Tarzan and Jane Share an iPad

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Abstract: Increasingly, tablets are entering children's lives and the classroom. We developed the Proportion iPad application to investigate how tablets can support at-device collaborative learning. We provide a microanalysis of a particularly successful dyad to concretely demonstrate our vision of at-tablet collaboration. We analyze the processes of strategy development, territoriality, modes of collaboration, emotion regulation and task focus.

Collaborative learning with tablets

Multi-touch devices are starting to replace PCs (both desktops and laptops) as the dominant form of computing, particularly for children. As a result, serious efforts are underway to investigate and integrate tablets into both the primary (Gasparini & Culén, 2013) and secondary (Kaganer et al., 2013) classroom. Most of these research efforts are software agnostic, assuming that the current software ecology is sufficient to realize and study the potential of the hardware. In such a research mode, it is natural to think of tablets as personal devices since the vast majority of software is built around that premise (e.g., tablets as ebooks). Can tablets support collaborative learning?

One approach is to have tablets act as personal devices (one user per tablet) but orchestrate activities through software to further collaboration. For instance, Group Scribbles utilizes a classroom projector as a large shared display that can be used to share objects across tablets (Roschelle et al., 2007). The SINQ tablet application allows children to keep and share notes on their inquiry activities; as the information is shared, it affords others noticing connections and spurs on face-to-face collaboration (Ahn et al., 2013). There is less work on using tablets as collaborative devices (multiple users per tablet). One notable exception is the work of Hourcade et al. (2013) on using at-tablet interaction to help children with ASD (Autism Spectrum Disorder) to become more comfortable working with one another; the joint tablet use encouraged a greater rate of verbal interactions than comparable non-electronic activities. Why would at-device collaboration be useful?

A seminal vision of how technology can support at-device collaborative learning is Roschelle's (1992) theory of *convergent conceptual change*: a process by which two novices working with a *reflective tool* help each other converge on a better domain understanding. Roschelle illustrates the process with two children working with a Newtonian motion simulation. The children were instructed to hypothesize solutions to problems and test them with the software. As both were novices, neither came in with the correct understanding; however, the two generated many ideas and were able to build on each other's successes and failures. Using the tool, they were able to test their hypotheses and reflect on the outcome. Over time, they converged on an understanding that was more closely aligned with each other and the underlying principles. While Roschelle used a desktop PC, interactive surfaces may be more suited for supporting this type of interaction. First, they may further more equitable interaction as no user can dominate the mouse. Second, they may enhance shared focus as large body movements are easier for partners to monitor than small cursor movements. Third, they may make it easier to switch from gesturing to communicate with a partner to gesturing to interact with the application. Already, there is an established research tradition of using interactive tabletops to support collaboration (Higgins et al., 2011) and learning (Dillenbourg & Evans, 2011; Evans & Rick, 2014).

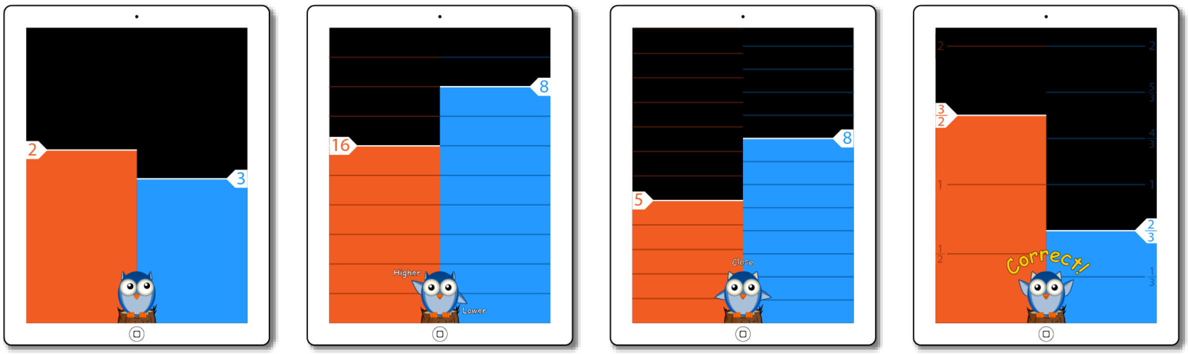
Tablets as tiny tabletops

Interactive tabletops are commonly regarded as collaborative devices; in contrast, tablets are thought of as personal devices. While significantly smaller, tablets share two key properties of tabletops: direct input and multiple access points. *Direct input* means that an end user can directly manipulate the software interface using touch, pen and / or by moving tangible objects. In comparison to using a mouse to control a cursor, the cognitive distance between intent and execution is shortened. This benefit is particularly salient for younger users (e.g., toddlers using tablets). *Multiple access points* means that multiple concurrent interaction points are sensed by the hardware and utilized by the software. This enables both multi-point gestures, such as pinching with two fingers to zoom out, and switching which hand to use. In addition, the access points can be distributed among multiple participants, thereby enabling collaboration. Because of this common core, we hypothesize that collaborative learning can be similarly supported with tablets. We ground our tablet efforts in tabletop research.

We start with the premise of working with learners in the age range of 9-11. This has been a particularly fruitful user group for tabletop research. In comparison to older children, they are more willing to experiment without fear of embarrassment and do not mind working in physical contact with their peers. They generally prefer working side-by-side (Scott et al., 2003). In contrast to younger children, they have a refined ability to work with peers (Harris et al., 2009). Though there are similarities in the two technologies, we expect display size to have an effect. Tabletops are large enough that children can work independently (Rick et al., 2011); however, interface conflict can be an impetus for learning (Pontual Falcão & Price, 2009). Tabletop applications tend to promote territoriality, where users take responsibility for the screen area near them (Scott et al., 2004). This may be partially attributed to reach as users cannot easily reach all parts of a large tabletop (Rick et al., 2009), which is not an issue for tablets. To investigate such differences and at-tablet collaboration in general, we developed the Proportion iPad application.

The Proportion app

Ratios and proportions play a critical role in students' mathematical development (Lamon, 1993). Because of its importance and depth, the topic is covered repeatedly and in increasing sophistication in several grade levels. *Proportional reasoning* is realized through multiple strategies, where one strategy will be appropriate for one set of problems but inappropriate for another set. For instance, in cases where the denominators are the same, the ratio of two fractions is the same as the ratio of the respective numerators; if the denominators are different, this strategy fails. Gaining competence requires both acquiring such strategies and understanding when and how to apply them (Tourniaire & Pulos, 1985). Proportional reasoning is notably difficult to teach (Lamon, 1993). Digital technologies can support this process by offering both immediate feedback and creating accessible embodiments of the mathematical concepts (Abrahamson & Trimic, 2011; Leong & Horn, 2011).



(a) no support (b) fixed grid (c) relative lines (d) labeled lines

Figure 1. Four interfaces for supporting learners in solving problems

In Proportion, the tablet is positioned in portrait mode on a table in front of the learners. The children (aged 9–10) work together to solve a series of ratio / proportion problems. The interface features two column: a left orange and a right blue ones (Figure 1). For each problem, users must size the columns so that they are in proportion to their numerical labels. For instance, for the problem in Figure 1a, the blue column (3) must be resized to be 50% larger than the orange column (2). A touch or drag on a column changes its position. The application features a young owl at the bottom of the display to provide reflective feedback. The owl "watches" the children work, moving its eyes to the last touch location and peaking its ears when they talk. When all touches are released, the ratio of the column heights is evaluated. If it is correct (Figure 1d), the owl announces "Correct!" and hoots loudly; the next problem is presented. If the ratio is nearly correct (1c), the owl announces "Close" and hoots softly. If learners have been working for more than one minute on a problem, the owl provides directional feedback (1b); this allows learners to make progress without the help of a teacher.

Proportion has been refined through two cycles of user testing (Rick et al., 2012). Its curriculum contains 215 problems divided into 21 levels. Each level uses one of four interfaces (Figure 1). With no support (1a), learners must estimate the ratio. With a fixed 10-position grid (1b), learners have precise places that they can target, which, if correctly utilized, will allow them to quickly solve the problem. With relative lines that expand based on the position of the columns (1c), learners can use counting to help them solve the problem (e.g., when solving 5:8, students can count down three spaces from 8 to achieve 5). When the lines are labeled, it becomes even easier to line up the correct values. In the fraction example (1d), a useful strategy is arranging columns so that the whole numbers (e.g., 1) are at the same level. In addition to the numerical labels and the interface available, each problem has a specified tolerance level for what is accepted as close and what is accepted as correct. As a sequence progresses and children gain competence, more precision is demanded.

With its two columns, there is a natural symmetry to the interface that does not privilege a specific partner. Both have good access to the entire display and how they utilize it is up to them. A common strategy is that the partner on the left controls the left column and the partner on the right controls the right column. Such a strategy would utilize a concept of territoriality based on nearness, rather than comfort.

The case study

We conducted a field study of Proportion in local schools. For each session, we took half of a fourth grade class (10-12 participants per session) and randomly assign them into three conditions. In the *single-user condition*, a learner works alone with the iPad. In the *multiple-touch condition*, two children work together with a Proportion implementation that allows both columns to be resized simultaneously. In the *single-touch condition*, two children work together, but only one column can be resized at a time. This allows us to investigate the value of collaborative learning and multi-touch support. Each session takes 90 minutes. First, participants are randomly assigned to a group / condition. Next, they complete a short survey and pre-test. Then, they spend 40 minutes working with the iPad; their interaction is recorded on video. Finally, they complete a short survey and post-test.

While we aim to ultimately compare across conditions, we wanted to get a better sense of *successful* at-tablet collaboration. How do proportional reasoning strategies develop while children work together? How does the collaboration at the tablet differ from collaboration at the tabletop? In particular, how do children physically engage the tablet? What makes for a successful group? To address these questions, we concentrate on one remarkable group from this larger sample: Tarzan and Jane. A case study is a well established technique for analyzing novel forms of learning as an exemplary case can give a feel for what is possible and ground the abstract theory in a concrete instantiation. For example, Roschelle (1992) illustrates how two novices can benefit from collaborating with a reflective tool. Bruckman (2000) shows how mentoring relationships can work between children in an online forum.

To analyze the case, we four authors closely examined the video and screen capture of this dyad, noting important elements to capture the essential parts of the interaction. We have grouped our findings into three categories that seemed most salient. First, we describe how learners acquire and exercise proportional reasoning strategies. Second, we discuss the nature of the collaboration at the tablet, concentrating on body and tablet position, which differs significantly from the literature on tabletops. Third, we analyze task focus and emotional valence. We provide both qualitative (overall description and illustrative examples) and quantitative (descriptive statistics, coding) analysis. Before presenting our findings, we introduce the pair.

Tarzan and Jane

Tarzan and Jane are nine year olds in the same class; to aid the reader, we translate their German speech into English. We focus on them partly for convenience: Their loud voices are easily deciphered while other groups regularly mumble or whisper. They also stand out in key ways. First, their interaction features a lot of tablet movement and diverse body configurations, which contrast to the literature on stationary tabletops. This behavior is largely activated by the single-touch condition, where the common *territorial strategy* of "left user manipulates left column, right user manipulates right column" proves unsatisfactory. Second, they present an unusual, yet effective interaction pattern. Collaboration at interactive surfaces, as with other group work (Stahl, 2006), often depends strongly on the how learners regulate each other. Strikingly diverse dynamics can lead to useful collaboration (Rick et al., 2011). As our fanciful pseudonyms suggest, he is a bit unruly and she provides a calming influence. The teacher specifically warned us about Tarzan, noting that using an iPad and being filmed will overstimulate him. Third, they are a highly successful group. Of the seventeen dyads using Proportion at this school, they started off with the second lowest combined pre-test result. They also liked math class slightly less than the average. None of this suggested that they would be remarkable; however, they reached third furthest into the problem set of the groups (127 problems in 40 minutes) and had the highest post-test score by a wide margin. They were pleased with their collaboration, giving maximum marks to all questions on the post survey. Hence, they provide an excellent case of how a tablet can support at-device collaboration.

Learning new strategies

The Proportion problem sequence has been carefully designed to highlight various proportional reasoning strategies (Rick et al., 2012). By solving the problems, learners should discover and apply these strategies. While it is possible to make progress without a particular strategy, utilizing the appropriate strategy makes it significantly easier. As such, children can recognize that the strategy is a valuable one: It saves them time and effort. Accordingly, we focus on the appropriation of new strategies. Acquiring a strategy generally goes through three phases: *discovery*, *application* and *pertinence*. First, children try various strategies to solve the current problem. If one works, they might try it again. If it is a viable strategy, it works again. Thus, they discover the strategy. Once it has been discovered, the next step is to apply it. Repeatedly practicing it demonstrates its utility. For this task, none of the strategies are universal; they all have their limitations. At some point, learners will face problems where that strategy does not work or where another strategy is significantly better. So, learners will have to figure out when that practiced strategy is pertinent to the problem. To demonstrate these phases, we detail how Tarzan and Jane engage with the maximum column strategy.

The *maximum column strategy* has users placing the column with the highest value to its maximum height. This is done so that it is easier to precisely place the smaller column. A prerequisite is understanding that there are multiple solutions for each ratio problem. Tarzan and Jane first glimpse the strategy while working on 3:2 with labeled lines. 3 is set fairly low (based on the last problem); although they know roughly where 2 needs to be placed, placing it correctly requires near pixel accuracy. Jane fails to place it just right. Tarzan says, "wait, wait, I'm going to set this one higher." He sets 3 to a higher position (though not to the maximum position) and they quickly place 2 to solve it. On the next problem, he again sets the higher number a bit higher to make the lower number easier to place. On the following problem, he first employs the (full) maximum column strategy. He repeats it on the next problem, verbalizing, "that one [column] to the top." He has discovered the strategy. As it works, he continues championing it, while it takes her a while to adopt it. At one time, he places a column to the top. When she accidentally brings it down, he proclaims "no, to the top" and corrects it. On the next problem (5:1), she adopts the strategy (placing 5 to the top). They continue applying the strategy. Both have now accepted it as a useful strategy. On one problem, Jane is working alone and employs it.

Next, a sequence of fixed grid problems arrive. For these, the maximum column strategy will be less useful. Instead a *counting strategy* (place each column at the grid line for the respective numerical labels) will displace it. At first, they continue to use the maximum column strategy. It does not work well. In particular, Tarzan does not realize how to utilize the fixed grid. He tries to use a combination maximum column and subtraction strategy. He places the column with the highest number at the top of the screen and then counts down one grid division for the difference in numbers. For 4:1, he places 4 at the top, i.e., grid position of 10, and then counts down three (the difference between 4 and 1) to place 1 at the grid position of 7. It is an imaginative strategy that allows him to keep the successful maximum column strategy. Unfortunately, it does not work. When the owl does not signal that 10:7 is a solution for 4:1, Jane takes over. She aligns the 4 column to the fourth grid position. Together they place the 1 column on the the first grid position to solve the problem. On the next problem, he reverts to the maximum column strategy but she solves it using the counting strategy. After that, the counting strategy dominates.

Then, there is a particularly tricky problem sequence that causes most learners problems: 1:2, 4:2, 4:8, 16:8 and 16:32 on a fixed grid (note that one column stays the same and the other has twice the opposing column value). At this point, the counting strategy has been firmly established. 1:2, 4:2 and 4:8 are easily solved. 16:8 presents an inherent challenge. The application only has a 10-division grid so it is not possible to place the 16 column on the sixteenth grid. The counting strategy no longer works. Many struggle here, trying things like placing the 16 column on the sixth grid position (Figure 1b), incorrectly supposing that the tenths digit does not matter. Remarkably, Jane and Tarzan do not have that problem. When presented with 16:8, she is initially confused ("huh?") as the established counting strategy will not work. He steps in with the maximum column strategy: "That [16 column] just needs to go to the top." She explains, "it is always half," and places the 8 column on the fifth grid position. They successfully apply that with the 16:32 problem. With the next problem (15:5), it does not work as well. There is no grid line that corresponds with one third of 10 (the highest grid position). Working on it, she figures out that she can place 15 at the ninth grid position and 5 at the third grid position to achieve the 3:1 ratio of the 15:5 problem. Again, the pertinence (i.e., whether it can be useful for a certain problem) of the maximum column strategy is refined through practice.

This example demonstrates several important features of collaborating on Proportion. First, given the right sequence of problems, children can arrive at useful strategies, which prove themselves useful in further problems. Second, when a previously successful strategy fails, the children are willing to abandon it in favor of one that works better. Third, though a strategy can be abandoned for some time, it can reemerge when faced with a difficult problem. Fourth, it is useful to have two partners to come up with possible strategies. Tarzan first discovers the maximum column strategy; Jane adopts it. She first discovers the counting strategy; he adopts it. He comes up with using the maximum column strategy for 16:8. She realizes its limitations for 15:5. Fifth, as Proportion is a reflective tool (i.e., the owl gives feedback about whether a certain configuration solves the problem), they are able to test strategies. The good ones are adopted; the bad ones are abandoned. Sixth, the adoption of new strategies is fairly fluid, requiring little discussion or causing unwieldy conflict.

Collaborating at the tablet

The pair starts in a collaborative mode, jointly manipulate the columns to solve the tasks. As they are in a single-touch condition, this is not always easy. After seven minutes, Tarzan suggests that they take turns: "I'll do one, then you." Jane silently accepts. He tries to solve two tasks alone but gives up and lets Jane finish them. They smoothly switch back to a collaborative mode. After 20 minutes, Jane suggests the commonly used territorial approach ("You do this [left] column, I do that [right] column"). At the time, Tarzan is distracted and does not engage her suggestion. She ends up manipulating both columns. After the completion of that problem, Tarzan returns to the group, pulling the iPad to himself. Her suggestion is never employed. So, though suggestions for different working arrangements are made, they ultimately spend most of their time in an ad-hoc (anything goes) collaborative mode.

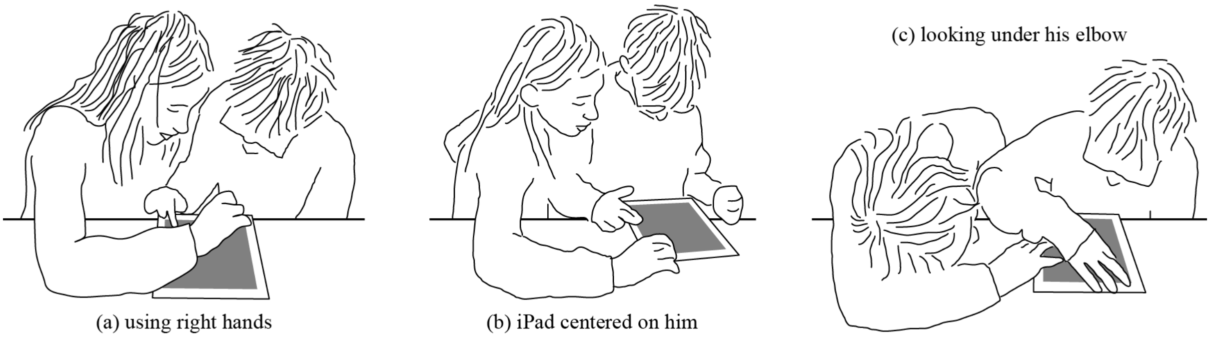


Figure 2. Configuration of learners at the tablet

Partly, they do not adopt the territorial approach because they cannot move both columns simultaneously. Partly, they do it because they both use their right hands. Most groups end up employing an approach featuring a centrally placed iPad and outside hand alignment, where the left partner uses the left hand and the right partner uses the right hand. This works particularly well with a territorial approach. That approach is never used as Tarzan uses his right hand. Both children predominantly use their dominant right hands (Tarzan: 60%; Jane: 98%). In such an alignment (Figure 2a), it is more comfortable for him to manipulate the right column and for her to manipulate the left column (i.e., the opposite of the territorial approach). As time progresses, Tarzan increasingly pulls the iPad towards himself (2b), allowing him to utilize both hands (45%). While this position clearly favors him as user, her right hand still has good access to the interactive surface and it does not negatively impact the collaboration. Jane uses both hands infrequently (5%), i.e., only when she is left to work a problem alone. Neither uses only the left hand. As Tarzan employs his right hand, the positions at the tablet are never symmetrical. His proximity to the iPad can cover up the iPad, making it difficult for Jane to interact or see. That said, she never complains and even goes to extremes (Figure 2c) to be able to see and interact with the tablet.

Both children are adept at negotiating who has control of the device. One common gesture is to lightly touch the other's hand to indicate that it should not be used. This subtle gesture works well: It never elicits a verbal follow up and does not disturb progress. He employs it 10 times and she 5 times. Bigger gestures to get rid of the other's hand appear over time. He employs them 13 times and she 4 times. Tarzan is quite dominant concerning the placement of the iPad: He turns it towards him (7 times), pulls the iPad to himself (11 times), and takes it into his hands (9 times) or even onto his knees (2 times). Jane usually accepts these movements and just continues participating in a calm style. She occasionally changes the tablet's position, turning it 6 times and pulling it to her 8 times. She never takes it into her hands or onto her knees. He controls who is working on a problem. Occasionally, he declares that he will solve the problem and pulls the iPad towards himself. She generally concedes. As he returns the iPad to her on the next problem (i.e., turn taking), this does not contribute to an equity problem. He also voluntarily passes the iPad to her when he is stuck and wants her to solve the task, typically accompanied by a verbal "you try it." In those cases, he observes how she solves the task.

Taming Tarzan

A defining property of this group is its interaction pattern. Tarzan regularly loses focus, becomes overly emotional and imposes his will. Like her fictional counterpart, Jane manages to deal with his eccentricities, allows him to be himself and makes the partnership work. Emotion regulation is considered to be an important phenomenon of collaborative learning, though not many good measures to capture its dynamics have been developed (Järvenoja, Volet & Järvelä, 2013). Here we detail how this partnership works.

The evaluation of on- and off-task behavior is a main and a first step in content analysis (Weinberger & Fischer, 2006). In terms of task focus, Tarzan varies widely: Often he is concentrated and excited; sometimes he abandons the task to look around or to do something else. To better understand focus over time, we coded the behavior over the period on a per second basis into four categories: iPad use (when actively engaged with the task), observation (when watching the partner work), recreation (when doing things not related or relevant to the task, such as drinking a beverage) and goofing off (behavior that distracts the partner from the task). The first two categories can be considered on task while the last two categories are off task.

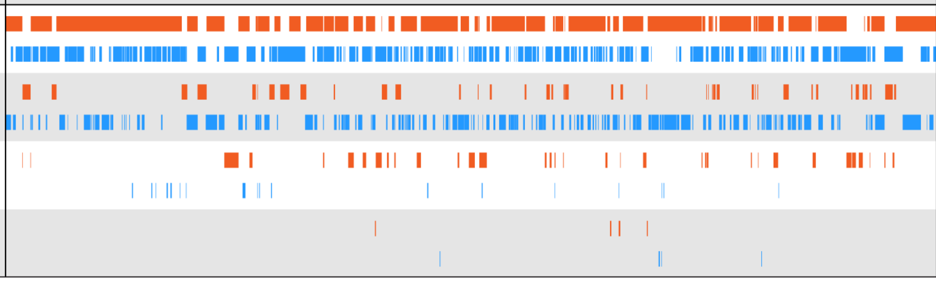
Task Focus	Over 40 Minute Session	Tarzan Jane
On Task (iPad Use)		77.00 % 59.04 %
On Task (Observation)		12.67 % 39.33 %
Off Task (Recreation)		9.88 % 1.38 %
Off Task (Goofing Off)		0.46 % 0.25 %

Figure 3. Categorizing focus over the session

The results (Figure 3) are based on one coder. A second coder evaluated Minutes 13–18 for reliability; Cohen's Kappa was acceptable (κ=.611) for Tarzan and fair for Jane (κ=.346). As seen in Figure 3, the frequency of his off-task episodes increased over the session. His movements became bigger and his voice became louder (to the point where classmates asked him to be quiet). In contrast, Jane is consistently on task. She is rarely distracted by his actions and works by herself when he is doing other things. Only once (Minute 33) does she briefly join him in goofing off.

Remarkably, the driving force for his off-task behavior is his strong engagement with the task. Unlike Jane, Tarzan has access to an iPad at home and is used to playing games on the device. So it is not surprising that he treats Proportion as a game. Proportion has some game elements (positive feedback on success, levels) but intentionally avoids other common game elements (competition, scores, timed elements, narrative). When he finds out that others are at a further level, the gamification of the task kicks in. "Why won't it go to level eleven? I want to reach level eleven" (Minute 26). He frequently checks in with other groups to see how they are progressing (classified as recreation). For him, the game aspects appear to be motivating.

Though they are often in agreement, his emotional valence is significantly higher than hers. In Minute 12, she calmly remarks, "it is starting to get boring." He barks, "it is getting boring" and turns away. In Minute 14, he complains, "man, when are we ever getting to the next level? It is getting boring." She calmly responds, "I know" and they proceed on the task. To better understand the emotional valence, we coded the emotional valence on a scale of --2 to 2, where 0 is neutral, -1 is a loud negative remark and 1 is a loud positive remark (celebration after completing a level). Rankings below -1 and above 1 were reserved for extreme interaction, which happened rarely (never for Jane and a few times for Tarzan). Tarzan (μ=0.06, σ=0.25) had both a significantly higher mean and standard deviation than Jane (μ=0.01, σ=0.10). For both, the means were positive, indicative of a largely positive experience. Tarzan's higher standard deviation is both a function of higher frequency (he has more episodes that can be coded as something besides neutral) and valence (higher values to those episodes).

Throughout the session, his emotions are highly charged. On regular occasions, he claps his hands together in celebration on receiving "Correct!" feedback. He even questions why he does it, explaining that he can't control himself. His emotions are frequently manifested in his interactions with the owl, whom he directly addresses. At the beginning, most of these are negative: "dumb owl," "stupid owl," "fucking owl," etc. Over time, his treatment of the owl improves. He makes positive statements: "hello owl" and "[soothingly] okay owl." At one time (Minute 30), he even apologizes for saying "fuck." From then on, his interactions are positive or neutral: "the owl just said close." Overall, there were 67 interactions with the owl (40 negative, 17 neutral, 9 positive, 1 other). Critically, none of the emotional outbursts are aimed at his partner. The owl allows him to act out his emotions in a safe way: He is able to stay on task after such an emotional outburst. Jane does not engage his outbursts and that may be a reason that they never escalate. At one time, she emotionally supports him. He dramatically announces, "I'm too dumb, I can't solve any of these" and turns away. She replies, "that's not true, you've solved many of them." He joins back in.

Thus, though he easily gets off task, he easily gets back on. He does not go off task to avoid the task or to move the group away from it. As such, Jane is able to continue to work, seizing the opportunity to monopolize the iPad. When he has calmed himself back down, he is able to rejoin her quickly. Though the occurrences are frequent, their duration is not. In total, his off-task behavior only accounts for 10% of his total time. Partly, the steady Jane tamed the wild Tarzan; partly, the steady Jane enabled Tarzan to tame himself.

Discussion: At-tablet collaborative learning

We have presented the case of Tarzan and Jane to show the potential of at-tablet collaborative learning. In several ways, tablet usage is similar to tabletop usage. As they use their hands to interact, the movements of the partner are easy to follow and regulate. Consequently, the children require little verbal interaction to collaborate. Even subtle gestures (e.g., tapping a hand to indicate that the partner should stop interacting with the tablet as the initiator has an idea to test out) can be utilized without being discussed. Though Tarzan's insistence on using his right hand often puts him in the dominant position, it does not hinder Jane from making contributions. A children working on a tabletop (Harris et al., 2009), the two were able to navigate the imposition of a single-touch interface without equity problems. As children working on a tabletop (Rick et al., 2011), the two were able to appropriate and build on each other's ideas.

In a couple of ways, tablets differ from tabletops. As particularly evident in this group, tablets can be moved and reoriented, leading to different body arrangements (Figure 2). Though this had the potential to lead to problems given Tarzan's propensity to grab the tablet, it did not. Frequently, position and orientation was used to communicate who had responsibility for a certain problem in turn taking (e.g., turning the iPad towards the partner to cede control). Because of their size, territoriality based on access need no longer define the interaction. Though many groups used the two columns of Proportion's interface as an implicit cue for how to interact (i.e., the territorial strategy), there is no physical impetus. Tarzan and Jane ignored this cue and it did not harm their interaction. A more substantial factor in shaping their interaction is that both primarily used their right hands.

Convergent conceptual change posits that two novices can benefit from at-device collaboration when using a reflective tool. This is certainly true for Tarzan and Jane using Proportion. Each is able to contribute and adopt ideas. Coordination losses are minimal. Collaborative learning is especially beneficial if both learners individually acquire knowledge, which in turn stimulates successful collaboration (Stahl, 2006). As Tarzan and Jane had a remarkably high learning gain (+11 points from pre- to post-test) compared to their peers (+2 on average), this could partially explain their success. In addition to cognitive support, this case demonstrates the emotional support that a partner can provide. On the pre-survey, Tarzan marked that he preferred to work alone; Jane marked that she preferred to work together. From our observations, she is a great collaborator. Our guess is that she would probably have worked well with anyone. In contrast, he probably would have had problems working with somebody who was not as supportive or who was easily distracted. We have highlighted how the calm Jane helped tame the wild Tarzan; however, the reverse is true as well: The boisterous Tarzan animated the cool Jane. In the end, the learners co-regulated each other productively. Both contributed, made significant progress, enjoyed the interaction and showed significant learning gains. Though she never interacted with other groups during the session, after completion, Jane proudly informed others of their outstanding task progress.

Implications: Beyond this pair

In this paper, we have presented a case of successful at-tablet collaboration. In critical ways, the interaction was extraordinary. The software was created specifically to promote co-located collaboration. The pair worked particularly well together. Hence, this interaction is not indicative of average at-tablet collaboration. But, we do feel that the case suggests important points about what can make at-tablet collaboration work. First, it demonstrates the process of acquiring new knowledge in a collaborative setting. The phases of discovery, application and pertinence can shed light on what makes for successful or unsuccessful collaboration. For instance, a group might fail in discovery as good ideas get drowned out by the partner (e.g., Barron, 2003). Alternatively, a group might fail in pertinence, not being able to solidify understanding and thereby not being able to transfer learning to outside the immediate context. Second, it shows how emotional regulation can be a significant part of successful collaboration. Roschelle (1992) concentrated on the cognitive benefits of co-located collaboration. In addition, co-located collaboration can have significant emotional benefits, motivating and engaging learners. When one partner loses interest, the other sustains the collaboration, allowing the partner to easily rejoin the task. As such, we would expect children working together to enjoy the task more and to persist longer when encountering difficulties. Third, it shows how adept children are at working together using a touch interface, with speech, gesture, body position, eye contact, etc. contributing to a smooth interaction experience where the benefits of working together greatly outweigh the coordination costs. This suggests further across-group analysis of how children communicate in this rich setting.

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