Design-centered Learning

Developing collaborative skills by making games

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A thesis submitted to the School of Design, Carnegie Mellon University, for the degree of Master of Design in Communication Planning & Information Design

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Abstract

Communication technology drives new opportunities and expectations for employees to collaborate across countries, continents and time zones. This has the potential to bring people together, increasingly connecting individuals with different experiences, perspectives, and areas of expertise. However, it also complicates collaboration. People working together in these situations must both adjust to differences between in-person and digital interactions, and also navigate the complexities that accompany a dynamic and diverse team.

I address this need by I creating a set of design-oriented activities aimed at building a specific situation for children that affords the development of their collaborative skills. Over the course of three months, I ran a 9-session workshop with twenty-four fifth graders where the students collaboratively engaged in a game design project. During the workshop, children made physical games to teach players about the science of flight. As the students worked through this process, they investigated games and flight, developed game concepts, and then designed, play-tested and shared their games with others. Pre-post observations and test results show increases in fifth graders' collaborative interactions and understanding of flight content. This study provides qualitative data to support the claim that game-making workshops can increase children's collaborative skills, and lays the groundwork for further investigation.

Introduction

Communication technology drives new opportunities and expectations for employees to collaborate across countries, continents and time zones. This has the potential to bring people together, increasingly connecting individuals with different experiences, perspectives, and areas of expertise. However, it also complicates collaboration. People working together in these situations must both adjust to differences between in-person and digital interactions, and also navigate the complexities that accompany a dynamic and diverse team.

Educational leaders acknowledge this need and currently investigate how to teach people to collaborate in a variety of situations. One area of success has been in the development of curriculum guiding teachers to explicitly instruct children in how to have conversations that support collaboration. I build on this work, proposing a set of design-oriented activities aimed at building a specific situation for children that affords their development of collaborative skills.

Building on my experience in education, I created and facilitated a 9-session design workshop with twenty-four fifth graders. During the workshop, children made physical games aimed to teach players about the science of flight. They worked through a process, investigating games and flight, developing game concepts, then designing, play testing and sharing their games. This approach offers three distinct advantages. First, it builds on children's expertise with game play, where they often have already experienced successful collaboration with peers. Second, the fifth graders create a physical game. This balances the need for complexity—a critical

element of a collaborative situation—with a visible, concrete goal appropriate for fifth graders' level of development. Third, children have direct access to resources and tools, such as game exemplars, basic materials, etc., so they can make choices and lead parts of the process. The combination of game play, physical making, and child-led opportunities creates a concrete and engaging space for children to build their collaborative skills.

In this paper I share findings regarding learning as well as direct observations that inform my reflections on the usefulness of these physical game design workshops. Comparisons of pre- and post- collaborative assessments show a positive shift in the ratio between children's collaborative and non-collaborative interactions. Children's content understanding, as measured by comparing pre- and post- tests on the science of flight, increased as well. I also reflect on how well the process of game making supports collaboration by using excerpts from the game making workshops to depict thecollaborative challenges children worked through as they created their games. Finally, I reflect on game making as a space for children to learn to collaborate and suggest opportunities for future exploration.

Background

To frame the contributions of this thesis, I review the literature on collaboration and educational approaches to teaching collaboration. I also provide background on other novel design-oriented approaches that could support children in developing their collaborative skills.

Collaboration

In lay terms, collaboration means, "to work together on a task" (Dillenbourg, 1999). For social psychologists, collaboration "involves the construction of meaning through interaction with others" and is characterized by people's "joint commitment to a shared goal" (Littleton & Hakkinen, 1999, p. 21).

This definition makes it clear that **interacting** (working together) is the process through which collaborators develop a shared understanding, not a goal in itself like in cooperation. I use these expert distinctions throughout this study as they clarify what it means to "work together". They also inform my focus on participants' process of collaborating which I assess through their observable interactions.

In exploring collaboration, researchers have identified numerous factors that one can externally control in order to set up **situations** that support collaboration. These external factors include, for example, a space for synchronous communications and for interactions that are negotiable, with a potential for misunderstanding (Dillenbourg, 1999). People tend to collaborate most effectively when they have

similar range of knowledge and status, an awareness of shared goals, and low-division of labor (Dillenbourg, 1999).

Certain types of projects and problems afford collaboration. These include problems with no known "right" answer or complex problems requiring deep expertise in several domains. Opportunities for negotiation and misunderstanding occur naturally in these tasks. Also, because the need for collaboration may be more apparent, participants may stay more invested in the collaboration.

At the same time, these types of situations challenge teams' ability to collaborate. For example, fluid goals and widely varying team member perspectives help create a space for negotiations, but also make it more challenging for the team to develop a shared understanding of the problem. Also, an obvious, but necessary prerequisite for collaboration is that individuals choose to join in the collaborative situation and interact with one another (Dillenbourg, 1999). At some point during the collaborative process, individuals on the team have to overcome both situational and individual challenges on their own terms.

Many researchers including Joiner, Littleton, Faulkner and Miell, explore how people learn to collaborate; the process of collaboration. They pay close attention to individuals' interactions within a collaborative situation. Building on this work, I observe collaborative interactions to investigate and measure the development of children's collaborative skills as they work together to make physical games about flight. These interactions include: questioning; explaining or demonstrating; sharing ideas or information, observing one another; jointly creating; challenging others' contributions; advocating increased effort and perseverance among peers (Dawes & Sams, 2004; Bachman & Grossen, 2004; Swan, Shen, & Hiltz, 2005). Similarly, I observe and document behaviors that hinder collaboration. These include: ignoring or not responding to one another and dismissing other's ideas out of hand (without requesting more information or explaining why they disagree).

Because my goal is to explore whether the specific collaborative situation of game making can support children in learning to collaborate, I need to understand what happens when people collaborate. Researchers have identified individual cognitive processes characterized as collaborative (including induction, conflict and internalization) (Dillenbourg, 1999). However, these processes happen internally and

researchers have no evidence of these processes occurring unless the participant shifts how they interact with their team, actively demonstrating this learning. Experts have also found that collaboration can positively affect learning even when the resulting product is considered inferior (Littleton and Miell, 2004). Therefore, I did not want to use project outcomes to assess collaboration. Instead, I chose to develop a process intended to encourage fifth graders to interact collaboratively and assessed their collaborative skills by observing their collaborative and non-collaborative interactions which I listed above.

Teaching Collaboration

The process of teaching children to collaborate used to live primarily in early education programs. Strong examples of collaborative learning curriculum in early education exists in Emilio Reggio and Montessori programs as well as other programs that create environments supporting children's development. These programs are known for their focus on the 'whole child' and intentionally set up situations for children to learn social-emotional skills including collaboration. In these early childhood education environments, teachers provide opportunities for children to engage in "free play" where they enact different social situations, swap roles, and experiment with peer interactions to see what happens. These programs are generally adept at building on children's existing interests and motivations. The teacher sometimes joins children in their play to model effective collaborative strategies or give direct instructions when children struggle. However, they balance their interjections with observation, providing children with opportunities to experiment and work through collaborative challenges on their own. These early childhood programs are clear examples of ways to scaffold and support child-led collaborative situations.

"Collaborative learning" became a popular catchphrase in the education world when some studies demonstrated higher learning gains when students collaborated than when they worked individually (Damon and Phelps, 1989). However, more recently researchers have begun investigating people's collaborative interactions rather than focusing primarily on collaborative outcomes (Littleton & Miell, 2004). Educators have started to re-envision education for future, and place new emphasis on the

process of learning to collaborate (The Partnership for 21st Century Skills, 2009 & Deeper Learning Initiative, 2010). This has led to the development of new curriculum around teaching the communication skills that support collaboration. Currently, many curriculums including, "Exploratory Talk" (Barnes & Todd, 1995), "Accountable Talk" (University of Pittsburgh, 2013), "Thinking Together" (Dawes & Sams, 2004) and Visible Thinking (Harvard, 2014) focus on explicitly teaching children how to interact collaboratively. Researchers began developing these teaching curriculums after they found that children who were put in groups to collaborate in a school setting were frequently "off-task, uncooperative", and the conversations had "little educational value" (Dawes & Sams, 2004, p. 96). These researchers also address concerns around issues of cognitive load as the curriculum directly teaches children how to talk productively with others and highlights specific interactions useful for helping children develop their thinking. These include, "asking for help, questioning, observing one another and jointly creating"(Dawes and Sams, 2004).

Other areas that support learning to collaborate

Design-centered learning

Design-centered learning is another growing area that overlaps with design and education while focusing on 21st century learning goals including collaboration. In the design world, Allison Druin has pioneered intergenerational co-design design teams for the purpose of developing children's technology. She has developed strategies for effectively facilitating design workshops where children are "design partners". Because one of the main goals of Allison Druin's co-operative inquiry methodology is to get design teams to explain and elaborate on ideas. The strategies within her "co-operative inquiry" framework are useful not only in creating design workshops but also in helping children develop their collaborative skills (Druin, 1999). This work also discusses participants' self-reported learning, which includes learning how to "work together" and identifies the opportunity for further exploration of learning through design workshops (Druin, 2002).

In K-12 education, designers, educators and researchers are currently developing different activities for integrating design-centered learning into schools. Several of these supports focus on collaboration in addition to the related skills of critical thinking, communication, innovation, creativity, and systems thinking. Some of the most interesting developments in design-centered learning include Stanford's Redlab, Design Thinking for Educators from the design firm IDEO and the Institute of Play with their partnership with Quest for Learning schools. I am particularly interested in the Institute of Play as they are creating multiple solutions to "pioneer new models of learning and engagement" through "games and play" (Institute of Play, 2014). Their "Design packs" support educators in using games in school design, curriculum design, and suggest specific lessons supporting systems thinking. These investigations of the integration of design-thinking in education and learning identify key processes in the design/making process and report on challenges in implementation.

Play and making

I also investigated informal collaborative learning opportunities in environments outside of school, particularly, play spaces. Examples of digital play spaces that intentionally focus on learning include "Scratch" from MIT and "Game Star Mechanic" from the "Institute of Play" (Gamestar Mechanic Learning Guide, 2009 & ScratchEd, 2009). While these digital game spaces don't require collaboration, the platforms of both systems do support sharing. Also, researchers have been exploring learning that occurs within the environment surrounding digital games, the "in room" learning. This research looks at learning as transfer and "show[s] how actual game play is shaped, sometimes in very consequential ways, by people and material resources present in the room but invisible 'in-game'" (Stevens, Statwicz & McCarthy, 2008).

Physical making kits bring this "in-room" and "in-game" learning even closer together. For example littleBits and Lego-Mindstorms, while again not expressly focusing on collaboration, can easily become informal collaborative and content learning spaces (Electronics Inc., 2013 & Lego, 2014). littleBits is a collection of tiny circuit boards that easily connect to make larger circuits and Lego-Mindstorms are kits to help people code their own robot made out of Legos. These game/play kits merge digital and physical play and serve as examples of potential collaborative play environments that

are grounded in the physical world while taking advantage of the digital world.

Most of these digital and physical play spaces currently lack data that clearly demonstrates learning. However, informal observations of groups of children engaging in these spaces provide an indication of their potential value for various types of learning, including learning to collaborate.

Method

My goal in this project was to investigate if—through the process of designing a game as a team—children could learn how to collaborate and could learn scientific content related to the game. Because this is an exploratory research project in an environment with many factors at play, I chose a "research through design" approach (Zimmerman et al. 2007). This process helped me investigate the efficacy of this idea (children learning collaborative skills by making games) on the ground.

I chose fifth graders as the subject of my research for two reasons. First, fifth graders are at an interesting stage of development. They have the capacity to recognize that their perspective may not be the same as others, but may not yet be able to think abstractly without scaffolds to make things more tangible and concrete. Also, this age group overlaps with several related studies on collaboration (Howe, McWilliam & Cross, 2004, Dawes & Sams, 2004).

My research through design process consisted of several stages:

1. **interviews** with experts in the fields of game design, cognitive psychology and education;
2. **exploratory workshops** with children to investigate games;
3. **study** consisting of
    - **pre-tests** to assess collaborative skills and science content understanding (flight);

-**nine game-making workshops**; and

-**post-tests** to assess collaborative skills and science content understanding (flight)

4. **analysis**

-pre-post assessment analysis

-direct observations from the nine game design workshops with discussion

Interviews

At the very beginning of my process, I interviewed a child development expert/ educator from Carnegie Mellon University asking for feedback on my study concept and suitability for the age range of my potnetial child stakeholders. She informed my decision to focus on fifth graders, provided resources on knowledge creation, and suggested that I narrow game topics to something that I could make physical and concrete.

I also interviewed an educational game designer mid-way through my exploratory research to learn more about the process of game design and its challenges. The game designer felt that designing digital games provided a more challenging experience than designing physical games. He also shared his rather negative opinion of games that focus primarily on learning and said he couldn't think of any really fun and innovative educational games. This contributed to my decision not attempt to design a learning game, but instead to give children an opportunity to make and design themselves.

After deciding to develop and run game design workshops, I again interviewed the child development expert/educator to discuss assessments and potential workshop structures. She informed my pre- post- assessment structure and provided resources on direct instruction, informing some of the instructional aspects of the game design

workshop study.

I later interviewed two experienced teachers with current experience teaching children between the ages of eight and eleven. One has eight years of experience teaching in "high-need" schools, the other has taught for several years at a charter school. I asked them about whether/how they incorporated opportunities for collaboration. One said that after eight years teaching, she finally felt like she was comfortable enough with classroom management and required curriculum that she was starting research to learn more about supporting collaboration in the classroom. She shared about her recent experience using a composite of curriculums explicitly teaching 'talk' that supports collaboration. She also shared her challenge of stepping back and giving students the authority to work through conversations on their own. The other teacher works in a school that vocally supports collaboration. She uses the Visible Thinking curriculum from Harvard and a composite of other resources. The examples she gave regarding her students' development collaborative skills focus on accountable talk. She shared a rubric her school uses to assess teachers. Her proficiency as a teacher is partially measured by her integration of Visible Thinking curriculum, collaboration with other teachers and stakeholders, and her ability to structure opportunities for students to engage in collaborative learning.

These two teacher interviews confirmed that educators have a vested interest in teaching collaboration and actively seek resources. However, outside of accountable talk and related communication-based resources, there were many opportunities to develop other forms of collaborative resources.

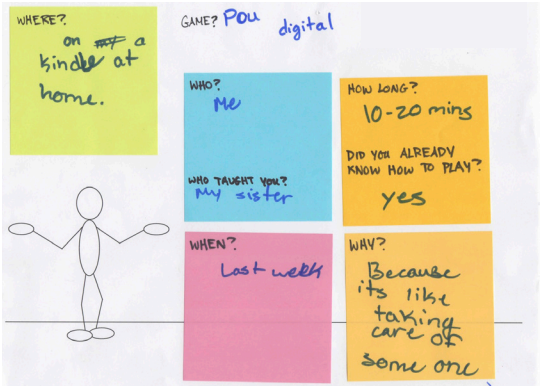


image 1: children share about the last game they played and their surrounding environment

image 2: observing interactions during game play

Exploratory workshops

I ran eight exploratory workshops in the fall with 24 fifth graders. I ran each session four times during the course of a week breaking the 24 fifth graders into smaller groups of six. Each session was 20-30 minutes long (to ensure that I didn't impinge on classroom instructional time). To work effectively within this time constraint I stretched some activities over two sessions.

I focused much of my exploratory research on children, as research has shown that

image 3: embodying game during exploratory workshops

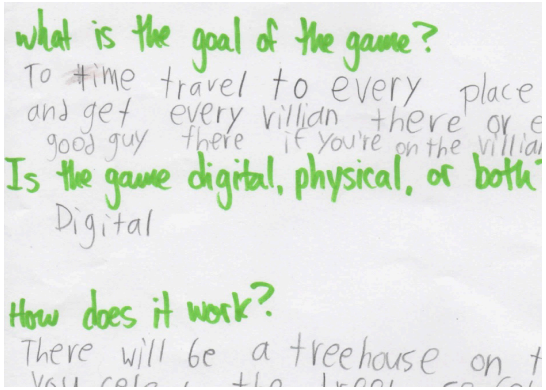


image 4: game concepts from exploratory workshops

children are frequently under-utilized stakeholders in the design process (Allison Druin, 1999). In the beginning, I wanted to learn about fifth grader's game experiences including what kind of games they played, who they played with, their preferred game forms and what interactions occurred naturally during their game play (image 1). In one of the sessions children played Pick-Up Sticks according to the written rules at first, but when time was running out, changed the point system. This fit with my early research on game play affordances. While digital game play usually has constraints built into the game structure that requires coding knowledge to change, physical game play rules tend to be more fluid and children can change them to suit their goals and constraints.

Because these fifth graders demonstrated an eagerness make, in later sessions I shifted my focus away from game play and into making so that I could get feel for how much scaffolding they would need to actually make games. In these later sessions, fifth graders brainstormed ideas, and briefly worked in teams to develop game concepts (image 2). They then embodied their concepts, physically enacting how their game would work (image 3). About half of the participants quickly brainstormed game ideas they were ready to share and develop (image 4). Originally, I had thought I might create co-design workshops and partner with fifth graders to design games. However, in these exploratory workshops I found that the fifth graders wanted ownership over their game-making process. They wanted to drive their game-making direction.

At the end of the participatory design workshops, I also ran a couple brainstorming activities where participants discussed what they knew a lot about and what they were curious about. This helped me to choose a content area—flight, and made it possible for me to assess content learning with pre- and post-tests.

Study

After analyzing what I learned from literature reviews, interviews, and exploratory workshops, I designed a game workshop for fifth graders. My goal was to investigate

whether the process of making a game about flight could support fifth graders in developing their collaborative skills. I chose to run pre- and post- tests so that I could see if game design workshops might lead to changes in my participants' collaborative and non-collaborative interactions. I also video recorded the workshops so I could gather and review qualitative data.

Pre-assessments

To test children's collaborative skills before the workshops, I challenged groups of children (eight groups of three, controlling for academic level and gender) to a short team challenge. For more information on the challenge, visit: http://marshmallowchallenge.com/Welcome.html. I video recorded and later coded the challenge activity noting each child's collaborative, neutral and non/collaborative interactions.

Collaborative interactions

Positive interactions

- questions
- explains how or why, demonstrates
- shares, suggest, or observes ideas, plans, feelings
- agrees, affirms
- advocates
- reflects
- disagrees with positive interaction following

Neutral interactions

- states a need, directs, comments
- has side conversation
- disengages

Negative interactions

- no response, ignores
- disagrees with no or negative interaction following
- repeats multiple times with no change
- makes without agreement

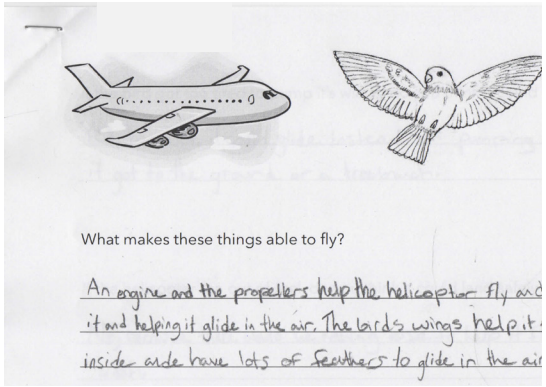


image 5: game workshop boxes

To assess flight content learning, I gave children a paper pre-test on flight (image 5) and scored their responses using a rubric.

Game design workshops

For the game design workshops, I again grouped children in teams of three (different teams than for the collaborative assessment) and controlled for academic level, gender, and game-interest level. Each week I ran 4 game design sessions. Each session ran for about 25 minutes. I worked with two teams during each session. I guided children through nine workshop sessions in which they investigated games and flight, developed game concepts, then designed, play tested and shared their games. I based this process on the Game Design toolkits from the Institute of Play and a condensed version of IDEO's framework of Design Thinking for Educators.

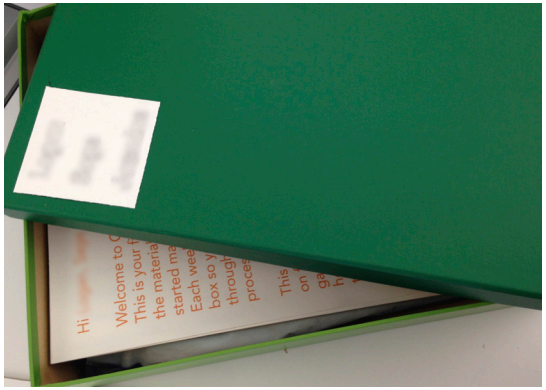


image 6: game workshop boxes

My primary goals were for students to fully participate and engage in the game-making process with their team and for individuals to develop their collaborative inquiry skills. Specifically, I wanted to see if there were changes over time in how children work through disagreement, respond to one another, and explain why/how they want to do something. I also had a secondary goal for children to learn content knowledge about flight. I wanted them to be able to name the four forces that affect flight and explain how these forces relate.

Process

Project definition (Week 1)

I formally challenged teams to begin the process of designing games. I gave each team their own box of materials with written instructions for the session (image 6). The first week this read, "Hi, Welcome to Game-makers! This is your first box with all the materials you need to get started making your game. This Game-makers kit focuses on flying."

Teams used worksheets as guides and investigated the workshop plan, made choices

image 7

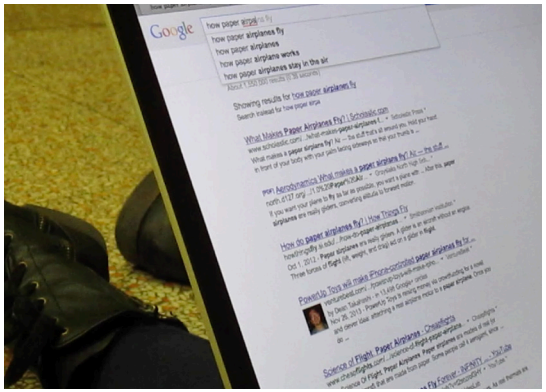


image 8

image 9

about their audience, game style, and game goals. They also worked together to design a coach character that would give them feedback throughout the process.

Investigating games and flight (Weeks 1-2,4)

Children investigated flight. They choose to research online, play with things that fly (image 7 & 8), read a printed document on flight and/or watch interactive videos from the Smithsonian about flight. For one of these sessions they received instructions from the coach they had designed and I animated. I also brought games and toys for teams to investigate. These included GoldieBlox (a making/story game), littleBits (a sandbox style game with electronic modules), a Frisbee, the Game of Life, Pick-up Sticks and Uno. Teams played games of a similar style to the one they had chosen to make and noted what worked about the game, what they liked, as well as what they would do differently or change (image 9).

Ideating and making (Weeks 3-5)

Children shared their game ideas and negotiated their game plan. They made their game, making adjustments to the plan as they worked and figuring out their game details (image 10). I provided each team with supplies. These included paper, card-stock, sticks of balsa wood, sticky notes, markers, pencils, glue and tape. Each week I asked teams to make a list of any additional supplies they needed. Their supply requests included feathers, paper clips, a ruler, tiny bird figures, and dice. During one session, I instructed four teams to try taking on specific roles. These roles included that of facilitator, game expert, and learning expert. Similarly, I asked four teams to discuss and document "team agreements" specifically how they would handle disagreements.

Play testing and Iterating (6-7)

During these sessions, one teams explained to another team how their game would work. They also tried playing one another's games. I joined the teams, listening to

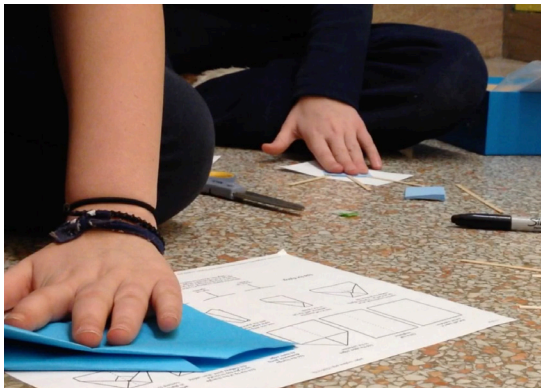


image 10

designers' explanations and also asking questions to clarify misunderstandings about how the game worked. We also made suggestions. Teams then continued to make their games, adding to their game designs based on what they learned.

For one of these sessions I gave some teams who seemed to be struggling a choice. Their instructions read, "Hello! Today you have a couple choices. 1. Work on finishing your game. You can play a video clip on the computer if you want to review the feedback you received last week. 2. Take a break from your game and have some fun with your team—explore flight materials or play a game…you choose. Sometimes, if you have a team conflict or just feel stuck, it's worth it to take a break and have some fun together."

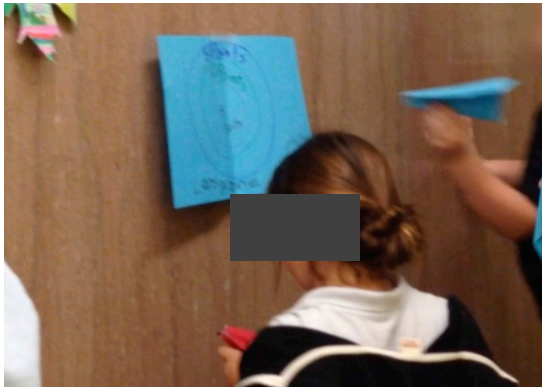


image 11

Sharing (Weeks 8-9)

The instruction sheet for the last session read, "Hello! Today is our last day of game making workshops. It's time to share what you made. Talk with the other team and ask them to try playing your game. Watch them play and notice what's working and what you would like to change. You've worked really hard on your games and it shows! Great work!"

In these sessions, teams shared final versions of the games they made (images 11 & 12). I made changes to the instructions so teams explained and demonstrated how their game worked, clarified questions and then played their games with the other team rather than just observing.

image 12

Post-assessments

I followed up with a post- assessment of children's collaborative skills. Again I challenged groups of children (eight groups of three, controlling for academic level and gender) to the same building challenge as the pre-assessment. I changed the teams again to ensure that children worked in teams that were different from both their game design teams and their pre- assessment teams. I video recorded the challenge activity and coded each child's collaborative and non/collaborative

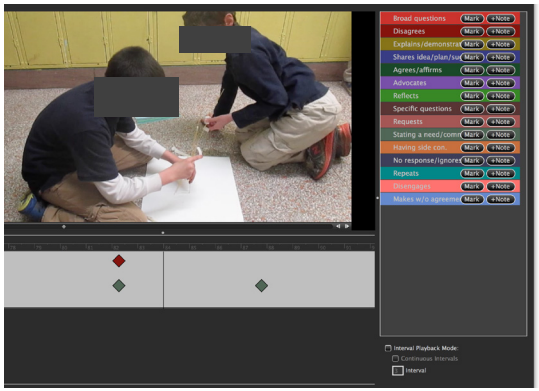


image 13

interactions

To assess flight content learning, I again gave children the paper pre- and post- flight tests and scored their responses using the rubric (table 1 & 2).

Analysis

I analyzed the data from pre- and post- collaborative assessments using V-code (image 13) to mark instances of children's collaborative/non-collaborative interactions. I then compared the percentage of children's collaborative/non-collaborative interactions pre- and post- game making. I also compared participant's scores from the paper-based test on flight before the nine session game-making workshop with their post- scores.

I analyzed qualitative data from the game making workshops by reviewing videos from each stage of the game-making workshops and documenting participants' challenges and successes in collaborating as well as in game making. I reflected on the collaborative situation afforded by their physical game making process.

What makes these things able to fly? (Pic. of airplane, bird and helicopter)	
5	Explains the forces of flight. These include lift (air pressure on wings) vs weight (gravitational force), and thrust (engines, propellers) vs drag (aerodynamics, air/wind against the object). Student uses visual/verbal descriptors to clearly communicate how these factors relate.
4	Explains how wings work (movement/air) and sometimes mentions other factors.
3	Mentions multiple factors (including wings/lift) but doesn't explain how they work
2	Mentions a couple factors (including wings/lift) that make flight possible in our world, but with no attempt at explaining relationship.
1	Addresses factor of wings/lift that make flight possible in our world with no further explanation.

table 1: Rubric for flight pre- and post- test, p1.

If a bird was too tired to pump its wings/helicopter ran out of fuel could it land safely?	
5	Answers question correctly. Thoroughly explains the imbalance of weight for the helicopter and the potential for the lift of the birds wings to help it glide safely down. Covers all applicable biomechanical factors (weight/thrust/lift for helicopter, lift of bird's wings to help it glide)
4	Answers question correctly. References most obvious biomechanic that affects each situation.
3	Answers question correctly but explanation is unclear.
2	Does not answer question correctly but explanation hits on some factors that affect flight
1	Do not answer question correctly and if there is a explanation, it doesn't mention factors that affect flight.

table 2: Rubric for flight pre- and post- test, p2.

Findings & discussion

I share and discuss two forms of findings from this "research through design" project. First, I share data from pre- and post-game design assessments and discuss children's learning of collaborative skills and flight content. Second, I share what I learned from observing the game design workshops, using excerpts to demonstrate findings and guide discussion.

Table 3 provides a breakdown of the coding from the pre- and post- collaborative activity. Column 1 shows the categories of positive, negative and neutral interactions. Column 2 shows the pre-assessment numbers and percentage of total interactions for each category. Column 3 shows the post-assessment numbers and percentage of total interactions for each category. Column 4 shows the percent change between the number of pre-assessment interactions and post-assessment interactions for each category.

figure 1

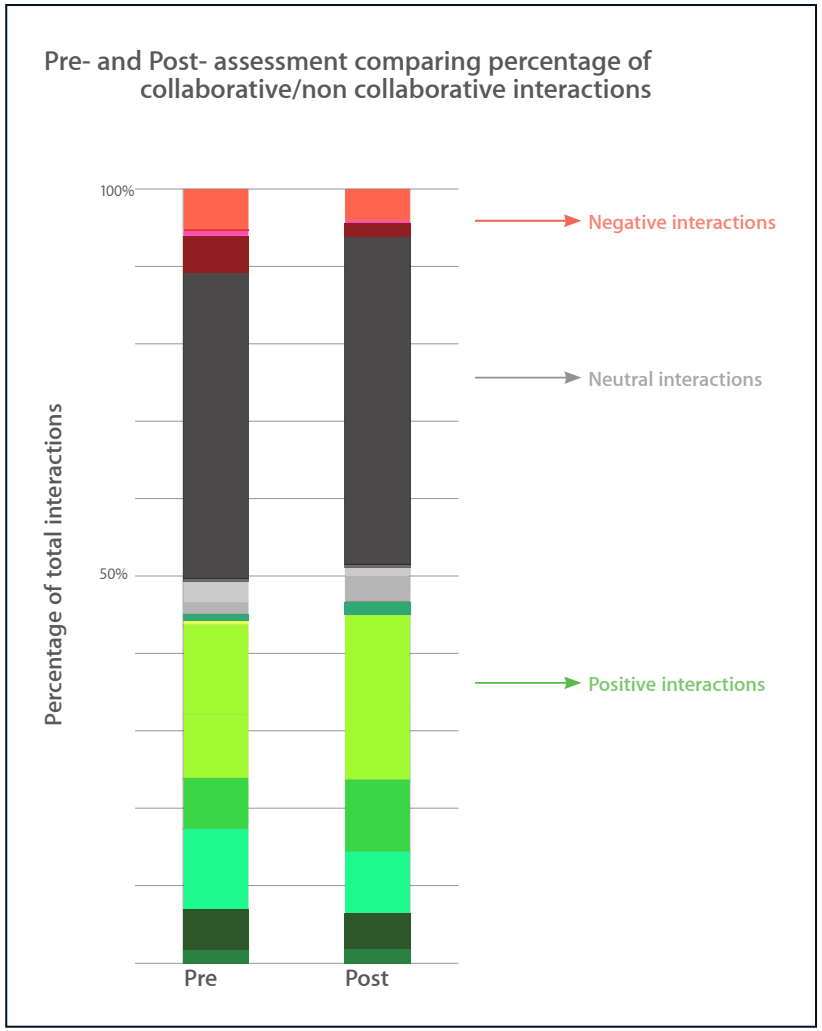


Figure 1 displays a stacked bar graph showing the change in behaviors from the pre- and post- collaborative activities. The items shown map to the structure of table 3, where the top item is "disagree" and the bottom item is "agrees, affirms."

The most important findings from this table and chart are:

Fewer disagrees and ignores— The data from the collaborative learning pre- and post- observational assessments shows that interactions negatively affecting

table 3:

	Interaction	Pre #	Pre %	Post #	Post %	Change %
Negative	disagrees, no or negative follow-up	56	5.55%	45	4.46%	-19.64%
	makes w/o agreement	7	0.69%	4	0.4%	-42.86%
	repeats (more than 2x, no change)	2	0.2%	0	0%	-100.00%
	no response, ignores	51	5.05%	20	2.00%	-60.78%
		116	5.94%	69	2.4%	-40.52%
Neutral	states need, comments, directs	430	42.28%	465	46.18	+8.14%
	disengages	4	0.39%	5	0.50%	+25.00%
	disagrees w/ neutral follow-up	30	2.97%	13	1.29%	-56.67%
	side conversation	15	1.47%	35	3.48%	+133.33%
		479	44.15%	518	50.15%	+8.14%
Positive	reflects	9	0.88%	18	1.79%	+100%
	advocates	7	0.69%	3	0.30%	-40.%
	questions	126	12.39%	136	13.51%	+7.35%
	disagrees w/ positive follow-up	20	1.97%	22	2.18%	+10%
	explains or demonstrates	71	6.98%	102	10.13%	+43.66%
	shares or suggests ideas or feelings	113	11.1%	88	8.74%	-22.12%
	agrees, affirms	56	5.51%	50	4.97%	-10.71%
		402	39.53%	419	41.61%	+4.23%

collaboration—"disagrees with no follow up","makes without agreement","repeats", and "no response, ignores"—all decrease. The most interesting decreases in negative interactions occur in "disagrees with no or negative follow-up"and "no response, ignores" as these categories each have a fairly large number of instances and a sizable decrease in percent change comparing pre- and post-, "Disagrees with no or negative follow-up" decreases from 56 instances to 45, showing a 19% decrease. "No response, ignores" falls from 51 instances in the pre- assessment to 20 in the post, a 60% decrease. These interactions also have the benefit of being the most straightforward to code. For example, when a child voiced disagreement, usually saying, "No!" or "Stop," I then looked at whether he followed up with another interaction. If the child failed to follow up or followed up with another negative interaction, I coded the interaction as "disagrees with no or negative follow-up". Also comparatively straightforward, I coded, "no response, ignores" when a teammate clearly made a

request, shared an idea, or made some kind of comment that he was waiting for feedback on and the person(s) to whom he directed his question failed to respond.

More explains—Positive interactions from pre- and post- observational assessments increased slightly overall. The instances of the interaction "explains or demonstrates" jump from 71 to 102, a 43% increase. I experience some challenges in coding "explains or demonstrates" as some explanations overlap and also fall under other categorizations of interactions. Therefore, I differentiate "explains or demonstrates" from other interactions, by coding "explains or demonstrates" when participants explained why or how to do something. For example, "I was thinking like this…" participant demonstrates how his plan works, using materials. When participants explained what they wanted to do, I categorized it in "shares or suggests" or "directs, comments" depending on their wording.

Fewer shares—While instances of "explains demonstrates" increase, instances of the positive interaction "shares or suggests" decrease by 22%. This may have occurred because when increases occur on one area, this likely leads to decreases in another area and vice-versa since I kept pre- and post- time the same. Also, while coding I sometimes struggled to distinguish between the positively coded interactions "shares or suggests" and the neutrally coded interactions "directs, comments, states". Phrasing and tone played a large role in how I coded these interactions and one could interpret these nuances in different ways.

*Some interactions like, "makes without agreement", "repeats", "reflects" and "advocates" show large shifts in their percentage change between pre- and post- assessments. However, I ignore this data because the interactions occur so infrequently that one instance changes the percent shift significantly..

While the main learning goal of the study was learning to collaborate, I also chose to capture data on content learning to see whether children gained an understanding of the science of flight in their effort to make a game that teaches players about flight. I used a 5-point scale to score fifth grader's content knowledge on flight and compared the flight learning pre- and post- assessments. These scores increased from an average of 2.48 to an average of 3.00 out of a possible 5.00 points showing gains in content learning (see Figure 2). Table 4 and Figure 2 show the percent change between pre- and post- flight content tests. The graph shows that 16 out of 23 participants

increased their scores. 4 participants' scores went down and three remained the same. Given that these 4 students scored high on the pre-test, I suspect I could have phrased the questions for this assessment differently to prompt participants to give more detail in their responses. Alternatively, a verbal test with prompts could have provided me with more insight into their deep understanding of flight.

Participants	Pre: Q1	Post Q1	Pre Q	Post Q2	Pre Q3	PostQ3	PreTotal	PostTotal
M1	2.0	2.0	2.0	3.0	2	3	2	2.5
F1	1	2	3	2	3	3	2	2.25
M2	2	3	2	3	3	4	2.25	3.25
F2	0	2	2	1	3	3	1.25	2
F3	2	2	3	1	1	3	2	2
M3	1	1	1	4	3	4	1.5	2.5
M4	2	3	4	4	3	3	2.75	3.25
F4	4	4	4	4	4	4	4	4
F5	0	1	2	1	3	3	1.25	1.5
F6	4	4	4	4	3	4	3.75	4
F7	4	2	4	4	5	3	4.25	2.75
M5	2	4	2	4	3	4	2.25	4
F8	2	3	2	2	4	4	2.5	3
F9	4	4	4	3	3	3	3.75	3.5
M7	1	1	4	4	4	4	2.5	2.5
F10	1	1	4	4	2	3	2	2.25
M8	1	4	2	5	2	4	1.5	4.25
M9	2	3	2	4	4	4	2.5	3.5
F11	3	3	4	4	4	3	3.5	3.25
F12	4	4	4	2	3	3	3.75	3.25
F13	2	1	1	5	3	3	2	2.5
M10	1	4	4	4	3	4	2.25	4
M11	1	2	2	4	3	4	1.75	3

table 4: flight content pre-post tests

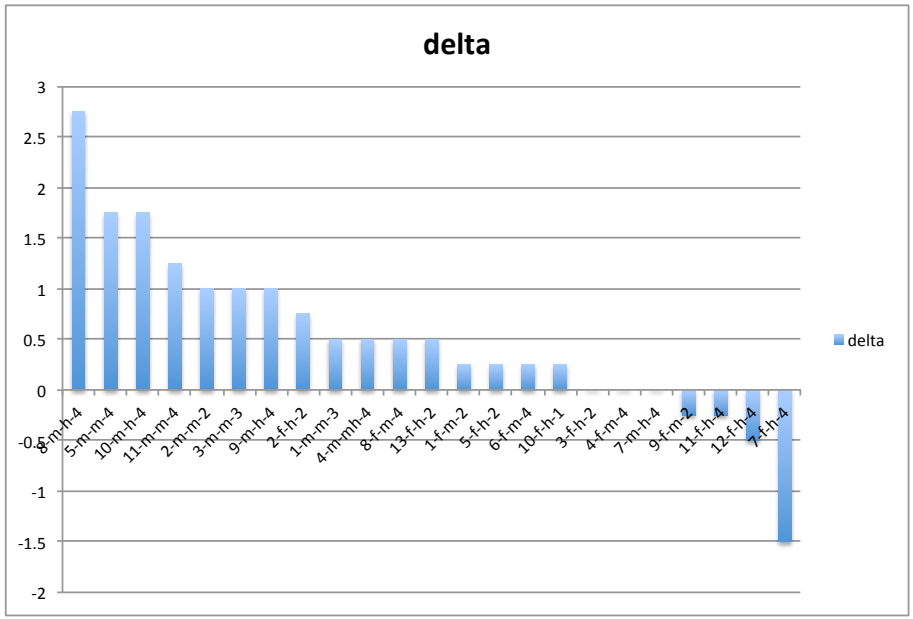


figure 2: Percent change between pre- and post-tests on flight

As part of an exploratory study, the findings from both the collaborative assessments and flight tests lack control groups. However put in context with my observations from the nine-session game design process, the quantitative shifts in collaborative interactions (decreases in "ignores, no response" and "disagrees with no or negative follow up" as well as increases in "questions" and "explains or demonstrates") support the hypothesis that game-making workshops can help children learn collaborative skills as well as content. This study lays the groundwork for further investigation regarding game-making workshop's potential to increase children's collaborative skills

Findings based on excerpts

Because I was able to quickly design, run and iterate on a series of game-design workshops with fifth grade participants in a school environment, I gained insight on nuances and complexities of the process that may not have come up in a more

Gender Participant #	Academic Performance	Team #	Notes
M1	3	1	outgoing
F1	2	2	quiet
M2	2	3	frequently missed workshop
F2	2	4	frequently missed workshop, quiet
F3	2	5	
M3	3	2	easily distracted
M4	4	4	
F4	4	3	outgoing
F5	2	1	
F6	4	6	
F7	4	7	
M5	4	5	
F8	4	8	
F9	2	8	moody
M6	3	7	frequently missed workshop
M7	4	8	high energy
F10	1	6	
M8	4	6	
M9	4	4	
F11	4	3	outgoing
F12	4	1	
F13	2	5	
M10	4	2	
M11	4	7	

Table 5:
Participant chart

controlled setting. I worked within common education structural constraints including a limited amount of time, space, and occasional absent participants. Twenty-four fifth graders participated in this study. Table 5 provides an overview of who they are.

The following excerpts from the game design workshops highlight some of the key shifts demonstrated in pre- and post- assessments particularly "explaining or demonstrating" and "ignoring or not responding". A couple excerpts demonstrate the change over time seen in pre- and post- assessments while others depict the complexity of these interactions. I use additional excerpts to then share observable patterns in collaborative/non-collaborative interactions. These include certain participants' demonstration of persistent collaborative challenges and other participants' demonstration of interesting strategies for supporting collaboration.

Explaining and demonstrating

Reflecting on the game design workshops and reviewing videos from the sessions, I saw evidence of children's collaborative skill development as several individuals increasingly explained and demonstrated their opinions, ideas, and rationale for disagreement rather than just stating them or disagreeing without explaining why. Throughout the workshops, I also observed team members setting one another up to explain by asking questions when something didn't make sense.

Excerpt from Team 1, session 1

In the very first workshop session, team 1 discusses what kind of game they want to make.

M1: "Let's make a card game."

F5: "No."

M1 suggests his idea again, but directs his suggestion to the other teammate, F12.

F12: "No, a board game," F12 disagrees but asks a question, clarifying why she doesn't want to make a card game. "How are you going to have a card game that teaches

little kids…about teamwork?"

M1: "Numbers. We can show which number is bigger than another number"

F5: "We should have the game of Spit."

M1: "What's Spit?"

F12: "The best game in the world." She then begins explaining how Spit is played, but still argues against a card game format. After several rounds of "No's" from all three team members, F5 suggests, "We can do both. We can have cards with the board game."

F12, agrees, but M1 claims, "But then that's dumb."

After a couple more rounds of "No," I interject with an example of an existing game that uses both a board and cards. F5 and F12 come up with other examples and the team decides to make a board game with cards.

In this excerpt, participants disagree and debate. All team members miss opportunities to explain why they disagree, although at one point F12 does get to why she she doesn't want to make a card game through her question, "How are you going to have a card game that teaches little kids…about teamwork?" This question sets up M1 to respond, and he unsuccessfully attempts to explain.

Excerpt from Team 1, Session 8 (images 14 & 15)

During session eight, the team again experiences a situation where an explanation would be helpful. Another team is playing their game with them and some of the rules of the game lack clarity.

"I call Red." M1 says.

"I call orange." M19 adds. Players negotiate color choices.

"You put them at the start. I'll go first," says F12.

Image 14:

Image 15:

"No…," others disagree and they decide to spin to see who goes first. "F5's third, I'm 4th" says M1.

"Choose solo or flock" directs M1.

"I choose that one (flock)," says M19.

M1 asks his team, "Should they start out with one (baby bird) if they start out with flock? M1 answers his own question. You have a little child because you start out with flock,"

"No not yet," F12 disagrees and then clarifies. "Remember red (the red space on the game board) equals mate and then you have a kid."

"But the flock…" M1, trails off, clearly thinking.

A moment later M1 adds, "M19, also whenever you mate you have to go over there," M1 builds on F12's explanation. He also makes a change to the game board by adding a new track, then pointing to it. Children continue to negotiate, play and make changes to their game.

This later conversation shows a shift in how M1 interacts with his team. M1 and his team have come to an agreement over how the game works and when F12 corrects him, he takes a moment, then accepts her explanation and builds upon it. This shift could be the result of M1 learning that explanations help M1's teammates to understand his ideas and make it more likely that they will listen. However, the collaborative situation has also changed over time—the team has moved from discussing plans for the game to figuring out how the game should work. This change in the collaborative situation likely affects how participants interact as well. Both excerpts from this team also highlight that one teammates' questions serve as an effective strategy to get another to explain.

Image 16:

Image 17:

Image 18:

No response/ignores

Here I share an excerpt from the workshop highlighting a consistent observation I made regarding instances of no response/ignores. Although participants clearly demonstrate instances of ignoring or not responding, their teammates frequently persist and do not allow the ignoring to continue. They catch one another. Also, even when teammates didn't call one another out when they failed to respond, I could easily catch it and guide them to answer.

Excerpt from team 6, session 7 (images 16, 17, &18)

As team 6 begins working on their game, M9 tells his teammate F6, "I'm the learning expert. I want to write the questions."

"No!" says F6. She continues to work.

M9: "Let me write a question. You can't write all of them. I am the learning expert." F6 continues to work on the questions and doesn't respond.

"I am the learning expert!" M9 persists.

F6 responds jokingly, "Then you should be learning stuff." Eventually she relents and responds, "Listen, if you write them, you have to write them like this okay? Like A, B, C, D…" She begins to explain how she's been writing the questions. "A, B, C, D and you have to write how many." She shows M9 the questions she's made so far. "Number one is the regular one and number 2 and 3 are like bonus. There's only 2 bonuses…Don't make them too hard."

M9 thinks about the question he is going to write and then asks me what the end of an airplane is called. I suggest that he look it up and M9 researches his question on the computer.

F10, who is working on the game board, requests input from her team regarding their next steps. "After we're done with stuff, should we test the game?" she suggests. I step in when her teammates don't respond to her questions, asking her to repeat her question and then asking her teammates to respond.

This excerpt first shows M9 expressing his desire to work on a specific part of the game design while his teammate F6 disagrees and then ignores him. However, when M9 persists, F6 teases him a bit and eventually permits him to write some of the questions. I saw instances of ignoring followed by persistence in several teams throughout the game design process. Sometime these instances of ignoring followed by persistence look playful. I suspect that they occur more frequently when teammates have a friendly relationship. However, the result is the same—participants eventually respond when a teammate holds them to that expectation. On the other hand, as the end of the excerpt demonstrates, some collaborators don't follow-up when a teammate fails to respond. In addition to prompting the ignoring teammates to respond to their teammate, I suspect that explicitly teaching the person expecting a response to use strategies like saying a specific teammates' name or use a louder voice may be helpful.

Collaborative strategies

Explaining through embodiment and demonstration

While participants were not able to verbally articulate their ideas and concepts in conversation, they used the physical, concrete nature of their games to clarify their ideas and understandings thus moving forward in their game-making process. Most teams developed and communicated concepts by drawing them or making prototypes and then elaborating on them through verbal conversations with additional demonstrations. I observed almost all participants employing this embodiment and demonstration strategy during both the game-design workshop and the assessment challenges. During the workshop, this strategy of explaining through embodiment and demonstration tied directly into play-testing. I highlight this occurrence in the following excerpt.

Image 19:

Image 20:

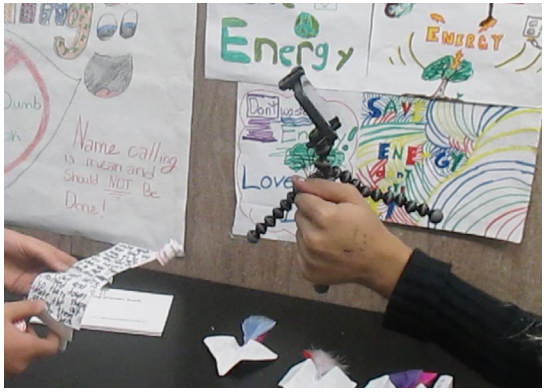


Image 21:

Excerpt from Team 5 and 3, session 8, (images 19, 20, 21)

Team 8 sets up their materials in preparation to play. "We'll explain first," says M5. "I'll explain it and then show it okay?" The other team observes as M5 begins to explain. "So someone stands by the chair and they…How about we'll both be competing?" M5 pulls his team member F3 over to help him demonstrate. "So two people take a plane and they try to throw it at that paper there." M5 points to the target on the floor. "And then…whoever gets their plane closest wins. So we're going to throw our planes now." F3 throws her plane first. "It landed there," M5 narrates. "And now I'll throw mine." He throws his plane. "And mine landed there. But F3's is still actually closest. And whoever's closest gets it."

"It is?" F3 questions whether her plane is actually closest.

"Yes, it's slightly closer, see." M5 points. "So whoever gets…"

"I don't think so." F3 interrupts M5. F4 maps the distance from the plane to the target with her foot, showing that M5's plane is actually closest.

"Okay so I guess it's me (who wins)." M5 accepts this explanation. "So I get this trophy that says, "Good job captain, you won," and F3 gets this trophy." He passes F3 a trophy with suggestions for how to throw the plane more accurately written on it.

This excerpt from the beginning of a play-test shows the value of providing different ways for children to explain and develop an understanding during the collaborative process. While M5 tells the other team that he will begin by explaining how the game is played and then demonstrate, he quickly changes his strategy. Essentially, he employs the strategy of demonstration to bring the new team into his team's collaborative situation. While teachers regularly employ embodiment and demonstration to reach students with different learning preferences, I find it interesting to consider this strategy in the context of collaboration and child led learning.

Playing around

Many teams working on their games together continually experimented with the balance between joking around as a way to connect with one another and taking joking around too far and distracting or even alienating teammates. At it's best, this playfulness showed up in highly collaborative situations. Teams argued and disagreed, highly invested in the outcome while still maintaining this sense of playfulness. Even when participants engaged in non-collaborative behaviors within this space of playfulness, teammates responded by either pushing back and correcting non-collaborative behaviors or moving quickly past them. This excerpt exemplifies teams engagement in this playfulness and their use of it to support their collaborative interactions. In these situations I saw high instances of disagreement, questioning, arguing, and explaining. Participants also moved at a very fast pace with loud voices

Excerpt from team 1 and 4, session 8

M1: "Alright, Now it's F12's turn, F12's turn, F12's turn…"

"Eight," she says after spinning the wheel. She counts eight spaces, "1, 2, 3, 4, 5, 6, 7, 8. I get a wild card now."

"Nu uh," M1 one disagrees loudly and other chime in. "No you don't!"

F12 explains, "It's a wild card, a wild card."

"Not it's not. It's (a) fact," M1 contradicts her.

"Then [how does it work]?" F12 asks.

"Blank equals card," M1 reads from the key his team has created. "I should have put, blank equals fact," he reflects.

His teammate, F5 picks up a marker to change the key and M1 directs, "put fact."

She begins to edit and M1 continues to instruct, "and then put (the word) fact after (the word) card".

F12 teases F5, "F5, what are you doing? Jeez no one can read that." F5 doesn't seem to mind the tease. After team 1 makes the change on the game board, they continue to play-test and F12 chants,

Go F5 go, go F5 go! F5 spins the spinner for her turn.

This example from game play is complex. Team 1 participates in animated debate, and seems to work collaboratively to come to an agreement. They make a lot of progress in 30 seconds. They support one another, chanting one another's name. They disagree and F12's question encourages M1 to explain his understanding of how the game works. They coach F5 to make their new agreement visual by adding clarification to the key on the game board. Yet they demonstrate non-collaborative behaviors as well, including teasing and disagreeing without follow-up.

This balance between useful playfulness and playfulness that derails a team's collaboration was tricky for teams. Sometimes teams took it too far, losing focus on their game goals or failing to differentiate between team members who didn't mind teasing and those who tended to interpret it negatively. This had the potential to cause big collaborative break-downs as demonstrated in the following excerpt.

Teams 8 & 6, session 8

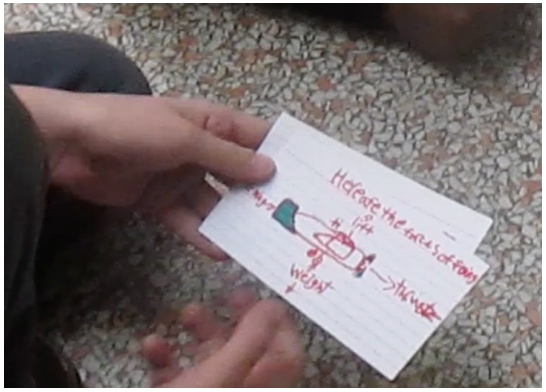
Team 8 and 6 have combined to test one another's games. Team 6 explains how the game works and everyone begins to play. In the second round, F9 rolls a 3 and everyone counts together, "1, 2, 3." She lands on a question.

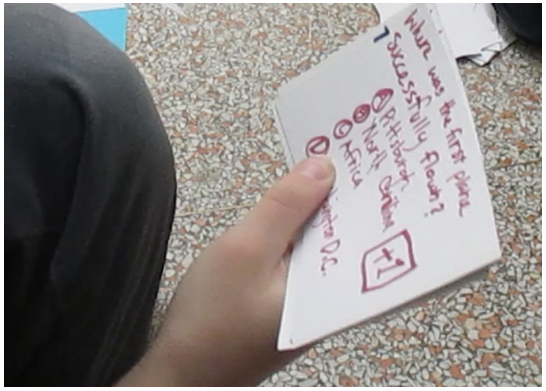
The player holding the cards, M9, misses that F9 has landed on a question and reads a fact. "Here are the forces of flight. Lift, weight, thrust and drag."

"She has a question," M7 informs M9.

"I have a question." F9 reiterates.

M9 finds a question card. "Here's a hard one. Where was the first plane successfully





Screen shots from vignette 4-2

flown? Pittsburgh, Africa, North Carolina, or Washington DC?"

"Washington DC," F9 guesses.

"No! Beep. North Carolina. You lose with negative 2 points. How do you feel?" M9 asks.

"I'm done. I'm done. Can I go in?" F9 asks me as she moves away from the group looking angry.

"Yes," I respond.

"That was a little harsh," M9 reflects quietly, looking surprised.

"F9 just left randomly?" M13 asks.

"She said she did not want to play", I say. "I think she was upset".

"I'm sorry," M9 says.

"Do you want to tell her sorry?" I ask.

"Maybe," M9 looks uncomfortable.

"It's up to you," I say. M9 goes into the classroom to apologize and then returns.

"Sorry," he says again.

In this situation, M9 clearly takes the teasing too far. Up to this interactive sequence participants demonstrated high energy levels but all collaborated to play the game. When M9 crosses the line with F9, the tone of the game play noticeably shifts and even those still technically participating withdraw a bit. The playful, fun note disappears.

Persistent collaborative challenges

Two teams worked through continual challenges with particular team members. I intervened frequently in these two groups. I describe an experience with one of these team members.

On team 2, one team member had a very different focus. He seemed unconcerned with the game making challenge and simply wanted to make something that could fly. His team planned to create a "making-style" game and he spent most of the sessions working on an airplane that could serve as an "example" for future players. He rarely engaged in collaborative interactions without direct instruction. Even in the last session when M3's team shares how their game is supposed to work and guides another team through the process of testing it, I reminded M3, "If your going to be here, participate. Otherwise you can head back into the class. It's up to you."

"There's nothing else to do here," M3 protests, although he doesn't leave.

His teammate, M10 responded to his complaint. "We can keep working on the different pieces [of the game]," he points out.

"There's not enough time," M3 claims. His teammates work around him as he flits from one area to another.

M3's absence of collaborative interactions may have been simply because he didn't want to make a game. Collaboration doesn't occur without participants choosing to participate and while M3 said he wanted to participate, saying something and meaning it differ. Or perhaps I didn't give him enough direct support to engage him in the process. He did participate in the collaborative assessment challenge and demonstrated several instances of collaborative interactions in both pre- and post-assessments, so I've seen him demonstrate collaborative skills.

Regardless of reason, this example brings up the question of whether all children should be taught or can be taught collaborative skills. I propose that it is useful for children to experience opportunities for collaboration within varying situations. Maybe they never reach the point of being able to collaborate in every kind of collaborative situation, but for example, they learn to collaborate with a close friend and build out from there. Much like any intentional learning, collaboration involves choice. It doesn't work to require collaboration. However, I see an opportunity to

develop a continuum of collaborative situations or have participants select variables within a collaborative situation. For example sometimes they might choose who they work with. Other times they might choose their activity.

Conclusion

This work takes an exploratory step towards figuring out ways to support and create engaging situations that help children develop their collaborative skills. I speculate that as children increasingly learn content knowledge online (Khan Academy, Code Academy, MOOCs), emphasis on learning social emotional skills like collaboration will increase in education settings. This study demonstrates that the idea of guiding children through the process of game making to increase their collaborative skills is worthy of further investigation.

The affordances of physical game-making create a dynamic collaborative situation that leads fifth graders to increasingly respond to one another's ideas and explain their thoughts and ideas. This process mirrors the some of the complexity of 'real world' collaborations as it takes place over time and is a part of a process. It also supports participants in embodying and demonstrating their ideas concretely and testing potential collaborative strategies including playfulness. They also get practice working through collaborative and process-based challenges.

Acknowledgements

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