Children's Collaboration in Emergent Game Environments

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ABSTRACT

The research presented in this paper examines how collaborative learning manifests in different environments of emergent play. Emergent games are interesting objects of study from a serious games perspective as their non-linear and open-ended nature can alleviate issues caused by impersonal and inflexible content. But, in order for them to be useful in learning contexts, methods for assessment of player actions and participation in emergent games need to be improved. Our approach to this issue was to device a methodology to track individual group members' work contributions during different types of group exercises. Groups of middle-school children, ages 6-9, were tasked to build structures out of LEGOs and in the game Minecraft and, through the devised tracking method, data from the different exercises were compared in order to determine how the collaborative patterns within the groups varied depending on what type of exercise they were performing. The results of the study indicate that the computer based emergent system was experienced as more engaging and immersive than the face-to-face one, and that it fostered continuous discovery, experimentation and problem solving throughout the game session. The devised methodology resulted in some good indicators regarding collaborative behavior, but more parameters need to be added for it to be usable for effective and meaningful player assessments.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer uses in Education – *Computer-managed instruction (CMI)*.
K8 [**Personal Computing**]: General – *Games*.

General Terms

Measurement, Human Factors.

Keywords

Emergent games, serious games, learning games, collaborative patterns, technology-mediated interaction

1. INTRODUCTION

Using games for educational purposes is a fairly well established and also increasingly prevalent practice. Games are frequently being employed during training of military and rescue service personnel, in corporate staff education, and in many different school subjects [14]. These types of games, that have a purpose beyond just providing an engaging game experience, have been dubbed *serious games* [21]. With their growing popularity as instructional, motivational and educational tools, serious games have spawned a plethora of research opportunities that need to be seized in order for the phenomenon to evolve further. Much of the research focusing on evaluating serious games' effectiveness as learning tools for children has so far been focused on linear games aiming to educate its users in very specific areas; for example math, physics, reading or linguistics [9, 3]. Less attention has been given to more open-ended and non-linear games that trade heavily on allowing the player to significantly manipulate the game world and establish new narratives. Such games, in this paper referred to as *emergent games*, may be a bit more unruly and unfocused. But, they contain certain qualities that make them interesting objects of study from a serious games perspective.

The purpose of the research presented in this paper is two-fold; to examine how emergent and non-linear game systems can function as collaborative educational tools, and to examine means for measuring and assessing student's work in emergent environments. This work was mainly prompted by two observations regarding educational serious games and the context they are placed in. Firstly, emergent games consist of elements which have intrinsic potential to solve many of the issues which traditional educational games are limited by; such as impersonal and predictable content and mismatches between game challenge and individual player skill [13, 15]. Secondly, recent changes in the Swedish school curricula place more emphasis on the development of soft skills, such as creativity, reciprocity and collaboration [23]; a change which emergent games might be able to accommodate for better than more linear ones. In order to investigate the prospects of emergent games in regards to these issues and requirements, an experiment was carried out with children between the ages of 6 to 9. During the experiments, the children collaborated on exercises in both virtual and real-world settings. This provided us with comparable data which we used to examine the differences in the children's interaction in different contexts, which would give us the means to describe how technology-mediated collaborations work in relation to face-to-face collaborations. The platforms chosen for conducting the experiments were LEGOs and the computer game *Minecraft* [17]. The crux of both Minecraft and LEGOs is their highly emergent nature, and we used them to ensure that the central concept of emergence remained present during both the virtual and real-world exercises.

The reason why emergent games' potential as collaborative learning tools is an interesting subject of study are the characteristics that distinguish them from more traditional, linear games. In a game which is predominantly emergent, players shape the game's narrative through their actions instead of progressing through a pre-established narrative constructed by the game's developers [16, 24]. Shortly summarized, emergent games can be seen as handing the players a set of brushes, colors and a blank canvas to paint on, whereas traditional games may hand them a similar set of brushes and colors but a canvas imprinted with a paint-by-numbers schematic that the players need to follow. With the canvas, the player can shape the work in a way that's appealing to her/him, and can paint with a resolution and choose a motif that she/he can execute well. The paint-by-numbers task is more closed down, and has a pre-defined end goal and skill requirement. This analogy, simplified and broad-brush as it may be, exemplifies the differences in player agency between the two types of games, and it's the facilitation of wider creative expression and the opportunities for dynamic challenge balancing in emergent games which make them interesting. However, the element of emergent games that make them engaging and sets them apart from linear games is also what makes them difficult to use. For instance, the open and player-driven nature of emergent games makes them unwieldy for teachers since student skill development and task participation becomes harder both to guide and assess.

2. BACKGROUND

Given the results of previous research within the field of technology mediated collaborations [1, 2, 10, 25] some general assumptions concerning what kinds of results this research would produce could be made. We hypothesized that the data would indicate that the test subjects were more engaged by the computer-based task, as that has been a commonly recurring result in previous research [1, 13, 18]. We also expected all participating groups to be of a pretty uniform skill level when it came to performing the LEGO exercise, as that is a fairly ubiquitous toy that almost all children are familiar with. This will most likely lead to the group members collaborating on an equal level without much tutoring of one another. This will most likely differ greatly from the Minecraft exercise, as the level of proficiency between the group members will be more varied as a result age differences and previous experience with Minecraft and games with similar interfaces. For instance, boys of a certain age group are more likely to be familiar with First Person Shooter-interfaces [20], which are similar to the interface in Minecraft, and they will likely perform at a higher level in the game-based exercise as a result.

2.1 Related Research

There has been a lot of previous research on collaborative learning among children and adolescents during computer based interactions [2, 5]. In 2001, a group of researchers studied collaborative learning between children through the use of word editing and gaming software [1]. Of particular interest for this research, is their summarization of Jehng's different forms of collaborative learning set in the context of computer usage [1, 11]. Jehng established a basic framework for identifying and categorizing different types of group dynamics during collaborative learning experiences. The established categories are *peer tutoring, peer collaboration* and *collaborative learning*. *Peer tutoring* is a collaborative pattern in which one or a select few members of a group has superior skill, experience and knowledge within the area of the group's work. This often leads to a collaborative situation where the more capable individual(s) of the group mentor the other group members, and acts as a tutor for getting other members up to speed with new tools and procedures [11]. The value of this pattern lies in the tutors transferring knowledge to their peers, and the tutors also fortifying and reevaluating their own knowledge as they themselves need a firm understanding of a subject matter or procedure in order to teach it to others [2]. *Peer collaboration* occurs when all of the group members are equally capable within the field in which they are working. This often occurs in situations where all group members are unfamiliar with their working circumstances and that they have to work together in order to solve a problem or complete a task. Thus, they collaboratively seek and acquire knowledge of the field in question [11]. This collaborative pattern is considered to be the most effective when it comes to stimulating learning and inspiring camaraderie between students since the participants experience the sensation of discovery through collaborative experimentation and trial-and-error [1, 8]. *Cooperative learning* manifests when participants with a variety of different competencies work in a structured environment where they utilize each other's unique skillsets to solve a problem or complete an assignment. In this collaborative pattern, tasks are often delegated to different members of the group so that they get to work in a way that maximizes the use of their expertise [11]. These categories were utilized by the previous researchers to facilitate a thorough dialogue and analysis regarding the different group hierarchies and patterns that became apparent during their studies [1]. During this research, these categories will be used in a similar fashion.

2.2 Benefits of Emergent Games

Impersonal, predictable and generic content is a real concern when it comes to the quality of serious games since these issues pose severe threats to player enjoyment and thus limit the time a student or trainee is willing to spend in the game [4]. In many games, all users are often treated as a homogenous entity and the game's difficulty setting is determined by the level of proficiency the game's developer expects the players to have [6]. However, all individuals within the target audience of a serious game aren't identical and start out at different levels of skill, whether it's actual gaming prowess, gaming literacy or knowledge within the subject area the game is meant to teach [13]. From the perspective of flow theory [7], this can explain why serious games are considered by many to be un-engaging. For many individuals, the game's challenges will either be too trivial or too difficult for them to be able to derive any real enjoyment from it. Commercial game ventures often have the luxury of catering to a very focused market segment, which is defined by their interests, age and gender and whose gaming literacy can often be expected, since they have enough interest in games to purchase them on their own incentive. Serious games, however, are often made for a more heterogeneous demographic since the only commonalities between the individuals within it is their profession or educational situation while age, gaming literacy, interests and mental or physical capabilities can differ greatly between individuals.

Emergent game systems may present a solution to these difficulty-related issues in a similar, but perhaps more dynamic way than procedural methods such as performance-based challenge increase [22] or scenario adaptivity [15]. Player-driven systems allow the player to calibrate the difficulty of the tasks presented to her/him intuitively during the play sessions instead of relying on pre-developed algorithms, or adaptive individualization mechanisms based on proficiency and task hierarchies. The player-driven narrative in emergent games thus helps keep both the relationship between challenge and player skill [6, 18] and the development of conceptual and computational understanding very balanced as students will gradually take on increasingly complex challenges and concepts as they master and stream-line computational actions within the game world through repetition [22]. The players are able to automatize simpler procedures and explore new concepts in a comfortable pace and thus increase their talent repertoire iteratively [19].

2.3 Minecraft

Minecraft has received much acclaim because of its innovative concept and player-driven narrative, but there are several other reasons behind choosing Minecraft as the representative for emergent games for the purposes of this research. For one, the game is void of any traditional video game goals (e.g. accumulate points, complete the level, etc.) for the players to achieve, and it really places a lot of onus on its player to create their own personal goals. During single player sessions, players are thrown into their own, vast Minecraft world upon starting the game. The world is populated by cattle, critters and monsters, but the main actors within the game are the inanimate blocks that the earth, mountains, and trees consist of. The player can collect the blocks and manipulate them in different ways, for instance combining different types of blocks to create furniture and tools, or they can be manually placed into the game world again to create buildings. When used under deliberate orchestration, the blocks can thus create structures, landscapes, visual compositions or even new game elements within the original game. Minecraft itself doesn't directly reward the player for this type of behavior; a player can just dig a small hole in a hill and spend an entire game session within her/his fortress of solitude without being punished or, from a strict gameplay perspective, fall "behind" more active players when it comes to game progress (since there are no goals, progression can't really be measured in the game). Yet, players naturally tend to start using the opportunities for creative outlet that the game supplies them with to plan, devise and create monumental structures, cities, re-enactments of famous movie scenes, sculptures and artwork.

3. METHOD

In order to successfully track changes in collaborative patterns and the way children work in different emergent environments, it's important to establish clear variables that indicate how these patterns and processes manifest themselves in the different exercises. The main variables that were studied during this research are differences in group communication, individuals' contributions as well as proximity and/or overlap of different group members' contributions during the exercises. Our hypothesis was that combining these more specific and quantitative ways of collaboration-analysis would result in more reliable results concerning how collaborative situations in a variety of different mediums may differ from one another and how they affect collaborative patterns in a group of individuals.

The setup and execution of the experiment went on during two weeks in the month of May, 2011. During this time period, 31 children played Minecraft; 15 of which went through the entire experiment process with both the LEGO and Minecraft exercise. These were given more specific instructions to collaborate and work on something as a group. The remaining 16 children only played Minecraft together in a more unstructured environment without directives, which served the purpose of providing us with some additional data regarding children's collaborative behavior during less guided technology-mediated interactions. The results presented in this paper are however mostly based on the data gathered from the more strict experiments. The groups that participated in the entire experiment had the following age and gender setups (there were 5 subjects in each group):

Group 1 - A mixture of girls and boys, aged 6-9
Group 2 - Girls aged 7-8
Group 3 - Boys aged 8-9

The groups participating in the "free play" sessions were divided into groups of 4. Both the groups in the experiment exercises and the free play sessions were put together at random with children from the same classroom – meaning that all students were familiar with one another beforehand.

3.1 Experiment Design

Our approach to creating a way to track and analyze the collaborations within a group without solely relying on the researchers' observations was to apply "invisible" color coding to the players' tools. This allowed us to specifically map out the individual contribution of each group member. We also recorded the conversation in the groups during the exercises and kept statistics of group members' communicative behaviors during the play sessions. Both of these means aimed to measure engagement and collaborative behaviors during the exercises.

3.1.1 Monitoring collaboration

In order to track individual students' contribution during the exercises we used a method we dubbed *Selectively Invisible Color Coding* (SICC). In essence, this meant applying colors that were visible to the researchers, but not to the students, to the tools that the students' used during the exercises. SICC was developed to specifically track individual contribution in a collaborative context without in any way influencing the behavior of the participating individuals. In situations where a group of individuals collaborate to produce or create complex objects and structures, back-tracking to determine which parts were constructed by which group member can be very difficult. That subsequently makes it difficult to assert how the group actually collaborated during the creation of the object or structure. If one is able to apply SICC to the toolset and materials used by research subjects in an experiment, their individual work will leave a residue visible and available for easy and extensive analysis. If the experiment is devised in a way as to conserve the work of the group indefinitely, the collaboration can also easily be retroactively examined and the researcher isn't left to solely rely on images and video of the experiment to assert how the group of subjects participated in the exercise that's being analyzed. In this experiment, SICC was applied to LEGO-pieces and building blocks in Minecraft. Groups of middle-school students were then asked to collaborate and construct anything they wanted both with the LEGO-pieces and within the virtual Minecraft space.

Beyond the fact that they both have thoroughly emergent qualities, the decision of using Minecraft and LEGOs for this research was also based on methodological considerations as both platforms have the ideal properties for being analyzed with the SICC method. They both provide means for the creation of complex structures from very basic discrete elements, and tracking which individual placed which block or piece in the larger structure can give key indicators regarding how the group collaborated, the idea being that frequent and extended color overlap is evidence of close collaboration. This data, coupled with data regarding the group's communication patterns, should suffice in creating a complete picture regarding their collaborative patterns during both the LEGO-exercise and the Minecraft-exercise, and thus revealing changes between both exercises in an easily visualized and precise manner.

In Minecraft, the color coding was applied by changing the texture packs for each individual subject of the research. The basic texture pack was manipulated in a way as to make different blocks appear identical in the eyes of the players. Since the players were assigned to use different blocks from one another when working on their construction, applying a different texture pack where the blocks appearance signified which player placed them allowed us to enter the game world to examine the exact individual contribution of each subject. Further software was used to also gather specific data regarding the amount of blocks placed by each player (Figure 1 shows the color coding in Minecraft). The LEGO-pieces were color coded by using UV-sensitive markers. The pieces were marked with different symbols, and the students were each given a set of LEGO-pieces with symbols specific to them at the start of the experiment. After the exercise was finished, ultraviolet lights were used to look at what the groups had built and, as it was done in Minecraft, determine which piece was placed by which group member.

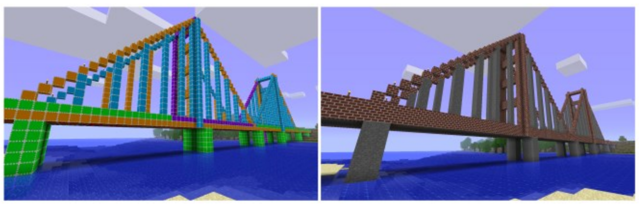

Figure 1: Comparison between color coded view (left) and the player's view (right).

3.1.2 Discourse analysis

Just tracking the individuals' physical contribution to the group's final creation isn't sufficient when trying to ascertain the entire complexity of the group's collaborative patterns. A member can, for example, take on a more administrative role during an exercise and be responsible for directing other group members' work. Such a person might not, if one is to only measure block contribution, seem to be functioning well in collaborative work, when in fact they have been very engaged in the exercise. In order to catch cases like these, and to be able to fully discern which collaborative pattern a group is following during the exercises, the communication within the group has to be tracked and analyzed as well. Collecting data regarding group members' communication should prove valuable when determining differences in how "at home" or unrestrained the individual might feel in the group context. But, merely measuring the individual's verbosity doesn't indicate their level of contribution to the group's collective thought processes or if they've assumed an authoritative role in the exercise, thus basic discourse analysis will be applied to get a better understanding regarding these matters.

The analysis of the recorded group discourse was done by establishing a few categories, each with different criteria, in which strings of dialogue could be placed. This resulted in data regarding what types of semantics were most commonly in use during the groups' collaborations, and provided more indicators regarding how their collaborative behavior differed between different exercises. All verbal exchange was tallied as *loquaciousness*, but some semantics that are of certain interest for this research will be specifically highlighted and categorized. To indicate the presence of different collaborative patterns, loquaciousness will be categorized as described in Table 1.

Table 1: Categories of loquaciousness and their signifiers.

Category	Description	Examples
Governing	Subject influences other participants to perform certain tasks.	*Can you/we…*, *Let's do…*, and similar requests.
Task Focused	Sharing or asking for information regarding the exercise.	*How do you/we…*, *Where do I…*, *This is how I…*

This categorization was in part inspired by the previously mentioned studies performed in 2001 [1]. In their study, the level of immersion in a task was partly measured by how much of the subjects' dialogue strayed from the task at hand; the tenet being that a task that doesn't immerse its participants is unable to keep said participants' dialogue focused on the task [1]. We expanded on this concept to capture more parameters than engagement.

4. RESULTS

It's important to note that the experiment exercises varied in duration for the different groups as some of them finished with their projects early. As a result, the data regarding instances of communication needed to be compared with exercise duration in mind when analyzing communicative behavior between exercises. Thus, the sheer amount of accumulated instances of loquaciousness isn't a good measurement to use for analysis, but the proportions of how the instances are distributed between different subcategories can provide some good indicators for how the children behaved during the exercises. In general, the participants were far more engaged with the Minecraft exercises as the majority of the communication during these was focused on asking questions regarding how to solve problems, describing something that they found in the game world, tutoring other members or trying to administrate other group members' efforts. This was very different from the communication during the LEGO exercise, which was often void of meaning or actual task information valuable to other group members' performance in the exercise.

In the LEGO exercise, group 1 and 3 only collaborated as a group to the extent that they established a theme that the members' creations would follow. In group 1, the participants split up into a few smaller teams of two or three students to create things together as they couldn't come up with anything the entire group agreed on. In group 3 all the group members worked on solitary projects, but with a theme the group established together. Group 2 had a more calculated collaborative work procedure, as they used the first few minutes of the exercise to brainstorm ideas on what to build and later distributing work duties between the group members. Whether or not these differences are typical of the groups' gender constellations is hard to say, but previous studies have shown that girls commonly adopt a more democratic and communal approach to collaborative tasks [1].

In the Minecraft exercise, the communication between the group members differed from the LEGO exercise both semantically and in intensity. As stated previously the dialogue was more focused on how the participants could manipulate and interact with the game, which is to be expected as many of them were new to it and wanted to discuss it during their explorative process. Here, much of the dialogue seamlessly switched from clear task-focus (e.g. "What shall we build and how shall we build it?") to tool-focused discussions (e.g. "How do we get to the second floor of our building?") to sometimes just informing group members of their crazy antics in the game world (e.g. "I saw a chicken and I hit it with a shovel!"). However, while the tools were, as indicated by the focus of the verbal activity during the exercises, much more engaging in this exercise than with the LEGOs, the productivity for some members plummeted during the Minecraft task due to their inability to effectively contribute to the building process. In group 1's execution of the Minecraft exercise, the older kids in the group (the 9 year olds) took charge of the project as the younger children initially struggled more with grasping the mechanics of the game and the interface, and were often more enthralled by exploring the game world than sticking to the building plans they had.

4.1 Collaboration and Exercise Execution

The proximity of collaboration was also very varied between the different exercises and in general the group members' building blocks overlapped to a much greater extent during the Minecraft exercise. This indicates that the virtual space is more conveniently designed when it comes to letting several people collaborate on a creation simultaneously. In the physical space, such collaborations are troubled by several obvious factors, such as other people's hands being in the way and sharing a confined working area such as a table with peers, limiting the space available for materials and tools.

The ease of simultaneous work, and how relatively effortless the removal of misplaced pieces is in the virtual space, encouraged the group members to experiment and explore their possibilities together at a much greater extent. An example of the difference between the effects of LEGOs and Minecraft on a group's collaborative process could be seen in the first minutes of group 2's execution of these exercises. The following discussions are transcribed from video recordings (translated from Swedish):

Captured during the Minecraft exercise
G1 (girl 1): What do we build?
G3: I don't know… a cave?
G2: No, a castle!
G5: A house?
G1: A castle could be cool; this flat place in between the trees seems nice, let's build here.
G3: I'll start clearing out the trees a bit.
[*G1,2,4 and 5 start placing down blocks, seemingly at random, on the ground in the area G5 picked out*]
G2: [*While looking at a row of blocks that have emerged from the clutter of blocks*] Oh, this can be the castle wall!
[*The girls start helping completing the newly discovered wall, and from there on rooms start to take shape, and additional floors are created through, mostly accidental, discoveries*]

Captured during the LEGO exercise
G5: Let's build animals!
G3: Let's build a house!
G2: A house? That'll be too large…
G4: A house for the animals!
G1, G3 and G5: Yes!
G4: Alright, me, you and you will build the house, and you two can build the animals. I'll start with the walls.
G2: I'll build animals.
G5: Me too.
G3: I'll help with the walls; I'll do this side first.
[*After the work duties have been distributed, the girls start building their house and animals while talking about non task-related things, such as homework and the schedule for the school day. The plans for exercise execution remain unchanged throughout the exercise.*]

There's a clear difference in the group's creative process in the two tasks. The Minecraft exercise was executed in a very exploratory manner, and they changed their plans and vision as they stumbled upon new realizations regarding how they could interact with the game world. This type of collaborative learning process wasn't apparent in the LEGO exercise, as they were all on an equally high level of proficiency with that toolset.

Another interesting example is group 3's approach to the exercises. In the LEGO exercise the group members, as previously stated, established a general theme for their creations, but that was almost the full extent of their collaboration. When they entered the Minecraft world, which they were all previously familiar with from game sessions at home, they approached it by looking around the environment to try and find a location where it would be very challenging to build something. They soon settled on building the legendary city *Atlantis* in a nearby lake. During their work, however, they discovered the ability to transport water in the game using buckets. Upon this discovery, their session changed focus drastically and they started experimenting with the water and what they could do with it. The experimentation resulted in the creation of waterslides and vertiginous jumping platforms that they used to dive into pools they had created below (see Figure 2). In this case, similarly to group 2, the boys found a new way to approach the game by experimenting with their tools and evolved new types of goals in the game. They started out with a plan to build a city, but ended up competing with each other in trying to create the best jumping platforms in a little 'mini-game' of their own devise. During this session, a group of relatively experienced players was able to have a mutual exchange of newly discovered knowledge between one another as a result of the game's emergent nature. The ability to manipulate water isn't very interesting in and of itself, but the group members experimented with what it could be used for in the game, and from that they were able to create new ways of experiencing the game and competing and collaborating with each other.

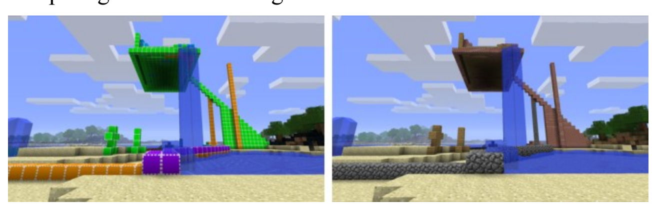

Figure 2: Group 3's "waterpark" creation, from researcher's (left) and player's (right) point of view.

4.2 Free Play Sessions

During the sessions where 16 children had the opportunity to play Minecraft without explicit instructions to collaborate or perform any specific tasks in the game, several interesting observations were made. Even without the instructions to build something together (they didn't receive explicit instructions at all during the free play), many participants naturally stayed grouped up while discovering the game world, and some decided to settle down in an area they found aesthetically pleasing and started to learn how to build their own houses. Here, several cases of mutual learning through peer collaboration emerged; this short dialogue between two participants aged 8 and 9 was captured during the free play exercise (translated from Swedish):

Captured during a free play session:
9yr: Alright, we've built a cellar, we need a roof!
8yr: Yeah, how do we build that?
9yr: We need taller walls first.
8yr: How do you build tall walls?
9yr: [*after some experimenting, he figures out how to stack blocks on top of one another to create a short wall*] You just point on the top of these and place the bricks.
8yr: Ok.
[*They build a wall out of two stacked blocks, they ponder how to increasing the wall height further, their character can only jump on top of one block, not two stacked blocks*]
9yr: We have to get up higher, the roof will be right on our heads…
8yr: [*creates a simple flight of stairs by placing a block next to the wall and jumping on top of it*] Look at me, I'm up here!
9yr: How did you do that?!
8yr: [*Jumps back down*] Like this, just place a block here and then you can jump up [*shows the maneuver by jumping up on his previously placed block*]

Similar tutoring events occurred if a player stumbled upon another player's creation and wanted to know how they built it. The self-taught player would then instruct the inquirer in how to mimic their building style, thus passing that knowledge on.

5. DATA ANALYSIS

Video recordings and analytics performed on recorded communication and SICC-data from the different groups indicate that there are clear differences between the groups' face-to-face and technology mediated emergent collaboration. There is a clear lack of intimate collaboration between all the group members in two of the groups (group 1 and 3). During group 1's LEGO exercise, there's not much evidence of any sort of communal effort to work together; in this case the participants formed their own clusters of the group to pursue their own goals rather than contributing towards a common goal. In group 3 the children established an overarching theme of their structures, as everyone agreed to make a "snowy landscape"; the execution of the vision was however far from uniform and the group members started pursuing their own ambitions without much regard for other group members' efforts. This behavior changed severely during the Minecraft exercise. A summarization of how the communication changed between the exercises can be seen in Figure 3.

5.1 LEGO Exercise

The factors that were the most prominent and consistent when it came to all groups' work process during the LEGO exercise were the group members' uniformly high tool proficiency and concerns for tool constraints and canvas accessibility. In two of the groups, group 1 and 3, there was almost no conversations about *how* their visions would be collaboratively executed, and the discussions about what they would build were also very ambiguous and limited. Group 2, however, were very organized in these manners and they all agreed upon what specific theme their buildings would have and how they would collaborate to build the necessary components (see Figure 4).

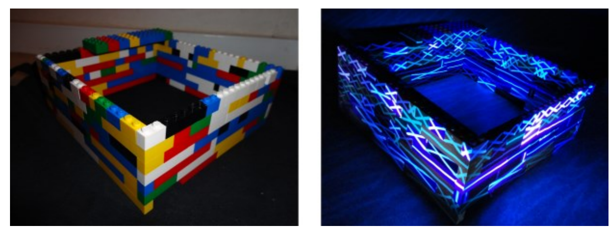

Figure 4: Group 2's LEGO barn from student's (left) and researcher's (right) point of view. There's a high amount of overlap between two participants' blocks (the X-es and horizontal lines belong to two different students).

That being said, according to Jehng's model for identifying collaborative patterns there are no variation in the different groups' cooperation, they all seemed to conform to the peer collaboration pattern seeing as they were all of an equal skill level with the caveat that they didn't need to explore the tools together as they were already familiar to them; none of the participants made an effort in educating others or to get educated themselves, there was simply no need to.

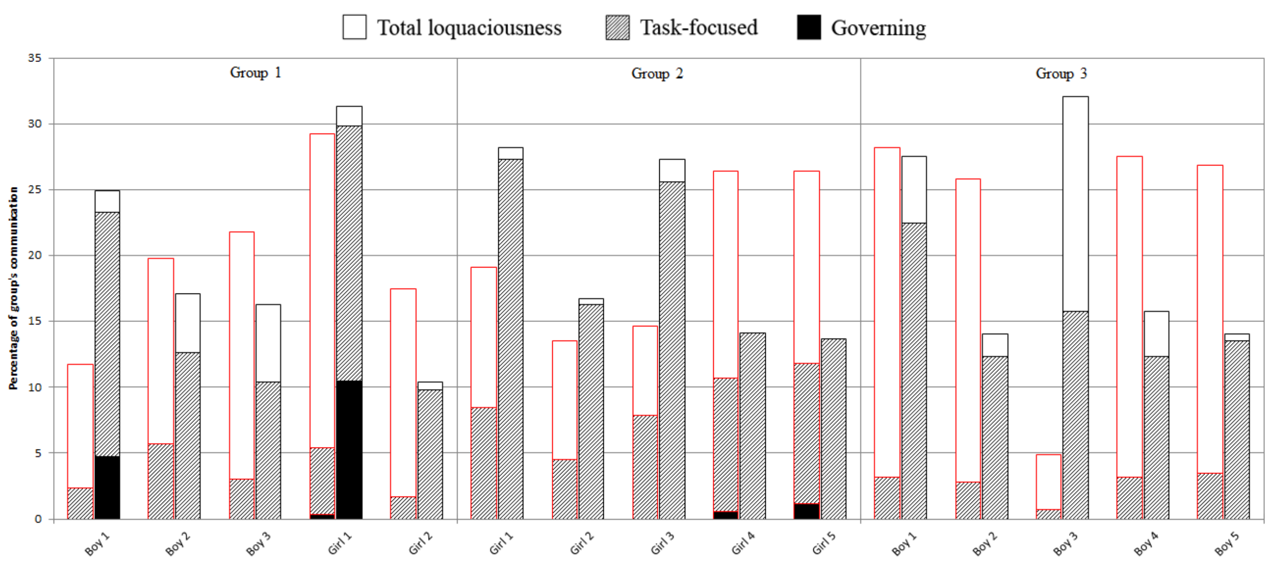

Figure 3: Group's verbal activity distributed between members during the LEGO exercise (left/red bars) and the Minecraft exercise (right/black bars).

The majority of the task-centered communications were focused on either establishing a general theme for the group members' work, or the participants narrating their own construction process. A fair amount of the verbal activity consisted of the children creating fiction around their work and crafting scenarios which would have led to the manifestations of their constructs if they were real objects (such as their real-world functions and reasons for existing). This can be a result of the LEGOs being very familiar to the participants, which made it easy to set clear goals and achieve them and to invest mental faculties in thinking further than merely building execution. Figure 5 is an example of highly distributed work that conformed to an agreed upon theme for a group's building efforts and of a constructed narrative.

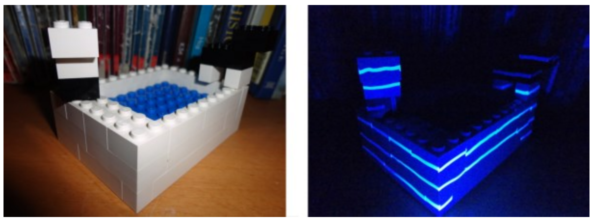

Figure 3: An example of more distributed work. Group 3 worked separately on individual objects with a "Snow" theme, one group member built an icy swimming lake for sheep.

At several occasions the constraints of the LEGO, that is to say the finite amount of pieces each participant was given, was directly responsible for what was constructed. Participants frequently stumbled upon blocks of particular color and shape that caught their fancy and these findings would often inspire the participant to build something suited to that particular piece and start looking for additional pieces with similar attributes. In this case, scarcity of material both acted as inspiration for creations that the participants hadn't previously considered (for example, creating flags became a common theme among some members of group 1 upon discovering thin pieces of suitable colors) and as a disruption of the groups' collaborative work as some members deviated from the agreed upon building themes to create something of the piece they were captivated by.

5.2 Minecraft Exercise

As opposed to the LEGO exercise, the participants weren't as uniformly proficient with the Minecraft interface and the groups varied from novice to adept when it came to navigating and interacting with the world; group 1 being the least proficient, group 2 being of average proficiency and group 3, in comparison, being highly proficient. This had a clear impact on the groups' collaborative patterns, and the patterns shown during the groups' executions of the Minecraft exercise were very diverse. As previously mentioned, there were big differences in how group 2 and 3 approached the different exercises; the LEGO being approached with pre-planning which was followed to the end of the exercise and Minecraft being more of an exploratory exercise in which the groups' vision changed when new possibilities were discovered in the game. The reason we consider these as positive results concerning emergent games' viability and value as educational tools is most evident in group 3's Minecraft exercise. A group of users experienced with the tools presented to them found a new way to view an element in the game world (in this case, water) and this new realization inspired a whole new approach to the game. In this new player-devised gameplay, the participants were pulled out of their comfort zone and started experimenting with the newly discovered element's properties and devised ways that it could be used to enhance their experience. In this case, the emergence encouraged the players to interact to a greater extent than just determining how they would use tools they had already mastered; something which could be very valuable in an educational context. This is also beneficial from a game designer's point of view, seeing as the lifetime of a game can be greatly expanded when players have the opportunity to find new variables within the game which they can combine with their previous knowledge, often leading to many interesting and compelling situations and encouraging creative entrepreneurship.

6. CONCLUSION AND FUTURE WORK

From the recordings and analysis of the children's buildings, we can identify some areas in which emergent games such as Minecraft can excel and which can be developed further if games of this nature are to be used in education. When it comes to the practical constraints and personal space of the collaboration area, technology mediated interaction have a clear advantage over traditional forms of collaborative platforms. Materials and access to work areas doesn't need to be constrained in the same way they naturally are in the real world, which often eliminates unpredicted antagonistic undercurrents during collaboration [26], unless the game's designer or the instructor explicitly wants to implement those constraints. The infinite amount of resources and their ease of use also encouraged many of the children to experiment wildly and explore the possibilities and limitations of the platform together. The data from the experiments also show that the participating student's verbal activity changed drastically between exercises (see Figure 3), in some cases in positive ways as reserved members would become more expressive and partaking in group discussions.

That being said, there are several disadvantages intrinsic to emergent games that make them unsuitable for certain types of educational activities. The broader verb palette you equip the players with, the more likely they are to use it in ways that don't necessarily contribute to the type of learning the educator wishes for. In more linear learning games, the educator can be confident that the student is gaining some knowledge within a certain subject by seeing that the game's narrative is being traversed, as mastering the heuristics the game focuses on teaching is necessary for the traversal itself. This is why clear and effective measurements that can show the work processes of the students are essential for emergent games to be usable in educational circumstances. The method used in this research, especially the analysis of audio recordings, is very high maintenance and seems difficult to automate. So, while the produced data was usable and provided interesting results, the process of analyzing the data was more cumbersome than what's acceptable for using an emergent game such as Minecraft in an educational setting. In particular, the SICC could be improved upon by implementing means to summarize the metrics as well as providing time-specific data to see the entirety of a group's working process. Currently, we used means that just summarized the end results of the collaborative work, but numeric data to track the amount of placed blocks in the world, and measuring the overlap between blocks could be implemented with a reasonable amount of effort and serve as a good starting point for teachers to evaluate students' work or help guide group debriefings. Beyond these metrics, finding means of assisting educators to visualize and contextualize the verbal activity and progression of a group's labor would dramatically increase the usefulness of emergent games as learning tools. The final goal of the research will be to determine how tracking individual actions and measuring collaboration could be used in emergent learning games in general, and not just for Minecraft. While the SICC may not be suitable for any emergent environment, the principle of tracking where students direct their efforts could be a necessary foundation for making emergent games usable for education in general.

With this in mind, in future projects we intend to find accessible ways of both gathering and visualizing data, with the goal of making the process efficient and easy enough to be usable in educational context without a researcher's assistance. The opportunity for the participants to explore and experiment with the game world in order to reach goals they set for themselves, or to acquire new ones, sparked several creative endeavors and spontaneous collaborative behaviors, even when the participants were not instructed to work together. Harnessing this potential by overcoming the difficulty to evaluate students' work in the emergent environment could certainly result in the creation of very engaging and flexible educational tools.

7. ACKNOWLEDGEMENTS

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