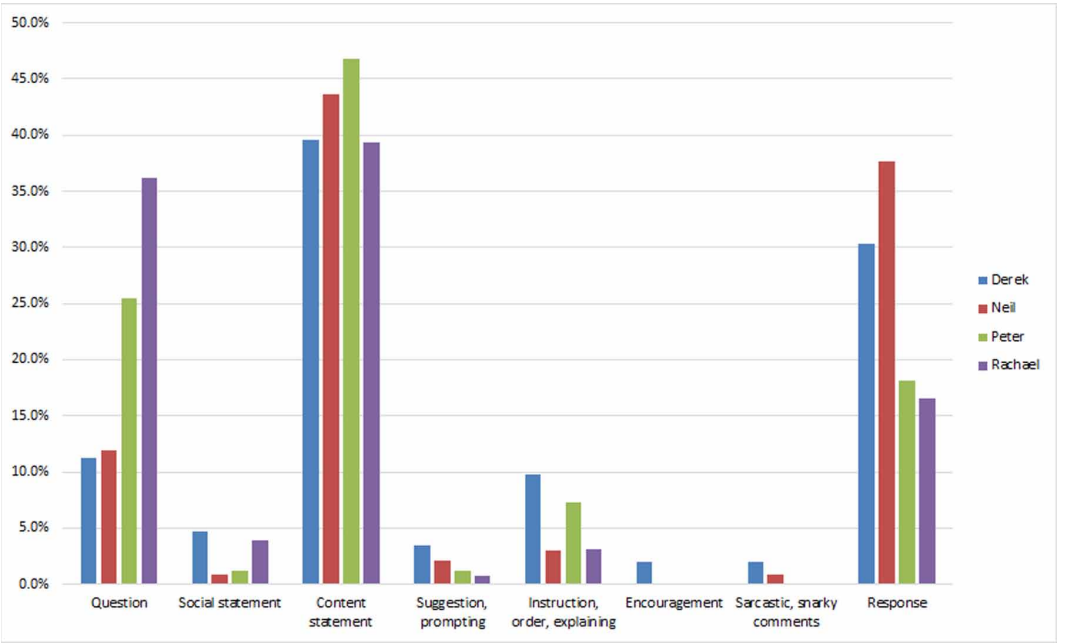
Derek was the only player to make significant progress toward building a structure during the session. He worked on his rollercoaster for the duration of the study, but both Neil and Peter impeded his progress by constantly trolling him. Whereas Neil's trolling behavior mostly slowed Derek's progress, Peter's trolling was more destructive. By the end of the session, Derek's rollercoaster was destroyed, Rachael had built an assortment of blocks loosely resembling a house, and Peter had built a single elevated platform.

Group 1's Conversational Patterns

Our analysis of Group 1's utterances showed that Derek was the only player to utter either Encouragements (2.0%) or Snarky Comments (2.0%). He also had the highest proportion of Suggestions (3.5%) and Instructions (9.8%) relative to his total utterances (*Figure 4*). These findings suggest that Derek positioned himself as the dominant player in the group, which was evident in our review of the video recording. Rachael, by contrast, was positioned as the least dominant player. Her comments represented only 9.9% of the total utterances made in Group 1, compared to Derek's 31.1%, Neil's 26.2%, and Peter's 32.2%. In addition, Rachael came in with the least experience playing Minecraft and without knowing her three co-players.

The two players with the least experience—Rachael and Peter—had the highest proportion of Questions relative to their total individual utterances (Figure 4). Over one third of Rachael's utterances (36.2%) and one quarter of Peter's utterances (25.4%) were Questions. In contrast, only 11.3% of Derek's and 11.9% of Neil's utterances were Questions. This pattern was reversed for Responses. As the most experienced players, Derek and Neil had the highest proportion of Responses (30.3% and 37.6%, respectively), whereas Rachael and Peter had the lowest (16.5% and 18.2%, respectively).

Figure 4. Group 1: Discourse function as a % of each participant's total utterances (N = 1,281)



Although Rachael had the highest proportion of Questions relative to her total utterances, Peter had the highest number of Questions overall (105 for Peter vs. 46 for Rachael). Only 40.8% of Peter's Questions were answered by one of his co-players, and most of these answers came in the first 15 minutes of gameplay. During this period, Peter asked nearly half of his Questions (49.5%), and 51.0% of them were met with a Response. As the study proceeded, however, Peter's co-players were less responsive to his Questions; only 30.8% received a Response.

The following excerpt represents a typical interaction among the players in Group 1. The code applied to each utterance is listed in parentheses. In this excerpt, Derek and Neil are co-located in the game world and primarily interacting with each other. Rachael must ask her question twice before she gets an answer from them. Peter is lost in the game world and entirely ignored.

Rachael: Wait how do you fly again? I forgot. (Question)
Derek (to Neil): Oh, yeah, glass. (Content Statement)
Neil (to Derek): Ahhh. (Response)
Derek (to Neil): Yeah. (Response)
Rachael: Wait how do you fly again? I forgot. (Question)
Derek (to Rachael): Uhhh. (Response)
Neil (to Rachael): Double A. (Response)
Derek (to Rachael): Double A. Double A! (Response)
Peter: I need a new map. This is evil. (Content Statement)
Derek (to Neil): Hey, wait, how can you see under water? I just put like glass here. (Question)
Peter: I feel like I'm going the right way. (Content Statement)
Derek: All right. (Content Statement)
Peter: This is gonna take forever just to get back to you guys. (Content Statement)
Peter: I don't even know if I'm going the right way. (Content Statement)

Group 2: Coordinating Action to Build Camp Minecraft

Overview of Group 2's Gameplay

Group 2 started their session by exchanging ideas about what type of camp they wanted to create. Upon settling on an idea, players began to construct the camp, which they named Camp Minecraft. By the end of the session, Group 2 had built and decorated numerous structures and outdoor areas of their camp. They transformed the plain free-build terrain into one dotted by buildings, trees, and other decorative vegetation. They built dorms and cafeterias and even an outdoor swimming pool. The group also did some exploring and building in the Netherworld as well as the Ender Zone. To ensure no one got lost, participants created beacons to mark their areas.

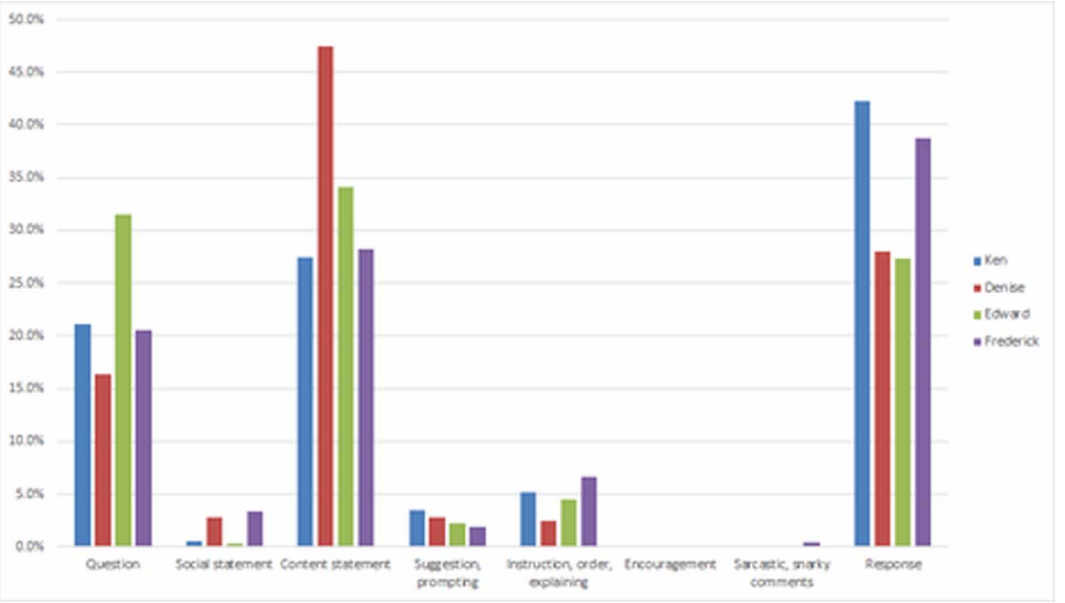
Group 2's Conversational Patterns

Our analysis of Group 2's utterances revealed that Edward had the highest proportion of Questions (31.5%) relative to his total utterances (Figure 5). Although he was an experienced Minecraft player, he played the game on the computer or iPad rather than on Xbox. He therefore needed some guidance in how to work the controller. Edward was also good friends with Ken, which may have helped him to feel comfortable asking questions. Indeed, Ken had the highest proportion of Responses (42.3%). Overall, Edward's co-players answered 57% of his 100 Questions.

Denise had the lowest proportion of Questions (16.4%) of the group and the highest proportion of Content Statements (47.5%). These findings reflect Denise's sustained focus on the activity, which was apparent in the video recording of Group 2's gameplay. As a skilled Minecraft player, she did not need to pose many questions to her co-players. Moreover, because she did not know any of the other players prior to the study, she may have felt more comfortable focusing her comments on the task laid out by the researcher.

The following excerpt represents a typical interaction among the players in Group 2. Edward directs Ken to help with the construction of a log cabin, while Denise comments to herself on the progress of the refrigerator she is building. The group's attention shifts to Denise's refrigerator and

Figure 5. Group 2: Discourse function as a % of each participant's total utterances (N = 1,036)



participants congratulate her and share their curiosity. Denise and Edward bounce ideas off one another to improve the design.

Ken (to Edward): What should I get to make it [a log cabin]? (Question)
Edward (to Ken): I'm gonna fill in the walls. You can make in windows or something, or you can make— (Instruction)
Ken (to Edward): Okay, I'll do glass. I'll do glass. (Response)
Denise: Yes! My refrigerator works and I've already messed it up. (Content Statement)
Edward (to Ken): Can I just fill it in? (Question)
Ken (to Edward): Wait, I got this. I got the windows so... (Response)
Edward (to Ken): Are we gonna make, wait, that's a pretty big window to make. Maybe not as big. (Suggestion)
Denise: There. (Content Statement)
Frederick (to Denise): Yeah, yeah, yeah. (Response)
Ken (to Denise): Oh yeah, that's cool. (Response)
Ken (to Denise): That refrigerator in there. Response)
Edward (to Denise): Does the refrigerator work? (Question)
Denise (to Edward): Yeah. (Response)
Denise (to Edward): I'm debating if I should do the pressure plates instead. (Content Statement)
Edward (to Denise): Do they have pressure plates over here? (Question)
Denise (to Edward): Over here, but [inaudible] not a fan but... (Response)

Group 3: Camp Craft Destroyed by TNT Rollercoaster

Overview of Group 3's Gameplay

Noah was the leader in this group, directing the build and focusing on the task of creating a summer camp. Aaron asked for Noah's approval on most tasks and constantly sought his attention. With this dynamic established early in the session, the two friends quickly created several structures for their camp, including houses for the campers and counselors, a path, and a dock. Like Group 2, they gave their camp a name: Camp Craft. At times, Noah rejected Aaron's offers of assistance, and Aaron responded by griefing. He made a TNT monument, laid TNT under Noah's counselor house, and played with the survival features of the world. Eventually, Noah responded to Aaron's behavior by helping to build a TNT rollercoaster/launcher, which subsequently destroyed half of their camp. After the destruction, Noah attempted to continue building, but eventually joined Aaron in fighting the Ender dragon as the study ended.

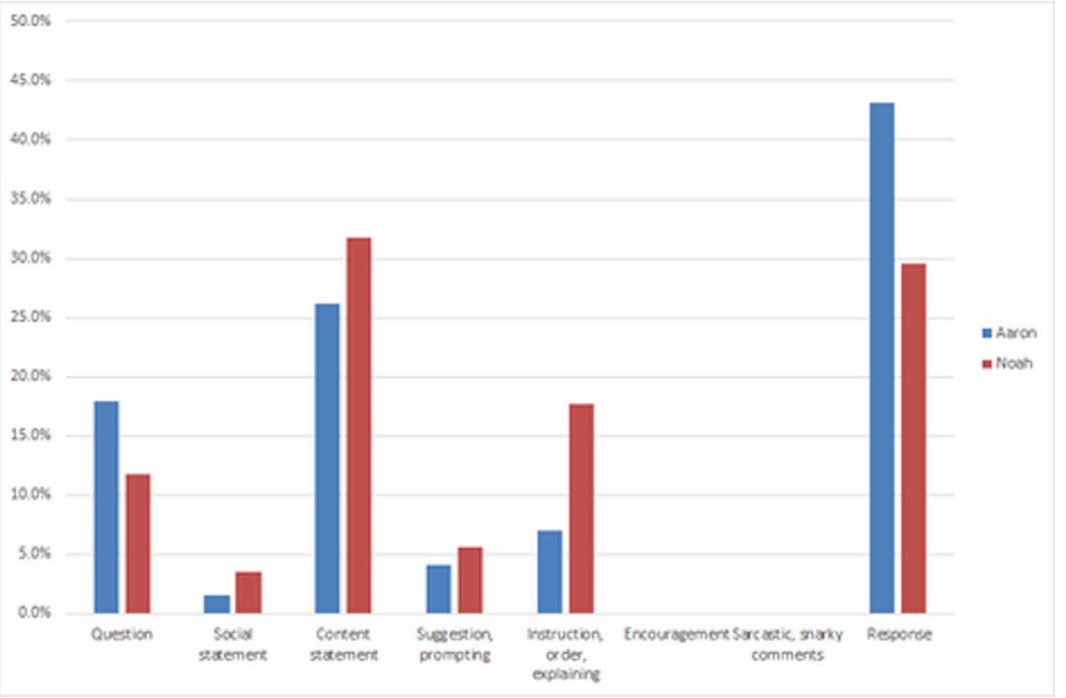
Group 3's Conversational Patterns

Aaron and Noah were experienced Minecraft players and good friends. However, our review of the video recording of their gameplay revealed Noah to be a somewhat more skilled player than Aaron. He quickly emerged as the dominant player, which was evident in the higher proportion of Instructions he gave compared to Aaron (17.7% vs. 7.0%) (*Figure 6*). As the less dominant player, Aaron had a higher proportion of Questions compared to Noah (17.9% vs. 11.8%).

The majority of Aaron's 69 Questions (85.3%) were responded to by Noah. Questions that weren't answered (14.7%) included questions asked quietly, questions that were later rephrased, questions that were vague or unanswerable, or questions that Aaron answered himself.

The following excerpt represents a typical interaction between the players in Group 3. Aaron, whose efforts and suggestions are rejected by Noah, begins shooting arrows rapidly at him. Noah continues to tell Aaron what to do, but Aaron resists his orders and eventually settles on building a path.

Figure 6. Group 3: Discourse function as a % of each participant's total utterances (N = 781)



Aaron: I already built a cabin. Well you wouldn't let me help build with that one. So what the heck am I supposed to do? (Question)
Noah: Stop it. (Instruction)
Aaron: Napalm strikes. (Response)
Noah: Stop it! (Instruction)
Aaron: Napalm strikes. (Response)
Noah: Seriously, stop. (Instruction)
Aaron: Okay. That was my last strike. (Response)
Noah: Are you kidding? Stop. Go build another cabin. It's a summer camp so there's gonna be lots of kids, right? (Instruction)
Aaron: There's only four of us. (Response)
Noah: No, like, if it was a real camp. Yeah, duplicate one of those, like next to it. Like even outta the ground or something. (Instruction)
Aaron: Or I'll build another pathway to the beach. (Response)
Aaron: Gonna need birch wood. (Content Statement)

DISCUSSION

The current exploratory study documented the discourse patterns that emerged as 10 middle school students played Minecraft in small groups of 2-4 players. Consistent with Bluemink et al.'s (2010) investigation of university students' utterances while playing a multiplayer game, we found that the three most frequently used discourse functions were Content Statements (36.7% of total utterances), Responses (30.8%), and Questions (18.8%). In other words, players' discussions mostly involved talking about gameplay, posing questions to other players, and responding to each other's questions.

The three groups displayed similar proportions of discourse functions overall. However, a deeper analysis of the discourse functions in conjunction with our review of the video data and researchers' field notes revealed notable differences. In what follows, we examine these differences and how they led to different outcomes in the effectiveness of players' collaborations.

Group 1 had the least successful collaboration as judged by their almost complete lack of progress toward building a summer camp together in Minecraft. Our review of video data and field notes alongside our analysis of players' discourse functions points to a failure of this group to achieve and maintain joint attention (Barron, 2003). The two dominant players, Neil and Derek, were largely unresponsive to either Rachael or Peter. Several factors contributed to this unresponsiveness, including prior social ties and gaming experience (Bluemink et al., 2010). First, Neil and Derek had the strongest prior social ties and were the most skilled Minecraft players on Xbox. It was therefore easy for them to break off instantly from the other two players and interact primarily with each other. As the least experienced player with no prior social ties to any of her co-players, Rachael was also the quietest player. Her 127 overall utterances were far fewer than Neil's 335 utterances, Derek's 399 utterances, and Peter's 413 utterances. With so few utterances, Rachael was unable to gain the attention of her more experienced co-players, an important skill in collaborative situations (Barron, 2003). With over three times as many total utterances as Rachael, Peter made many attempts to gain the attention of his fellow players. However, these attempts were largely unsuccessful. In particular, most of his Questions were ignored, especially towards the end of the session. Peter's destructive trolling behavior during gameplay, combined with the likelihood that Neil and Derek were aware of his autism (because they were classmates), likely contributed to Peter's inability to establish joint attention with his co-players.

Group 2 had the most successful collaboration as judged by the quality of the summer camp they constructed in Minecraft. Although our analysis showed that they did not always respond to each other or maintain unbroken joint attention, they were far more effective at achieving joint attention than Group 1. For instance, the results of our thematic analysis of discourse functions provide insight into group members' responsiveness to each other, an indicator of working together towards a common goal (Barron, 2000). Edward, who asked the most Questions in Group 2, received Responses to 57% of his Questions, whereas Peter, who asked the most Questions in Group 1, received Responses to only 40.8% of his Questions. These results provide evidence that members of Group 1 were somewhat less responsive to each other than members of Group 2.

Like Group 1, two of the players—Edward and Ken—were good friends before the study. As evidenced in the excerpt from Group 2's gameplay, there were times when Edward and Ken communicated primarily with each other. However, this excerpt also shows how Denise was able to gain their attention by constructing a refrigerator in the game world. The boys were obviously impressed by the skill she displayed, and were eager to ask her questions about how the refrigerator worked. Like Rachael in Group 1, Denise did not know any of her co-players prior to the study. Unlike Rachael, Denise was a highly skilled Minecraft player and was able to use this skill to achieve joint attention with her co-players. The dynamics observed in Group 2 illustrate that successful collaboration does not necessarily require symmetry in skill or social status among group members (Rogoff, 1998). What is more important is the ability to leverage the different abilities, temperaments, and social ties present in the group to achieve an "intersubjective attitude" (Crook, 1994).

The two players in Group 3 made considerable progress toward building a summer camp, but their collaboration derailed towards the end of the study session when their TNT rollercoaster/launcher destroyed half of their camp. The initial success of this pair is attributable to their ability to maintain joint attention, which itself was likely influenced by the fact that they were good friends before the study. However, this friendship was not one of equal status, at least in the context of playing Minecraft. Noah quickly emerged as the dominant player, as evidenced by his higher proportion of Instructions (17.7% vs. 7.0%) and lower proportion of Questions (11.8% vs. 17.9%) compared to Aaron. Despite this dominance, Noah was nevertheless very responsive to his co-player, responding to fully 85%

of Aaron's Questions. This dynamic further reinforces the point that successful collaborations do not require equal status among group members, but they do require group members to be able to coordinate their attention (Rogoff, 1998).

Implications

As multiplayer video games continue their popularity among young people and gain increasing attention from educators seeking to engage their students and promote twenty-first century skills (Plass et al., 2015), the findings from the current study provide needed insight into the nature of more and less effective collaborations in gaming environments. These findings extend prior work that examined collaborative processes in face-to-face and structured learning contexts (e.g., Barron, 2003; Okada & Simon, 1997; Rogat & Linnenbrink-Garcia, 2011; Sfard & Kieran, 2001), as well as multiplayer games (e.g., Ballagas et al., 2013; Bluemink et al., 2010; Chen, 2008). Consistent with this work, the ability to establish and maintain joint attention emerged as an important feature of successful collaboration in Minecraft. Our analysis uncovered specific factors affecting this ability, such as prior social ties among players, prior gaming experience, and the responsiveness of players to each other's questions and comments.

Our findings indicate that Minecraft has the potential to serve as a fruitful context for promoting collaboration among middle school students. However, successful collaboration is by no means guaranteed. In fact, there are certain features of online gaming that may present distinct challenges to establishing joint attention. For instance, there are many claims on one's attention while playing Minecraft. In our study, players had to coordinate action between their controllers and the movement of their avatars on the television screen (see Figure 1). Then, in order to coordinate their avatar's actions with the actions of the other avatars, they had to look at the sections of the screen corresponding to the other players' controllers and figure out how what they saw there related to their own avatar's position in the game world. Players could also look at and talk to each other since they were co-located in the same physical space. The complexity associated with coordinating physical and virtual activity may pose challenges with respect to achieving joint attention among group members (see Whittaker, 2003), particularly if some members are not skilled players.

Another challenge relates to the open-ended nature of the Minecraft world, which provides little structured guidance to players regarding how to navigate the terrain or build structures with the different materials at their disposal. Although this open-endedness presents opportunities for players to support and learn from each other, our findings indicate that some groups of students may need explicit instruction in how to provide and receive such support. The needed scaffolding may come from norms established at the classroom level (Barron, 2003; Matusov et al., 2002), or from real-time support provided by the teacher. Eventually, scaffolding could be provided by an adaptive support system designed specifically for the game world (Evans, Wobbrock, & Davis, 2016).

LIMITATIONS AND FUTURE DIRECTIONS

The purpose of the current study was to provide an initial understanding of factors affecting more and less successful collaboration in Minecraft. We see potential for future research to build on these findings in a number of ways. For instance, the current study did not involve a systematic analysis of the visual component of the video data, though we did use the video data to supplement and corroborate the findings from our analysis of participants' conversational patterns. In light of the complexity of action on screen and in person, it would be worthwhile to analyze conversational patterns in conjunction with players' physical gestures and eye gaze, as well as the movements of their avatars in the game world. Such an analysis would provide useful insight into the interactions among the many online and offline factors affecting the achievement and maintenance of joint attention in online gaming environments.

Because this was an exploratory study, we used convenience sampling and formed groups around participants' availability. Though this approach is appropriate for an exploratory study, future research would benefit from a more deliberate process of grouping study participants. For instance, it would be instructive to vary group composition systematically according to such factors as prior social ties, skill level, gender, and age. It would also be worthwhile to provide groups with a variety of different tasks in order to ascertain how the nature of the problem affects the quality of the collaboration.

CONCLUSION

With growing interest in using games to promote learning, there is a need for empirical research that investigates the types of learning supported by game-based environments and the conditions under which this learning is supported. Because collaboration has emerged as an important twenty-first century skill, and because multiplayer games are conducive to collaboration, the current exploratory study focused on examining 10 middle school students' collaborative processes while playing Minecraft in small groups of 2-4 players. Our analysis of participants' conversational patterns during gameplay revealed a number of factors affecting their ability to achieve joint attention, such as prior social ties, gaming experience, and responsiveness to other players. The ability to achieve joint attention affected the success of the group collaboration. These findings illuminate the opportunities and challenges associated with using Minecraft to promote collaboration, and should be useful to educators interested in using multiplayer games to teach twenty-first century skills.

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APPENDIX

Table 3. Inter rater reliability statistics

Code	Round 1 Coding			Round 2 Coding			Round 3 Coding			Round 4 Coding		
	Kappa	% Agreement	Code Occurrence (%)	Kappa	% Agreement	Code Occurrence (%)	Kappa	% Agreement	Code Occurrence (%)	Kappa	% Agreement	Code Occurrence (%)
01.question	0.71	94.93	12.16	0.71	94.52	13.44	0.77	94.13	17.98	0.82	96.15	13.87
02.social statement	0.66	95.39	9.59	0.91	98.77	4.94	0.79	97.22	4.64	1	100	0.00
03.content statement	0.69	86.44	39.11	0.90	95.48	37.75	0.74	87.94	43.34	0.87	94.23	34.14
04.suggestion, prompting	0.45	91.9	12.10	0.54	98.14	2.98	-0.01	97.33	2.66	0.77	97.17	8.00
05.instruction, order, explaining	0.85	97.13	11.93	0.95	99.07	10.71	0.42	92.33	10.93	0.92	97.73	18.34
06.encouragement	1	100	0.00	0	97.5	2.50	1	100	0.00	1	100	0.00
07.response	0.55	85.05	28.19	0.85	94.71	26.46	0.61	85.99	29.80	0.73	90.29	28.90
08.incoherent utterance	0.79	99.04	2.76	1	100	0.00	1	100	0.00	1	100	0.00

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