Abstract

This exploratory study considered the literature on the history of manipulatives, with attention to tangrams, and examined the use of manipulatives in the elementary classroom through the Osmo Tangram. Specifically, manipulatives can be utilized in assisting elementary students to develop mathematical ability and achievement, with an emphasis on spatial sense. This paper describes design features of first generation virtual manipulatives, the amalgam of real and virtual manipulatives (e.g. Osmo Tangram), and results of an exploratory observational study of Osmo Tangram at the elementary level. Findings are discussed tailored to the future design and implementation of integrating tangram into mathematics instruction.

Keywords: Elementary students; Mathematics education; Osmo Tangram; Manipulatives; Collaboration; Engagement

An Exploratory Study of Osmo Tangram and Tangram Manipulatives in an Elementary Mathematics Classroom

Advances in the fields of communication and technology have led to the development of multiple tools that enhance learning experience and engagement through collaboration and play. Among these technologies is Osmo Tangram, an iPad application with physical accessories bridging the physical and digital worlds. The purpose of this exploratory study was to analyze the experience of elementary students who interacted with the Osmo Tangram in a mathematics classroom and to compare their experiences with non-Osmo oriented tangrams.

Combining the use of physical and virtual manipulatives on a touch-screen computer or device may be beneficial to students providing both the interactivity of a computer and the stimuli of a concrete manipulative. The use of a touch-screen has yielded positive results in the mathematics classroom. Children between the ages of four and five demonstrated greater understanding in digital formation and number recognition (Spenser, 2013) through such interactivity. The use of feedback, such as audio and visual, and interaction, such as touch-screen, were beneficial to first and second grade students (Paek, Hoffman, & Black, 2013) in their mathematical formation. Fifth grade students displayed improvements in learning fractions (Riconscente, 2011, 2013) with interactive tablet gaming. An example of a similar, but relatively innovative interactive math manipulative is Osmo Tangram, a gaming accessory for the iPad that combines an application and physical manipulatives for several games such as Coding Jam, Coding Awbie, Numbers, Newton, Tangram, and Words (https://www.playosmo.com/).

This study focuses on the tangram, an ancient Chinese puzzle devised to increase children's spatial understanding of connections between shapes. It spans a long range of use from early childhood to college. Early on, children copy or make shapes with tangrams, and subsequently, they discover proportions of shapes.

Tangrams contain 7 geometric shapes: 2 small triangles, 1 medium triangle, 2 large triangles, 1 square, and 1 parallelogram. The pieces can be put together to form animals, figures, and abstract shapes.

Children are able to categorize, compare, and solve the tangram puzzle to enhance geometry concepts through problem-solving skills (Siew, Chong, & Abdullah, 2013). Once students become more familiar with tangrams, a teacher can integrate more structure with tangrams, such as copying and/or making shapes and illustrating stories.

(a) (b)

Figure 1. (a) a picture of an Osmo set and (b) a picture of the Osmo Tangram

Literature Review

Manipulatives and Spatial Reasoning in Mathematical Learning

In the elementary classroom, educators have used manipulatives in mathematics for some time and research has illustrated the positive effects of manipulatives in mathematical learning. Over the past several decades, much has been written on the use of manipulatives in elementary mathematics. Fifty years ago, the Cambridge Conference report (1963) recommended that all students should have the opportunity to manipulate physical objects (Gilbert & Bush, 1988). Suydam and Higgins (1977) reported that lessons that incorporate manipulatives are more likely to produce greater mathematical achievement than lessons that did not incorporate manipulatives (Gilbert & Bush, 1988). *An Agenda for Action* (1980) encouraged teachers to utilize manipulatives to develop mathematical concepts and skills (Gilbert & Bush, 1988). Further, Parham (1983) reported that elementary students that used manipulatives had greater achievement scores than students that had not used manipulatives (Gilbert & Bush, 1988). Students become more proficient in understanding locations, positions, and structures when they are able to manipulate materials (Lee, Lee, & Collins, 2009).

The Trends in International Mathematics and Science Study (TIMSS) *2007 International Report* reveals that the lowest competence in geometry is “the study of spatial relationships” as compared to all other areas of mathematics among children in the United States (Lee, Lee, & Collins, 2009). The reason for the poor performance in geometry could be attributed to a lack of spatial sense among American students

(Lee, Lee, & Collins, 2009). Maccoby and Jacklin (1974) found that fourth grade students benefited strongly from the instruction involving spatial ability (Smith & Schroeder, 1979). “Many studies have demonstrated that people who are better at spatial tasks also excel in mathematics” (Cheng & Mix, 2014, p.2). Research has shown that there is a direct link between mathematics and spatial ability by concluding that “children and adults who perform better on spatial tasks also perform better on tests of mathematical ability” (Cheng & Mix, 2014, p.2). Therefore, the National Council of Mathematics (2010) advocates integrating spatial reasoning into the elementary mathematics curriculum (Cheng & Mix, 2014).

Manipulatives in Collaborative Activities

Since tangram manipulatives are increasingly being used in classrooms, allowing young learners to investigate some basic geometry concepts, it is important to explore how learners interact in small groups, along with the artifacts around them, when they are learning basic math concepts. It is also important to explore how learners react to the technology that merges tangibles, with the virtual world.

From an information-processing perspective, and according to Webb (2013), collaboration in small-groups could have great positive outcomes on learners. In the Handbook of Computer Supported Collaborative Learning (2013), Webb focuses on a list of mechanisms that promote learning in small-groups including, stimulating previously learned materials, filling the learners’ knowledge gaps by repairing their mental models, and correcting misconceptions that they might have.

Such mechanisms encourage learners to externalize their internal cognitive processes in a way that allows them to present their ideas, explain them, and justify them when faced with questions or disagreement from other group members. Moreover, Webb (2013) explains that,

Students may fail to share elaborated explanations, may not seek help when they need it, may disengage from interaction or suppress other students’ participation, may engage in too much conflict or avoid it altogether, may not coordinate their communication, and may engage in negative social-emotional behavior that impedes group functioning. (p.4)

In Webb's work, it was found that within the use of tangrams, and virtual manipulatives in the classroom, both positive and debilitating processes were evident. Methods and analysis are followed by results of this study in the next sections of this paper.

Methodology

This exploratory study applied phenomenology to investigate young students' learning with the Osmo Tangram. We chose phenomenology because it focused on "the meaning of the lived experience of a small group of people from the standpoint of a concept or a phenomenon" (Schram, 2007, p.98). Additionally, we used qualitative inquiry to examine participants' learning experiences and to interrupt those experiences by capturing a description of their own perspectives. (Merriam, 1998).

Context and Participants

The research was conducted in a third-grade mathematics class of an elementary school located in the northeast of the United States. The class was selected based on availability, location, and willingness of the teacher to allow the investigation in their classroom. The length of a class was 40 minutes and a total of 19 students participated. The teacher assigned students to different groups and take turns to use Osmo Tangram and tangram manipulatives for around 20 minutes. The teacher already had stations work set up in the math classroom.

The students were randomly divided the students into 4 small groups with 4 to 5 students in each group. Each small group was paired with a researcher. The small groups engaged in both the Osmo Tangram and tangram manipulatives for approximately 20 minutes each. After the 40 minutes of engaging in both activities, the researcher interviewed their group for approximately 20 minutes asking the students about their experiences.

The role of the classroom teacher was to observe the groups of students to ensure that they remained on task throughout the research study. He walked around the room monitoring their interactions with the researchers and with the tangrams.

The researchers experimented with both the Osmo Tangram and the tangram manipulatives to determine the proper construction of artifacts used in the study. We determined that each group would have the opportunity to complete approximately 3 figures using the Osmo Tangram and approximately 3 figures using the tangram manipulatives.

Upon approval from the institutional review board (IRB), the researchers reached out to recruit participants in this class. 18 (9 boys and 9 girls) out of 19 students and their guardians agreed to participate in this research. The average age of these participants was 8 years old. During the observation and interview, one participant was absent because of health-related reasons. So, the final sample in this research included 17 participants (9 boys and 8 girls).

Data Collection

To examine participants' learning experience with two types of tangrams (traditional manipulatives and Osmo with iPad), the research enabled each participant to play with both Osmo Tangram and traditional tangram manipulatives as a comparison. Creswell (2007) claimed observation and interview as two primary methods to examine the respondents' experience. So, the researchers observed participants' experience of using Osmo Tangram and tangram manipulatives to assemble geometrical patterns and kept field notes based on an observation checklist. Then, the researchers conducted focus group interviews (Gikas & Grant, 2013) with each group about their perceptions and experiences with both tangram manipulatives and Osmo Tangram.

(a)

(b)

(c)

Figure 2. (a) Assembling tasks at the basic level; (b) Assembling tasks at the intermediate level (c) Assembling tasks at the advanced level

The researchers pre-installed Osmo app on two iPads and brought two pairs of tangram manipulatives. Thus there were four stations with two each manipulatives and Osmo. Before the session started, the researchers briefly introduced Osmo app and tangram manipulatives in the font of the classroom. Seventeen participants were assigned into 4 groups, each of which would take turns to play with Osmo Tangram and tangram manipulatives for 20 minutes. For example, Group 1 first played Osmo Tangram for 20 minutes and then they would switch with another group to play with traditional tangram manipulatives for another 20 minutes. Each group started with 5 geometric patterns (e.g., square, triangle, cat, two versions of horses) as warming up. Then in the following 20 minutes, each participant collaborated with their group members to create 10 figures as required on Osmo Tangram or tangram manipulatives. Those 10 figures were selected by the researchers with the consideration of increasing difficulties in creation, including swan, cat, tree, dog, eagle, diamond, dancer, rabbit, dolphin, and horse in a sequence. After 20 minutes, each group working on the Osmo app would switch to the tangram manipulatives for the second round of trials, and vice versa. When all groups completed the second round of trials, the researchers conducted a follow-up focus group interview with each group. The focus group interview lasted for around 20 minutes and each of the researchers took notes on participants' reported perceptions.

Data Analysis

Once the researchers completed the data collection, each of them transcribed their observation notes and focus group interviews and then shared data among the researchers for data analysis. Specifically, each group was observed and interviewed by more than one researcher and several groups' data had to be collected and combined to better understand the entire picture. Thematic analysis (Braun & Clark, 2006) was applied in this research to analyze the collected data. Each of the investigators was open to many potential theoretical patterns in the data set while generating initial codes. Each researcher individually read through the notes of observation and interview to get familiar with the content. Then they generated the initial codes sentence by sentence and initial codes were shared among the research team. Researchers worked together to discuss inconstant codes and finalize common themes from the emerged patterns. The researchers applied constant comparative method to identify the common themes (Glaser & Strauss 1967), including collaboration, engagement, problem-solving strategies, and usability. Finally, the researchers collaborated to provide a holistic descriptive account of participants' experiences and perceptions of Osmo Tangram and tangram manipulatives.

In interpretive qualitative research, the researcher makes meaning of the data that is learned (Rossman & Rallis, 2012). The researcher filters the information through a lens, which shapes how the researcher sees and thinks about the phenomenon. Data and information "do not speak for themselves; they are interpreted through complex cognitive processes" (Rossman & Rallis, 2012, p.34). Therefore, it is important for the researcher to understand how their personal beliefs and opinions may influence their work.

All of the participants voluntarily joined the project. Transcribed notes of observation and interviews were reviewed by multiple researchers to reach agreement. Further, the researchers depended on constant comparative method (Glaser & Strauss 1967) to identify common themes from the dataset. The use of this method allowed the researchers to compare the findings within subgroups (Glaser & Strauss 1967). The subgroups consisted of the Osmo group and the tangram group. The themes that emerged from the data are discussed in the next section.

Results

In this qualitative study, we examined the perception, collaborations and interactions of elementary students during the implementation of the Osmo Tangram, in a mathematics lesson. It is clear that the overall experience of using the virtual/physical Osmo Tangram, during the in-class activity, and in groups, seemed to have a motivating effect on the students. However, some debilitating processes were also observed. The following are a few themes that emerged throughout the lesson. The emergent themes are considered from a collaborative information-processing perspective and future design and instruction recommendations follow.

Collaboration, Engagement, and Teamwork

Collaboration and socialization are critical components to higher-order thinking skills essential for early childhood mathematics (Cicconi, 2014). Computers increase collaborative work and social interaction (Clements & Sarama, 2002). The majority of participants reported, and were observed, enjoying the use of the Osmo Tangram. They engaged actively and supported each other through positive praising-remarks such as: "You got this!" and "Good job!" During the group interview, they tended to highlight that they enjoyed the challenge they faced during the transition from the simple to more complex levels. As the complexity of the puzzles increased, the collaboration also seemed to increase, as if teamwork was more valued as problems became more difficult. The students reported appreciating help from their teammates for difficult puzzles. Through their participation in the activity, students engaged in discussions that emerged as they played. They started discussing ways in which they could solve the puzzles, and the best way to place or move the pieces. Some students shared personal stories that related to the shapes they were building. Others seemed more interested in the technology itself and were inquiring about it. According to Barron (2000), this lack of coordination between the group members may get in the way of the function of the group, as well as the learning outcomes of the individual. Cicconi (2014) supports the use of technology as a tool for collaboration by stating, "Technology's role as a catalyst for student collaboration and therefore a medium for higher order thinking, renders international support on the educator and policy level" (p.61). Clements and Sarama (2002) explain the advantages of computers in teaching and learning mathematics. Specifically, computer manipulatives allow for application of mathematical operations, extended manipulation, and flexibility and manageability. Although engaging positively in discussions was evident, a few students preferred to show discontent by withdrawing silently, or making remarks regarding how they feel about playing in a large group with a negative tone. Some students were showing boredom during the first few simple levels. However, their impressions shifted to excitement as the complexity of the puzzles increased. None of these findings seemed to be significantly different between the two treatments.

Some students reflected negatively on the concept of collaboration. One student explained that the cause of this feeling was the limitation of the playing space, due to the size of iPad tablet. Another student seemed less interested in the overall activity and happened to fall asleep within a few minutes of starting to play with it. Such loss of interest can be caused by many factors, which reflect the complexity of collaborative learning. Disengagement from the collaborative activity will typically result in the hindrance of the learning experience (Webb, 2013).

In one group, students seemed to have an acute sense of honor that was exhibited by boys more strongly than girls. The boys seemed to take offense at poor teamwork. According to Webb (2013), negative practices, such as hostile or disrespectful behaviors, may result in the withdrawal of individuals from the group activity. Through our observation, some learners had a strong sense of “fair play”. One boy removed himself from the activities for about five minutes when he felt conflict in the team. These actions can hinder both group and individual learning. It can minimize “help-seeking, especially when students are insulted when they seek help, receive sarcastic responses, or have their requests rejected or ignored” (Webb, 2013, p.8). This sense of honor observed among groups seemed more pronounced for boys and was a clear indication of engagement for that population.

Creative Problem-Solving Strategies

As puzzles increased in difficulty, we observed students coming up with problem solving strategies that they either enacted, inquired about, or recommended to teammates. For instance, as the complexity of the puzzles increased, one student started to use the paper diagram as a template to work on. Although the strategy itself was not effective, it is important to highlight the student’s effort to solve the puzzle. Once the students got used to the game design, they took advantage of sound alerts, color clues, and used the hints provided by the game in order to solve the puzzles.

Osmo Tangram Usability

When asked about the usability of both tangrams, the majority of the students seemed to prefer Osmo to the physical tangram blocks and described the experience as more fun. This was also confirmed by observers’ conclusion that all the children were more interested in and engaged with the tasks at the Osmo station than the traditional tangram blocks. Of particular note, observers found that while all learners were more engaged with Osmo, boys, in particular, were observably less distracted at the Osmo station. Learners stated that they enjoyed the colors and the sound alerts that came up when they solved a puzzle and described it as “happy” music.

Not all students noticed the *Hint* button but those who did either loved it, or used it conservatively, as they discovered that use of the *Hint* button cost the team some game performance points.

Several students disliked the limitation of the space in Osmo. They also criticized the inaccuracy between the size of the physical blocks and the size of the shapes on the screen. One other issue that they seemed to critique was the fact that the Osmo Tangram requires the player to be very precise about the placement of the pieces in the game space; otherwise the puzzle would not be counted as solved.

Conclusion

This exploratory study of Osmo Tangram and its comparisons with traditional tangram blocks was an early opportunity to observe the use of Osmo Tangram in classroom practice with mathematics learning. The study observed third graders and interviewed them in a focus group after their experiences with tangrams and Osmo tangram. The research found that learners were very engaged in the Osmo iPad game, and distractions appeared decreased as a result of using Osmo tangram, however, learners did have a few complaints about the technology interface which should be noted in going forward with use. In addition, as the complexity of the manipulative tasks increased, most of students were more involved in the tasks as well as the collaboration with peers. Some participants were fond of the Osmo Tangram and were highly engaged. Based on these findings, it is recommended that teachers utilize Osmo Tangram with both collaborative activities and individual exploration. In doing so, the benefits of both self-exploration and collaboration are in good stead. In addition, this study illustrates the increasing level of complexity of the tangram activities as a preferred model for students to gradually adapt to the experience and strengthen their learning outcomes. The warm-up activities at the basic level of the Osmo tasks present participants a brief picture of how the activity, the technology, and the tangram work. The model of increasingly difficult design is also recommended for effective integration of Osmo Tangram.

This research project is limited by the small sample size and short duration, and as such only attends to the level of engagement and participation in the learning process on a relatively exploratory level. In addition, whether participants had played with the tangrams or the Osmo Tangram before the experiment was unknown since the study did not include a pre-survey to collect relevant information about the participants. Lin et al. (2011) indicated that participation in collaborative virtual tangram activities improved younger students' efficacy towards mathematical problem solving and also promoted their peer collaborations. Overlooking the participants' prior experience of playing with these two sets of tangrams might decrease the validity of our findings about the effect of tangrams on their engagement and collaboration. Furthermore, this exploratory study did not consider the subtle influence of the order in which the participants played with different sets of tangrams on their performance in this activity. Their initial tangram experience might alter their preferences. Therefore, future research might extend the investigation by including more rigorous experimental design, such as pre- and post- survey to collect participants' demographic information and validated instruments to test the effect of using Osmo on the improvement of the children's spatial sense in math learning with larger groups over longer periods of time. Osmo Tangram showed significant potential in this study to engage boys, create positive collaborative moments and increase mathematical learning and as such deserves additional investigation to better hone the implementation guidelines presented tentatively in this paper.

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Figures

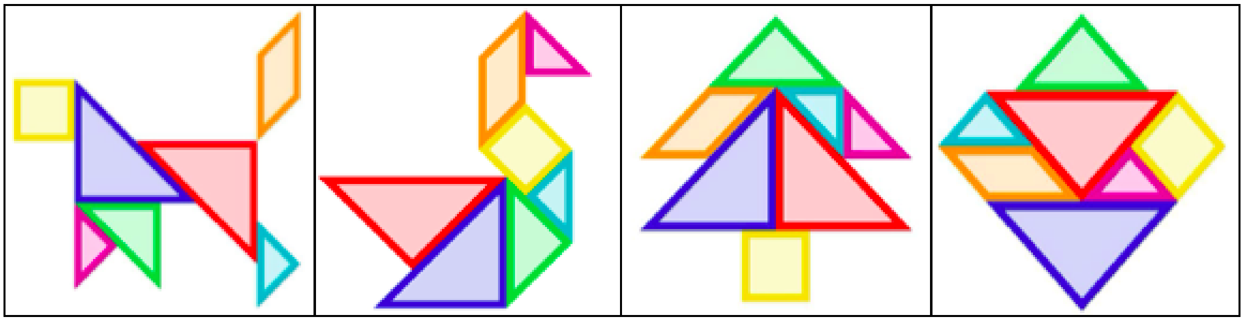
Figure 1. (a) a picture of an Osmo set and (b) a picture of the Osmo Tangram

Figure 2. (a) Assembling tasks at the basic level; (b) Assembling tasks at the intermediate level

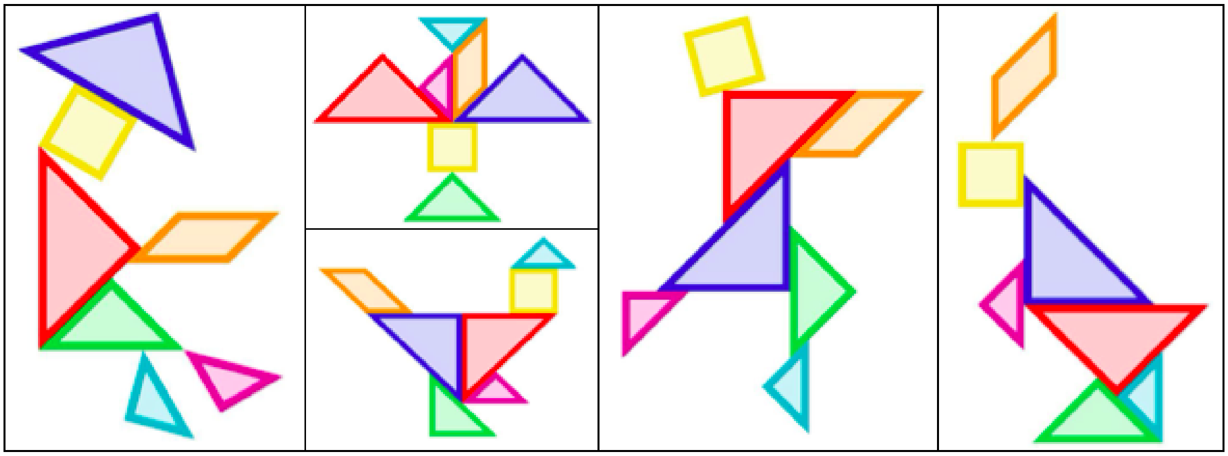
(c) Assembling tasks at the advanced level

(a) (b)

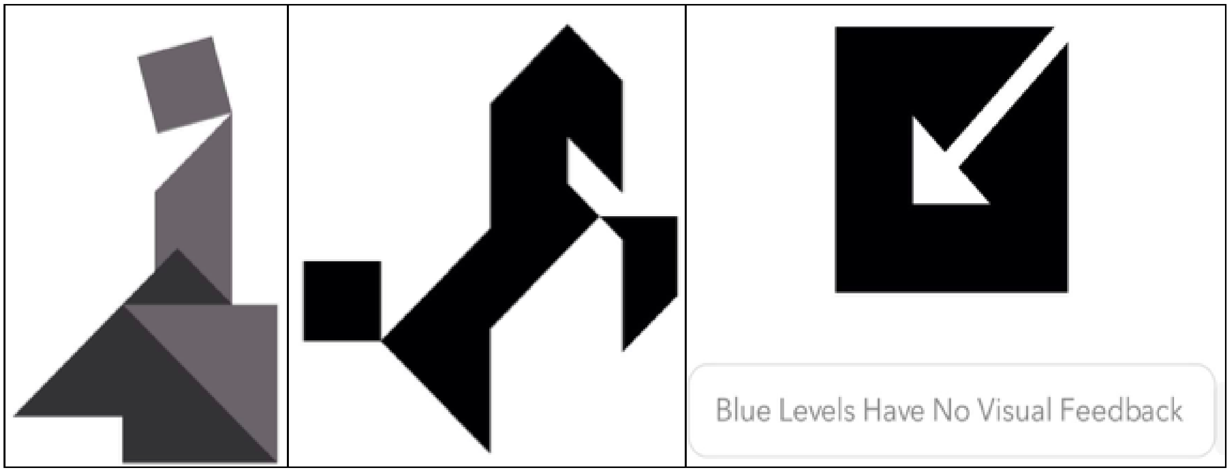
Figure 1. (a) a picture of an Osmo set and (b) a picture of the Osmo Tangram



(a)



(b)



(c)

Figure 2. (a) Assembling tasks at the basic level; (b) Assembling tasks at the intermediate level (c) Assembling tasks at the advanced level.