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Effects of tangrams on learning engagement and achievement: Case of preschool learners

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Abstract

The purpose of this research was to compare the effectiveness of physical and virtual tangrams on preschool children's learning engagement and achievement. Children listened to an e-storybook narration and solved puzzles individually. The experimental group (N = 31) completed puzzles embedded in the e-storybook using virtual tangrams, while the control group (N = 30) completed the same puzzles using physical tangrams on outlines drawn on a paper. Results indicated that the experimental group had significantly higher overall engagement than the control group. The experimental group had significantly higher learning achievement (time taken to complete outlines) when using virtual tangrams. It is hoped that the study will be beneficial to classrooms concerning how to use tangrams in teaching and learning and to instructional designers on how to design an e-storybook for young readers.

KEYWORDS

achievement, e-storybook, engagement, preschool, tangram

1 | INTRODUCTION

Learning mathematics can be difficult for children as most mathematical concepts could be abstract and not easy to savvy due to the cognitive challenge that the subject gives. Thus, most of these young learners get demotivated to learn mathematics, yet engaging this kind of learners is quite a challenge for teachers (Sedighian & Klawe, 1996). This is because to engage the learners, they need to consider the learning of mathematics activities as enjoyable and interesting and thus participate in willingly without any form of coaxing (Marcum, 2000). Engagement is essential in effective learning as it ensures that learners are affectionate and enthused with the learning activity (Fredricks, Blumenfeld, & Paris, 2004).

According to Trowler (2010), learner engagement refers to the extent to which learners are occupied and involved in a learning activity that results in a high-quality outcome. That is, the quality of effort learners devote to educational-driven activities that contribute directly to desired outcomes. Willms (2003) defines learner engagement as learner's willingness, need, and desire, and compulsion to participate in, and be successful in the learning process. When learners' are engaged, they show sustained behavioural involvement in all activities to do with learning accompanied by noticeable interest. Thus, engagement is more than involvement or participation as it requires feelings and making sense out of activities (Marcum, 2000). In the study by Skinner and Belmont (1993), the authors ascertain that engaged learners select tasks at the border of their competencies, initiate action when given the opportunity and exert intense effort and concentration in the implementation of learning tasks; they show generally positive emotions during ongoing action, including enthusiasm, optimism, curiosity, and interest.

Belenky and Nokes (2009) illustrates that teaching aids such as manipulatives can be used to engage young learners and to motivate their participation in the learning activities as these manipulatives assist learners to relate the abstract concepts being taught to their physical counterparts, which could be quite a challenge (Björklund, 2014). Manipulatives may be physical or virtual objects that are used to engage students in the 'hands-on' learning experience to introduce, remediate, or practice a concept, and able to represent abstract ideas concretely. Physical manipulatives are physical objects that can be picked up, turned, rearranged, and collected; for example, tangrams, fraction bars, and geoboards, among others (Perl, 1990). Advancement in technology has led to the development of manipulatives that learners can interact with digitally, that is, virtual manipulatives. They are interactive and give learners prompts and feedbacks while they work on problems that trigger an urge in the learners to explore more on their own (Moyer, Bolyard, & Spikell, 2002).

In consideration to other manipulatives, tangrams tend to have much contribution towards developing the learner's logical reasoning and mastery of fundamentals of geometry and to create a positive attitude towards mathematics (Lin, Shao, Wong, Li, & Niramitranon, 2011). Thus, we study the effects of physical and virtual tangrams in young learners' engagement and achievement. Tangram is an ancient Chinese geometric puzzle made out of a square. It has seven pieces: two large triangles, one medium triangle, two small triangles, one square and one parallelogram, which can be arranged in many different ways. Though initially tangrams were treated as puzzles, there are many strategies to let learners interact and explore tangrams. The easiest approach is to let the children create their own complex shapes; otherwise, children are shown a target shape (in outline or silhouette) and then asked to recreate the shape using the seven tangram pieces. This helps learners to classify shapes, master spatial relationships and develop interest and positive feeling about geometry (Brincková, Haviar, & Dzúriková, 2007).

1.1 | Theoretical background and purpose

The use of manipulatives is rooted in the theory of cognitive development proposed by Piaget (Huitt & Hummel, 2003). This theory identifies four stages of children's development: sensorimotor, preoperational, concrete operational and formal operational. The concrete operational stage is the basis for the use of manipulatives since children at this stage are able to utilize their senses. Therefore, manipulatives should be used more at this stage to provide children with more hands on experiences that will help them understand abstract ideas like mathematical concepts (Ojose & Sexton, 2009). According to this theory, only after experiencing ideas on a concrete level can children be able to understand symbols and abstract concepts (Ojose & Sexton, 2009). Thus, to help a child learn, some recommendations based on this theory include the use of varied concrete experiences such as manipulatives, which help in clear representation of abstract ideas (Huitt & Hummel, 2003).

There are arguments that preschool children considerably learn better using physical manipulatives than virtual manipulatives with proposals that physical manipulatives be used in the early grades with a gradual shift to virtual manipulatives for the upper elementary grades (Olkun, 2003). However, other studies such as Burns and Hamm (2011) and Brown (2007) focusing on effectiveness of physical and virtual manipulatives have reported that either virtual or physical, or a combination of both manipulatives can be used for learning. Nonetheless, in a study by Steen, Brooks, and Lyon (2006) to assess the impact of virtual manipulatives on first grade geometry learning, the results indicated that virtual manipulatives are more effective compared to physical manipulatives when used as instructional tools. They noted that virtual manipulatives provide a unique learning experience such as instant feedback, flexibility and saving instructional time among others. Notably, there are arguments advocating for usage of virtual manipulatives in preschool learning and others supporting the retention of physical manipulatives while others have floated the need to combine both manipulatives. It is observed that each of these manipulatives have distinct advantages but whether they can replace each other or should be used jointly for robust and effective learning highly depends on re-evaluation of the learning circumstances using these manipulatives. Moreover, technology-aided learning being new, most parents and teachers are yet to conceptualize how to adopt it as a learning tool as there are many reservations regarding allowing young learners to use computer technologies. For instance, parents have fear that the use of technological devices may cause addiction to the devices, less play and reading time, and health issues like eyestrain, among others.

In this paper, we argue that technology may be used to facilitate learning and mastery of concepts as it creates a learner-centred environment as the instructor focuses on designing learning materials and facilitating the learning process. This is because most digital learners exploit technology to enjoy ubiquitous and pervasive learning at their comfort using their personal digital devices. In this regard, it is noticeable that though the teaching methods adopted by the instructor may influence learning as reported by Clark (1983), the medium used to deliver the learning could significantly contribute to learning outcome as it has an impact on the learner's cognitive skills as shown by Kozma (1991).

To this end, the purpose of this study is to compare the effects of manipulatives on the learning engagement and achievement in preschool children towards ascertaining the effectiveness of each for learning as a tool of instruction for young learners. The specific objectives are to compare the effects of physical and virtual tangrams on preschool children's learning engagement and achievement when interacting with a specially developed e-storybook. Different from previous studies that have evaluated the effectiveness of technology in learning by examining the learning outcomes, this study focuses on engagement and achievement. Moreover, while previous studies on effects of manipulatives on learning, such as Olkun (2003) focused on older children, this study focuses on preschool children. Therefore, this study seeks to answer the following research questions:

i. What are the effects of the use of physical and virtual tangrams on preschool children's learning engagement?
ii. What are the effects of the use of physical and virtual tangrams on preschool children's learning achievement?

2 | LITERATURE REVIEW

2.1 | Children's learning engagement using e-storybooks

Application of technology in classrooms, for example, using e-storybooks has been shown to improve students' learning motivation and interest. Using e-storybooks generates students' interests, increases learning confidence, task value, and learning motivation of students by allowing opportunities for student control of the learning process and self-expression (Yang & Wu, 2012). Hong (1996) argues that storybooks provide engaging contexts for children since they mostly deal with situations that can touch children's interests and experiences, and this can catalyse their motivation. For instance, giving children activities that allow them to use mathematical concepts in a storybook context may make children to carry out mathematical activities more often and probably for longer periods, thereby becoming deeply involved in the learning activities (Hong, 1996).

2.2 | Using physical and virtual manipulatives for learning

Moyer (2001) reports that manipulative use makes learning fun and enjoyable as learners are always active and interested. In comparing the effects of virtual and physical manipulatives on students' mathematical understanding of fractions and symmetry, Burns and Hamm (2011) concluded that virtual manipulatives are as effective as physical manipulatives for introducing fraction and symmetry concepts. However, Olkun (2003) compared the effects of virtual and physical tangrams in learning two-dimensional geometry and suggested that for earlier grades, it is better to use physical manipulatives then slowly progress to virtual manipulatives. According to Reimer and Moyer (2005), learners find virtual manipulatives more interesting to use and thus tend to prefer them to physical manipulatives. Reimer and Moyer (2005) attribute this preference trend to the ability of virtual manipulatives to provide immediate feedback and some level of enjoyment and ease of use to the learners. Notably, both physical and virtual manipulatives have unique and distinctive contribution in aiding learning. For instance, virtual manipulatives have the advantage of being capable to connect dynamic visual images with abstract symbols that is not possible with physical manipulatives (Suh & Moyer, 2007). The findings of Brown (2007) on learners' attitude and preference towards physical and virtual manipulatives, however, tend to contradict Reimer and Moyer's (2005) findings as Brown (2007) illustrates that learners generally preferred the use of both physical manipulatives and virtual manipulatives. These mixed results indicate that either these manipulatives are activity- or concept-dependent or different user profiles have different preferences. Thus, it is important to look at the effectiveness of manipulatives in different learning environments and contexts to examine whether the different characteristics of different learning environments influence learning in different ways. To this end, this study intends to examine the effectiveness of virtual and physical tangrams towards engagement and achievement for preschool children.

2.3 | Effects of physical and virtual manipulatives on learning engagement and achievement

The findings by Kim (1993), Reimer and Moyer (2005), and Smith (2006) illustrate that virtual manipulatives enhanced student's enjoyment while learning mathematics. They also observed that many students had positive attitudes towards the virtual manipulatives and were engaged in the class activities during lessons. Kim (1993) owes this observation to the fact that virtual manipulatives provided students a more interesting learning environment. This is because learners who were using physical manipulatives were most times disengaged and played disruptive, non-instructional games with the manipulatives. Drickey (2000) which compares the effectiveness of virtual and physical manipulatives in teaching visualization and spatial reasoning in middle school also observed similar results. Drickey (2000) observed that students working with virtual manipulatives were actively engaged, and most of them were on-task as they worked on the computer. Students in the physical and no manipulatives group were observed to be off-task. In a study to examine the impact of virtual manipulatives on geometry instruction and learning among the first graders, Steen et al. (2006) also observed that students using virtual manipulatives showed increased motivation and challenged themselves to with more unfamiliar and higher level tasks. Though some findings tend to argue that virtual manipulatives have positive impact on the students' engagement and motivation compared to physical manipulatives, some findings such as Smith (2006) as discussed prior has found that both physical and virtual manipulatives have unique and distinctive contributions and values in teaching and aiding learning and that none can replace the other.

Through investigating how preschool children engage and interact with physical and virtual tangrams as they read e-storybooks embedded with tangram puzzles, we wish to quantify the extent to which the tangrams contribute to learners' engagement and achievement. This significantly informs how and where to use tangrams to enrich the learning experience and to begin harvesting the enormous benefits of using tangrams and manipulatives.

3 | METHOD

3.1 | Participants

Sixty-one preschool children from two kindergartens in Taiwan participated in this study. The schools are from the same region and have similar backgrounds. Like most schools in Taiwan, these schools had low student population. One school had 31 preschool children and the other school had 30 children. Thus, all the preschool children in the selected schools participated in the study. In order to ensure that the groups were roughly equivalent prior to the experiment, in each school, participants were randomly assigned to either the experimental

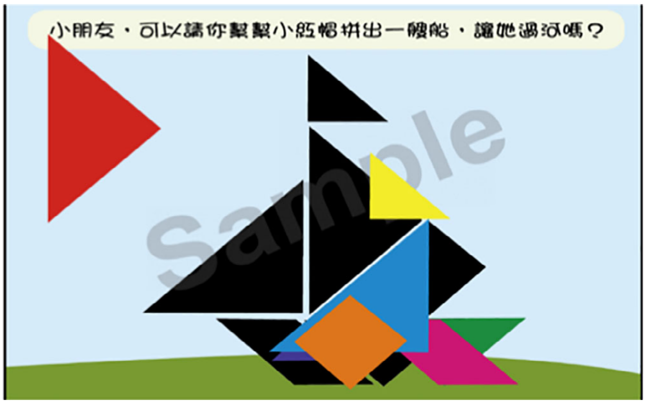

FIGURE 1 Example of outline to be completed using tangrams embedded in e-book (boat) [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 2 Example of paper outline to be completed using physical tangrams (boat) [Colour figure can be viewed at wileyonlinelibrary.com]

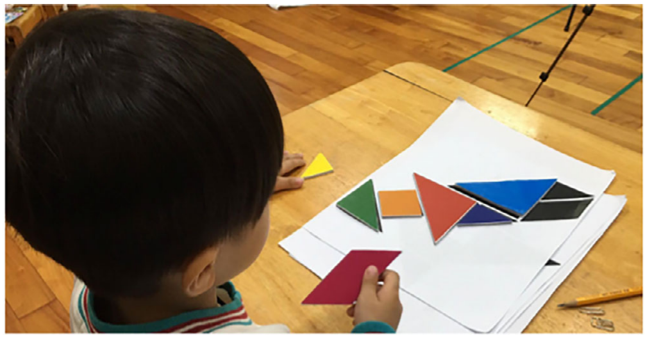

FIGURE 3 Student completing puzzle using physical tangrams [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 4 Student completing puzzle using virtual tangrams [Colour figure can be viewed at wileyonlinelibrary.com]

or the control group. Thus, in each school, we had some students in the experimental group and some in the control group. The participants included 30 boys (49.2%) and 31 girls (50.8%). Their mean age was 5.61 and standard deviation 0.61. All the participants used the same e-storybook. Before taking part in the study, all the participants were given an information statement outlining the details of the study as well as a consent form to be signed by their parents. Participants were advised that participation in the study was voluntary and all participants' parents gave their consent for their children to participate in the study.

3.1.1 | Procedure

The participants were introduced to the e-storybook and its features, for example, how to navigate through the pages of the book. The device used was an iPad. The participants completed the study in a one-to-one setting with the research team, and they were not surrounded by peers during the study. They worked individually, and during the course of the study, each participant was required to listen to the narration of the e-storybook provided and work on the puzzle tasks embedded in the e-storybook. The participants were required to complete the outline of objects – boat, sword, windmill, squirrel and candle – using the tangram pieces. Figures 1 and 2 display examples of outlines that were to be completed by the participants.

Both experimental and control groups listened to the narration of the e-storybook from the iPad. The control group used physical tangrams (pieces cut out from a cardboard) and outlines of objects drawn on paper to complete puzzles (Figure 3). The experimental group completed the outlines using the tangrams embedded in the e-storybook, by dragging each tangram piece to the right position on the outline in the e-storybook (using the iPad) (Figure 4). Video recordings as each participant listened to the narration of the e-storybook and manipulated the tangram pieces to solve the puzzle tasks were taken for further analysis. After reading the e-storybook and completing the puzzles, each participant completed a test that involved completing outlines of some given objects, using physical and virtual tangrams. Figure 5 displays the summary of the procedure.

3.2 | Instruments

3.2.1 | E-storybook

The e-storybook used was Little Red Riding Hood, which is about a young girl, Little Red Riding Hood, who is sent by her mother to take

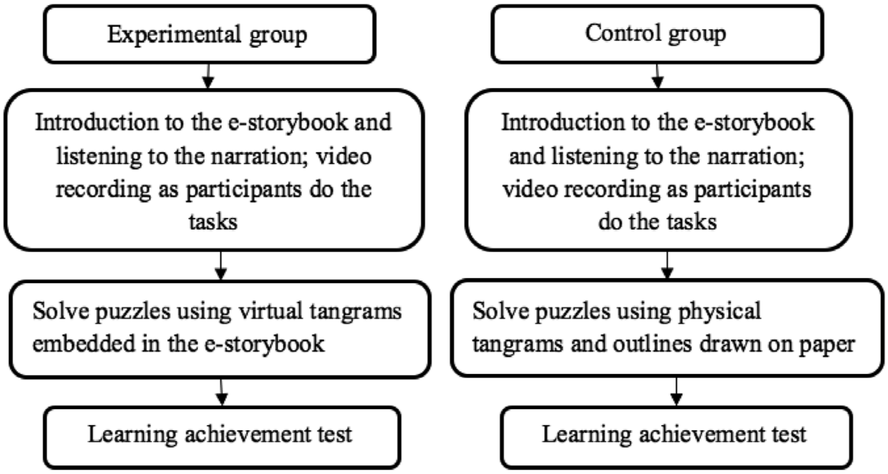

FIGURE 5 Procedure

food to her grandmother who lives in a different village from theirs. On her way to her grandmother's place, Little Red Riding Hood encounters obstacles that she overcomes using the magic tangrams given to her by her mother. She also meets people who need help, and she tries to give them assistance using the magic tangrams. After overcoming all the obstacles, Little Red Riding Hood finally arrives at her grandmother's place. There are five puzzles in the storybook. For instance, for Puzzle 1, Little Red Riding Hood has to cross a river but she does not know how to, and Mr. Fish suggests to her to make a boat, which she does, using the tangrams (Figure 2 and Figure 4). Other puzzles involved making a sword, windmill, squirrel and a candle.

3.2.2 | Learning achievement test

This test was developed by the researchers. To ensure content validity of the test items, three experienced kindergarten teachers were asked to provide feedback on the items. The participants were required to complete four outlines of objects. Two outlines were to be completed using physical tangrams by both groups and two were to be completed using virtual tangrams by both groups. The test was designed such that both the experimental and control group students used both virtual and physical tangrams to complete the outlines. This was done in order to reduce the bias that may arise due to familiarity with either type of tangram since the control group had used physical tangrams to complete the paper outlines as they read the book, and the experimental group had used virtual tangrams. It was assumed that familiarity with the kind of tangram used while reading the book could affect the results. The purpose of the learning achievement test was to investigate the score, that is, the number of pieces that the children were able to place in the correct position on the outline as they worked with each kind of tangrams. This test also investigated the time the participants took to complete the outlines when working with each kind of tangram (physical and virtual). Each outline was to be completed using seven pieces. A maximum score of seven points per outline could be obtained by placing all the pieces in their correct position on the outline. In other words, each piece placed in the correct position earned a child a point per outline. For outlines completed using physical tangrams, the maximum score was 14 points. Similarly, for outlines completed using virtual tangrams, the maximum score was 14 points. The overall learning achievement score was 28 points. The scores obtained for each puzzle and time taken to complete each puzzle by each participant were collected in order to compare any differences in learning achievement between the virtual tangram and physical tangram group.

3.2.3 | Engagement indicators

To identify the participants' levels of engagement as they read the e-storybook and worked with the tangrams to solve puzzles, we used the typology for observing children's engagement with e-books proposed by Roskos, Burstein, and You (2012). In this research, the definitions and coding rules of some behaviours were modified to incorporate observation of engagement while working with tangrams. For instance, in the original scheme, control was defined as operating the device. Appropriate use of tangrams was added to this definition. The coding rule for looking was also modified to include focusing on where to move the tangram pieces with minimum distractions. In the original typology, the use of language included commenting, asking and answering questions, but since the activities conducted in this research did not involve answering questions, answering questions was not analysed in this research. The typology was applied to a sample of 24 preschool children and was found to be reliable. In the original study conducted by Roskos et al. (2012), the inter-rater agreement was found to be 86%.

The behaviours demonstrated by participants as they solved puzzles using the tangrams as they listened to the narration in the e-storybook were coded and recorded. The observational data were coded at 2-minute intervals by a team of three independent researchers using the categories and salient behaviours defined in the typology. Each salient behaviour present in an interval was

TABLE 1 Engagement behaviours definitions and coding rules

Category	Definition	Salient behaviours	Definition	Rule
Control	Take meaningful action	Operating the device	Quick, easy access to device buttons, use of control buttons on device; appropriate use of tangram pieces; direct participation	Code CON if operating the device and arranging tangram pieces majority of the time with minimum or no assistance from the teacher
Multisensory behaviours	Using visual, auditory and haptic-kinaesthetic senses	Looking/consistent focus	Eyes directed to the screen	Code L if eyes and position are oriented to the screen and focusing on where to move the tangram pieces with minimum distractions
		Touching	Fingers applied directly to the screen	Code T if tapping, scrolling, swiping the screen to move and arrange the tangram pieces, picking the physical tangram pieces to arrange them appropriately
		Listening	Attending to the audio stream of the e-storybook	Code LIS if not talking, listening attentively (looking at the screen)
		Moving	Positioning to view the screen	Code M if moving the body to orient to the screen and in preparation to solve the virtual tangram puzzle or preparing to manipulate the provided physical tangrams, e.g., sitting, standing, changing position and wiggling
		Gesturing	Communicating via bodily actions	Code G when using hands and body to make motions
Communication	Using verbal and nonverbal behaviours	Facial expressions	Using facial gestures to express thoughts and feelings	Code P (positive) if smiling or puzzling; Code N (neutral) if no expression, gazing; Code Neg (negative) if appears angry, sleepy, frowning
		Making noises	Using sounds to express thoughts and feelings, such as squealing, laughing and gasping	Code S if making sounds that are not words
		Language	Using speech to comment and ask questions	Code C for commenting; Q for asking questions

Adapted from Roskos et al. (2012).

TABLE 2 Independent *t*-test comparing effects of tangrams on the three categories of engagement and overall engagement

	N	Experimental group Mean (SD)	Control group Mean (SD)	*df*	*t*	*p*	Effect size
Multisensory behaviours	61	54.55 (10.05)	43.77 (10.99)	59	−4.001***	.000	1.02
Communication behaviours	61	22.23 (8.44)	20.62 (6.43)	56	.842	.403	0.21
Control	61	92.97 (9.98)	90.00 (13.33)	59	−.986	.328	0.26
Overall engagement	61	56.58 (4.89)	51.46 (6.31)	59	3.549**	.001	0.91

$^{**}p < .01$; $^{***}p < .001$.

coded according to the coding rules (Table 1). Frequency counts of salient behaviours exhibited by each child at 2-minute intervals were obtained, that is, the number of intervals a behaviour occurred. The data were aggregated and the percentage of intervals in which each behaviour occurred was calculated. The data were compared between the two groups per category, per behaviour, and overall engagement.

3.3 | Data collection and analysis

Data on engagement were collected by video recording and researcher observation. Data on learning achievement were collected using a learning achievement test. The data were analysed using both qualitative and quantitative methods. Quantitative methods included descriptive statistics and independent samples *t*-test to examine

TABLE 3 Independent *t*-test comparing effects of tangrams on each multisensory behaviour

		Experimental group		Control group					
Multisensory behaviour	*N*	Mean	SD	Mean	SD	*df*	*t*	*p*	Effect size
Looking	61	84.45	22.00	51.20	34.26	49	4.494***	.000	1.15
Touching	61	77.61	7.17	76.63	7.94	59	.506	.615	0.12
Listening	61	83.71	30.79	68.57	31.11	59	1.911	.061	0.49
Moving	61	27.00	32.70	20.73	19.79	50	.909	.368	0.23

****p* < .001.

TABLE 4 Independent *t*-test comparing the effects of physical and virtual tangrams on the learning achievement

		Group	*N*	Mean (SD)	*df*	*t*	*p*	Effect size
Outlines completed using physical tangrams	Score	Experimental	31	11.16 (2.37)	59	1.175	.245	0.30
		Control	30	11.83 (2.09)				
	Time	Experimental	31	317.74 (188.19)	59	−1.904	.062	0.49
		Control	30	242.23 (110.28)				
Outlines completed using virtual tangrams	Score	Experimental	31	14.00 (0.00)	—	—	—	—
		Control	30	14.00 (0.00)				
	Time	Experimental	31	71.77 (45.10)	44	2.665*	.011	0.69
		Control	30	96.63 (24.41)				

* *p* < .05.

differences in engagement and achievement between the control and experimental groups. Cohen's *d* was calculated and used to determine the effect size for the comparisons between the means. Qualitative data analysis was used to code observational data as already described. Coding consistency was analysed between the researchers using Cohen's Kappa. The inter-rater reliability was 0.84. Few differences that were obtained between the researchers were discussed and resolved.

4 | RESULTS

4.1 | Objective 1: Comparing the effects of physical and virtual tangrams on the learning engagement

The means and standard deviations of the three categories of engagement, and overall engagement are presented in Table 2. Independent sample *t*-tests revealed significant differences between the two groups' multisensory behaviours, and overall engagement with the experimental group having higher means. The effect sizes were large. There were no significant differences between the two groups' control and communication behaviours.

For each multisensory behaviour, there was a significant difference only in looking with the experimental group having a higher mean than that of the control group. No significant differences were obtained for touching, listening and moving behaviours (Table 3). Gesturing was not analysed because there were only few students who demonstrated this behaviour. There were no significant differences when each communication behaviour was analysed separately.

4.2 | Objective 2: Comparing the effects of physical and virtual tangrams on the learning achievement

First, comparisons were done for the overall score and time taken to complete the test by each group. No significant differences were obtained between the two groups' scores obtained and time taken to complete outlines. Therefore, separate analysis were done to compare the scores and time taken to complete outlines when both groups used physical tangrams, and when both groups used virtual tangrams.

For the outlines that were completed using physical tangrams by both groups, there were no significant differences in score and the time taken to complete outlines. For the outlines that were completed using virtual tangrams by both groups, there was a significant difference between the groups in the time taken to complete outlines. The experimental group used less time than the control group. Differences in scores could not be analysed because the standard deviation for both groups was zero (Table 4).

5 | DISCUSSION

5.1 | Effects of tangrams on engagement

Results indicated that there was a significant difference in engagement between the two groups. The experimental group had a significantly higher overall engagement than the control group. This result indicated that use of virtual tangrams could have led to higher engagement.

The students appeared to enjoy manipulating the virtual tangrams due to the enriching technological experience that comes with it. It appeared that interacting with the iPad in itself was fun and thus increased the children's engagement. Most of the children (73.8%) had not used such technology before to read a storybook and this was a new experience to them. The children embraced technology and used the opportunity to explore the new experience. Moreover, arranging the tangram pieces in the case of virtual environment was much easier and direct, as the pieces would always fit in position so long as a correct piece is dragged on and a notification sound was given to confirm a correct action. This is in contrary to physical tangrams where placing the pieces on their correct position was a little tedious, and there was no notification to indicate if the move is correct or wrong. This feedback and ease of use could have led to higher engagement for the children as they were able to know when they had placed a piece in a wrong position. Since it was difficult to arrange the physical tangram pieces and the participants had to figure out by themselves how to place the pieces correctly, it appears that the use of physical tangrams presented the children with a higher cognitive challenge hence the lower engagement compared to the virtual tangrams, which were easier to work with. This result could mean that we could use virtual manipulatives, which appear to be fun and easier to work with, to help build learners' confidence especially in subjects like mathematics that presents a cognitive challenge to most learners.

These observations are consistent with Drickey (2000), Kim (1993), Reimer and Moyer (2005) and Smith (2006), who found that the use of virtual manipulatives leads to higher student engagement and enjoyment. Reimer and Moyer (2005) pointed out that while working with virtual manipulatives, students had a positive experience and were engaged in the classroom activities since they thought virtual manipulatives were fun to use. According to Kim (1993), virtual manipulatives provided a more interesting learning environment hence the higher engagement for children who used them. The immediate feedback provided by the virtual manipulatives makes it easier for learners to work individually without external assistance.

Considering the control category, there were no significant differences statistically between the groups. This result could have been due to usage of the same e-storybook by both groups, which required the children to operate the iPad by themselves. Probably, the outcome would be different if one group was using printed storybook while the other was using the e-storybook.

On multisensory behaviours, there was a statistically significant difference between the two groups with the experimental group exhibiting multisensory behaviours most of the time. Considering each of the multisensory behaviours, the experimental group showed significantly more looking behaviours. This difference could indicate that virtual tangrams made children to be more focused, attentive, and able to concentrate for a longer period as they did not have to shift between the e-storybook and the paper outlines like in the case of the control group. This result is consistent with Steen et al. (2006) that found that the use of virtual manipulatives kept the children focused as they showed increased time-on-task. Drickey (2000) also observed that students using virtual manipulatives had higher rates of on-task behaviour than those using physical manipulatives or no manipulatives. In addition, Yuan, Lee, and Wang (2010) reported that students using virtual manipulatives paid more attention to exploring the problem (finding the number of polyominoes) and therefore spent more time discussing the problem with their peers in the same group since they found it easier to work with virtual manipulatives.

There were no significant differences on communication behaviours. The non-significant results could be due to the fact that interacting with e-storybook was a new experience to most of the children and so they were probably eager to discover the fun in the activity. Besides, the activities that both groups were involved in were similar and thus solicited almost similar communication behaviours with small variance.

5.2 | Effects of tangrams on achievement

No significant differences were obtained between the two groups' overall learning achievement scores. The non-significant results could mean that virtual and physical manipulatives could be equally effective in learning. These results are consistent with those of Burns and Hamm (2011) where even though the results showed that the group using physical manipulatives had a higher improvement in scores, there were no significant differences between the groups. According to Burns and Hamm (2011), students were attracted to both kinds of manipulatives hence the insignificant differences. Kim (1993) and Steen et al. (2006) also found no significant differences in achievement between the group using virtual manipulatives and that using physical manipulatives.

However, when virtual manipulatives were used as assessment, there was a significant difference in the time taken to complete the outlines between the two groups. The experimental group used a significantly shorter time than the control group. Since the experimental group had used virtual tangrams to solve the puzzle tasks in the e-storybook, the group's familiarity with the use of virtual tangrams could have contributed to their use of a shorter time.

Although there were no differences in overall achievement between the two groups, there were significant differences when the virtual group used virtual tangrams to complete the outlines indicating the importance of familiarity in the learning process. This result supported by Björklund (2014) who concluded that when learning abstract concepts using manipulatives, familiarity increases learners' ability to relate abstract concepts with natural concepts.

5.3 | Implications for classroom instruction and instructional designers

The results on achievement indicate that both physical and virtual tangrams could have equal contributions towards learning. This could imply that virtual tangrams could be used in place of physical tangrams for teaching and learning, and vice versa. However, we noticed that children who had used virtual tangrams to solve puzzles performed better in the tasks that required the use of virtual tangrams. This could imply that prior experience with a given kind of tangram could have some influence in their learning achievements. Therefore, before using tangrams for teaching and learning, the instructors may need to ensure that children explore them to get familiar with them. Since the benefits of virtual tangrams outweigh those of physical tangrams, and with new technology, virtual tangrams may be used since learners find them more interesting. Besides, we noticed that children appeared to enjoy the technological experience that comes with virtual tangrams. Our results showed that having prior experience with the virtual tangrams led to significant differences in the learning achievement. Therefore, we suggest that parents and teachers should not discourage children from using digital products due to the fear that the technology may cause more harm than good as this will make them to miss the chance to gain new experiences brought about by interacting with these products. Instead, we recommend that children be allowed to take advantage of any opportunity that allows them to try out virtual manipulatives to familiarize themselves with the manipulatives.

There is the need to design tangram applications for learning, for example, e-textbooks, in a manner that is easy to learn and to use, and enjoyable to use such that children who have no prior experience in interacting with virtual or physical tangrams could still find them fun to interact with. In other words, they should have affordances such that learners can easily know how to manipulate them. In addition, the memory load required by the children to use the tangrams needs to be low. For instance, in our case we embedded tangrams in an e-storybook that had many interactive features to make it interesting and help reduce the memory load of the learners. Moreover, the storyline was familiar to the children. Thus, future designers could consider developing new ways of integrating interactivity into tangram applications to engage students learning.

We also noticed that feedbacks such as notifications for correct and wrong actions could encourage the learners when an action is correct while giving them a chance to react to their mistake. The manipulatives need to provide the scaffolding needed until a learner can develop the understanding of the concepts. Therefore, we recommend that instructional designers consider ensuring that the tangram applications designed provide feedback and scaffolding.

5.4 | Limitations and future studies

This study can generally be characterized as a comparison between conditions of 'technology with' and 'technology without' and is reported in the literature such as Brown (2007) and Burns and Hamm (2011), among others, that 'technology with' has negligence effects regardless of design, so called the no significant difference phenomena. However, in this study, we notice a significant difference probably due to novelty effect in virtual tangrams. Nonetheless, there is need for more data collection to ascertain this argument. Moreover, the study population was from only two kindergartens, which may not be a sufficient representation for the sake of generalization. In addition, the focus of this study was on the effects of tangrams as children solved puzzles in an e-storybook. This way, we established how tangrams could generally be exploited to enhance learning. To this end, it would be important that effects of tangrams on learning specific topics, for instance in mathematics or science, are established. Towards this, we are able to design tangrams that easily fit into the content requirements of these subjects.

6 | CONCLUSION

This study focused on the effectiveness of physical and virtual tangrams on the learning engagement and achievement in preschool children. Findings showed that children who used virtual tangrams had higher overall engagement and exhibited more multisensory behaviours. For learning achievement (time taken to complete the outlines) when using virtual tangrams, the experimental group used a significantly shorter time compared to the control group. Although there were no differences in overall achievement between the two groups, there were significant differences when the virtual group used virtual tangrams indicating the importance of experience and familiarity in the learning process. Since virtual manipulatives are more engaging and enjoyable to use than physical ones, why not allow children to use them yet they can equally be effective in enhancing learning?

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest in writing this manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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