Using the TrigOno Card Game for Mastery Learning of Trigonometric Identities

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Abstract: The lack of opportunities for students to practice and master their lessons may result in poor performance in advancing mathematics. This technical action research involved high school STEM students in developing TrigOno, a non-digital card game with popular shedding-type gameplay, to address a problem concerning poor student mastery of trigonometric identities. The intervention applied cooperative learning groups based on team-game-tournament structures with dyadic partnerships between developing and more developed learners. The activities included demonstrations, practice drills, and tournament games, covering only two weeks of implementation outside of the designated class time. Generally, results from pre- and post-tests found a significant increase in student mastery of the lesson, with a strong implication in the mathematics classroom. However, the study did not find evidence to close the gap between developing and more developed learners. Nevertheless, qualitative evidence from student reflections and narratives revealed that the learners benefited from the non-digital game-based learning intervention. Further, the findings suggested that the students not only achieved desirable mastery levels but also gained confidence in their abilities and awareness of using strategies. Insights and recommendations were provided to offer support to fellow mathematics teachers who wish to apply the designed game in their educational settings.

Keywords: Action research, Game-based learning, Mastery learning, Non-digital games, Trigonometry

INTRODUCTION

The lesson on trigonometric identities is presented as a learning unit in Trigonometry under the Pre-Calculus subject of the Science, Technology, Engineering, and Mathematics (STEM) track of the Philippine senior high school K-12 curriculum. The skills involved in performing mathematical computations using trigonometric identities should be developed with a desirable level of student mastery to help learners simplify complex trigonometric expressions, solve related mathematical problems, and understand other important mathematical principles. Moreover, student mastery of trigonometric identities should be attained to advance learners to higher mathematics learning competencies.

However, the senior high school students in a small local public high school located in the northern Philippines struggled to perform mathematical analysis involving trigonometry using trigonometric identities. The required competencies involving trigonometric identities served as a prerequisite to their present lesson on evaluating the limits of trigonometric functions. This problem should not be seen to be unique to the local setting as "students often have limited students' context of knowledge in understanding trigonometry" (Rosjanuardi & Jupri, 2022, p. 1).

As their present subject teacher, I investigated the problem by conducting a test along the target competencies and found that, indeed, the students had difficulties in simplifying trigonometric expressions and identities. The class generally got poor remarks in the test (eventually reflected as pretest scores). I conducted further investigation through informal interviews and learned that the underlying reason was due to the lack of opportunities for mastery learning, both as an educational philosophy and instructional strategy that maintains students to achieve a particular level of mastery in pre-requisite knowledge before moving forward to learn new lessons (Anderson, 2000). Empirical studies have shown that Bloom's (1976) mastery learning has positive effects on student academic performance (Kulik et al., 1990, 2013). Adeniji et al. (2018) asserted that students taught using the mastery learning approach can gain significant improvement not only in terms of mathematics achievement but also in retention of mathematical concepts. Especially in trigonometry, where students struggle to perform mathematical problem-solving due to errors involving procedural and conceptual knowledge (Dhungana et al., 2023), the lesson requires practice materials for mastery learning.

To address the pressing problem, I consulted the literature to find possible interventions that could help my students gain mastery of the prerequisite topic in order to cope with their present lesson. Research on mastery learning in a remedial instruction context suggests that the use of games is a viable intervention to improve student performance (Lin et al., 2013). Game-based learning (herein referred to as GBL) — a type of gameplay with defined learning outcomes (Plass et al., 2015) — has been the term used by scholars and practitioners to describe an approach to teaching that employs games in the learning environment. The purpose of GBL is to promote student motivation, engagement, and learning through game-oriented activities and environments (von Gillem & Alaswad, 2016). Ke et al. (2015) explained that the idea behind the use of games in the context of learning is that student engagement to play and learn "occur cohesively as a whole to compose a highly motivated learning experience" (p. 1183). GBL involves lessons that are competitive and interactive, and invite students to have fun while learning (Kingsley & Bittner, 2017). In the systematic review carried out by Bakan and Bakan (2018), they examined the trends of game studies. Using 190 original game-related research articles taken within a 12-year period from 2005 to 2017, the authors found that the use of educational games is more effective in learning and student achievements, especially when it comes to retention. The findings can be attributed to the learning activities in GBL in which repeated practice of key skills during gameplay allows students to better retention and mastery.

In recent years, most studies on game-based learning for STEM education have focused on the use of digital games (Wang et al., 2022). However, the educational value of creating and using non-digital games in teaching STEM has not been fully investigated (Rahimi & Kim, 2021). Given the urgency of the problem that needs to be addressed and the insufficiency of technological tools in my school, I leaned on non-digital game-based learning (NDGBL). Hamid et al. (2022) claimed that non-digital games have positive effects on students' STEM learning gains in that students can also benefit from teacher's implementation of NDGBL. Also, given the context of my classroom, I perceive that NDGBL is more potentially advantageous because it poses fewer problems as compared to its counterpart. According to Nitin (2015a), although non-digital games are less fashionable and relatively unsophisticated than digital ones, they inherit lesser barriers to adoption in the classroom, such as (a) lesser requirement of teacher's technological expertise, (b) less time required for its development, (c) lesser exposure to violence, (d) lower administrative overhead and lesser maintenance, and (e) no technological failure. Furthermore, non-digital games are cost-effective (Nitin, 2015b) and can enhance social interaction and enjoyment while learning (Corbett, 2014), making them an ideal instrumentation for mastery learning in remedial classes.

To this end, I presented the problem to my students as well as what I learned from the literature regarding the use of games as a possible course of action. We then agreed on my proposal and consequently deliberated on the details of the intervention. The class discussion resulted in the use of an educational card game that adopts the classic, popular shedding-type gameplay, UNO™. Several developed educational card games in mathematics focus on student mastery of pre-calculus lessons. For example, Finch ([U.S. Pat. No. 5,033,754], 1991) developed a card game that allows students to practice systematic solutions of algebraic equations. Likewise, Merritt ([U.S. Pat. No. 6,341,779], 2002) developed a matching game that employs mathematical cards and dice to practice the skill of identifying equations. Lastly, Baker and Baker ([International Pub. No. WO 2016/172781 A1], 2016) developed a math card capture game using a deck of cards that allows students to formulate equations involving integers and mathematical operations. However, none of these prior art games developed an educational card game that focuses on student mastery of trigonometric identities.

INTERVENTION

Game Design and Materials

The game material was an innovation of the mathematical flashcards. Research has demonstrated the benefits of using mathematical flashcards to improve mathematics proficiency (Kromminga & Codding, 2021). However, not all students benefit from the use of mathematical flashcards, as the practice material is static and not interactive, and many students would still find it boring. Fortunately, the inherited problem of mathematical flashcards being static and not interactive could be addressed if they were used within the context of games. Incorporating gameplay into the application of mathematical flashcards would better promote student motivation, engagement, and learning (Kingsley & Bittner, 2017).

The design of the game was based on the popular, classic UNO™ card game; hence, the name of the designed card game for the NDGBL intervention was *TrigOno*. The card game used a deck (Table 1) containing trigonometric identities and expressions whose value equivalent, when simplified, can be $\sin\theta$, $\cos\theta$, or 1. However, the trigonometric expressions were limited to the fundamental, reciprocal, quotient, and Pythagorean identities, as these were the focused lessons of the remedial instruction. The deck consisted of 100 cards, of which 24 were categorized as valued-special (contain trigonometric expressions with unique gameplay effects), 72 were valued-regular (also contain trigonometric expressions but with no special effect when played), and four were non-valued (just action cards). The identities and expressions were carefully selected to conform with the percentage distribution of 40-40-20% for easy, average, and difficult levels, respectively. Easy problems include mostly basic identities with one- to two-step solutions; average problems involve one to two different identities and require two to three steps to solve; and difficult problems comprise three or more different identities and necessitate more than three steps in solving. For problems involving radicals, the students were instructed to get the principal square root of the expression in order to continue in the game. In Table 1, the combined easy and average level problems were assigned to valued-regular cards, while the difficult level problems were assigned to valued-special cards, particularly the *draw* and *shed another card* cards. Given these, there were a total of 90 trigonometric problems to solve, each trigonometric value equivalent ($\sin\theta$, $\cos\theta$, and 1) having 12 easy, 12 average, and six difficult level problems. The assignment and distribution of trigonometric identities and expressions were considered to allow for dynamic, strategic, and competitive gameplay of the designed non-digital game.

From the design descriptions of the game, *TrigOno* was one of the numerous educational games developed that can help enhance student computational reasoning. However, the designed non-digital game was one of the few non-digital games that can be used in high school settings (cf. Hui & Mahmud, 2023). The game design intended to improve mathematical thinking concerning decoding and processing speed in performing mathematical operations using trigonometric identities. The learning game design elements of Plass et al. (2015) Integrated Design Framework of Game-Based Learning informed the development of the non-digital game, with the exception of the narrative and musical score, as these are elements of digital game-based learning. The game materials were then packaged with an accompanying players' guide.

Gameplay Modifications and Complexities

The designed non-digital game, *TrigOno*, adopted the shedding-type gameplay of the UNO™ card game in which the goal is to be the first to shed all cards at hand. The game starts by dealing an equal number of cards for each player and setting up the draw and discard piles. The first discard is determined by drawing and revealing the top card of the draw pile. The discard must be regular; otherwise, the next top card is drawn and this step goes on until players get a regular card. The top discard then reveals the trigonometric value in play. The first player has now two options: (a) to play a card at hand; or, (b) draw a card from the draw pile. If the first player wishes to play a card at hand, then they have two options of playing a non-valued card or a valued one; otherwise, the first player draws a card from the draw pile, ends their turn, and the next player to the right gets a turn. A player who plays a non-valued card can just lay the card on the discard pile without any condition and perform the game-playing instruction as indicated in the card before the end of their turn. On the other hand, a player who plays a valued card, be it either valued-regular or valued-special, should perform the gameplay for each specific type of card described in Table 1.

Pilot Testing

After completing the design of the non-digital game, *TrigOno* was pilot tested to a group of practitioners composed of four high school mathematics teachers and a group of students composed of six twelfth STEM graders. Both groups were asked to play the card game and provide feedback to improve the initially developed game materials and designed gameplay. A 10-item assessment questionnaire was used to measure the extent of satisfaction of both groups after playing the game. The questionnaire also attempted to assess the relevance, appropriateness, and appearance of the non-digital game. The assessment covered the clarity of the gameplay instructions, content and features of the game materials, inclusion of GBL elements (e.g., motivation, interaction, and competition), and objectives of the NDGBL implementation (mastery learning). The questionnaire was evaluated by two experts in the field of mathematics education.

Overall, both groups rated the TrigOno card game as interactive, competitive, and stimulating/motivating. They both assessed that the game instructions were easy to follow, the game materials were free of errors, and the contents of the cards were appropriate for the target students. Positively, both groups perceived that the designed game incorporates student learning, engages students to learn the lesson with the other players, encourages student enjoyment while learning the lesson, and promotes student mastery of the target lesson. The mean rating scores were calculated as 4.88 and 4.80 for teachers' and students' groups, respectively, based on a five-point Likert scale (with higher score means better satisfaction) and interpreted as both highly satisfied regarding the overall experience with the game. In addition, comments and suggestions such as color combinations and size of the cards were considered in the game development for further improvement. The game materials were then reproduced for implementation.

Intervention Activities

Meet-up and review

A meeting was held to solicit shared responsibilities and commitment from the students and communicate the study to their parents. Child assent and parents' consent forms were provided and secured. A short session with the students was organized for a review class.

Demonstration and practice games

A demonstration game was organized to help the students familiarize the mechanics and flow of the game. The class was divided into five cooperative learning groups. Each group consisted of pairs of developing and more developed learners. The pairs were required to play games within their assigned groupings during the demonstration but were also allowed to play with other groups of their choice during practice games. While the demonstration game was conducted as a regular meeting, the practice games were carried out outside of class time.

Tournament

A tournament was held to showcase the mastery learning gains of the students with the lesson. The tournament employs team-game-tournament structures based on their assigned groupings and pairings. A tournament bracket was prepared following the King of the Hill system of play in which a pair with two losses would automatically be eliminated from the game competition.

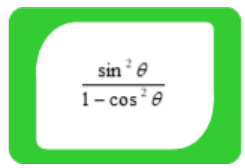
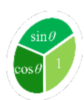
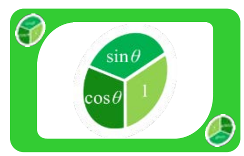
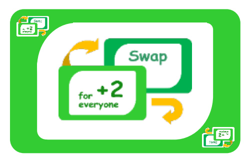
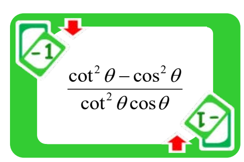
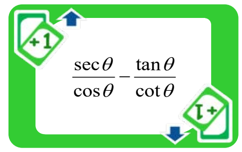
Card Name	Indicator	Category	Pcs	Sample	Gameplay
Regular Card	None	Valued-regular	72		The player should match the trigonometric value equivalent of the last valued discard on the discard pile.
Change Value		Non-valued	3		The player may pick a new trigonometric value in play.
Swap or Draw 2 for Everyone		Non-valued	1		The player may either exchange all cards at hand to any player of choice or require other players to draw two cards from the draw pile.
Shed All Equivalent Card		Valued-special	6		The player may shed all cards that are regular and equivalent to the trigonometric value as indicated in the special card.
Shed Another Card		Valued-special	9		The player may shed another card at hand. If so, then the player's turn may extend depending on the cards being played. The trigonometric value in play may change.

Table 1: Deck of *TrigOno* cards and their gameplay

Card Name	Indicator	Category	Pcs	Sample	Gameplay
Draw Card		Valued-special	9		The player's turn ends, but the next player will automatically draw a card from the draw pile. Unless the next player also holds a draw card, regardless of the trigonometric value equivalent, then they may play the same card, and this play goes on until a player in succession who refuses to play the same card gets the accumulated effect of drawing cards. The trigonometric value in play may also change.
		Total	100		

Note. All designs, including the package covers, game cards, and gameplay innovations, were registered in progress.

Table 1: Deck of *TrigOno* cards and their gameplay (Continued)

METHODS

Research Design

This action research was prompted to implement NDGBL as an intervention for mastery learning to address the pressing problem concerning poor student mastery of trigonometric identities in a local classroom setting. The practitioner's inquiry centered on the two action research questions:

1. How well does the NDGBL intervention using the *TrigOno* card game improve student mastery of trigonometric identities?
2. What are the students' experiences in the game activities that support learning gains derived from the implementation of NDGBL intervention using the *TrigOno* card game?

The technical action research approach of Kemmis' and McTaggart's (1992) classroom-based action research (CAR) model was used in the study. The CAR model presents an iterative process following a four-stage cycle that includes (a) planning, (b) acting, (c) observation, and (d) reflection. A total of eight weeks was covered in the first cycle of NDGBL implementation. Within this period, five weeks were covered for planning with the students including the process of game development; two weeks for acting and observation covering the implementation of game activities including practice and tournament games, and; one week for reflection covering the collection of data and conduct of a culminating program. The outcomes of the study were reported just after the first cycle upon achieving conclusive results. The CAR model was appropriate because it served as the overall guide in designing and implementing NDGBL as a classroom intervention for mastery learning.

Consistent with the pragmatic epistemological stance inherited from action research (Creswell & Creswell, 2018), this study also employed the mixed-methods approach to research with a quantitative focus to examine the applicability of using the *TrigOno* card game as a remedial intervention for mastery learning. The hybrid of pretest-posttest and basic qualitative research designs determined the concurrent typology that guides the collection and analysis of data. The pretest-posttest designs for one group and non-equivalent groups were employed in the analysis of the performance of the intact class and between developing and more developed learners, respectively. The pretest and posttest were appropriate to gauge the effects of the treatment (Dimitrov & Rumrill, 2003), which in this case was NDGBL intervention. The basic qualitative research design, on the other hand, was employed to gather qualitative evidence focusing on master learning gains. The basic qualitative research design was particularly well suited for this study as it attempted to uncover the experiences of the students with the NDGBL implementation and discover the meaning ascribed to those experiences (Merriam, 2009).

Participants

The study initially recruited 40 STEM students, representing the total enumeration of the 11th graders. However, 34 were able to complete the NDGBL implementation, of which 14 were males and 20 were females. Within the cohort, 24 were identified as developing learners, and 10 were identified as more developed learners. The selection of developing and more developed learners was primarily based on the results of their pretest using an arbitrary scale, such that students with a fair level of mastery (range: 9-16 points) or lower (Poor: 0-8 points) were categorized as developing while those with satisfactory level of mastery (range: 17-24 points) or higher (Very Satisfactory: 25-32 points; Outstanding: 33-40 points) were categorized as more developed. However, the social compatibility or dyadic relationship of the pairs was considered to ensure peer interaction and cooperation among participants. An independent samples t-test (Table 2) was carried out to establish significant differences between the mastery levels of the two groups in the pretest. The statistical difference found presumed that there exists a significant gap between developing and more developed learners before the implementation of NDGBL intervention.

	Levene's statistics		Mean Difference	t	Sig.
	F	Sig.			
Pretest Scores	.078	.781	8.225	9.537	.000

Table 2: Pretest comparison between developing and more developed learners

Instruments

Equivalent Tests

Teacher-made parallel tests consisting of forty multiple-choice items each were used in the study to measure the mastery learning gains of the participants. The pretest instrument was used not only as a pre-measurement but also as a validating test during the reconnaissance stage of the action research process and assessment in classifying developing and more developed learners. The pretest instrument, which has been developed and used for years of practice, had undergone validation and item analysis. From the scores of previous classes, the difficulty index ranged from 0.25-0.75 and above 0.75, indicating that most of the test items had medium to hard levels of difficulty. This scoring range was acceptable since the goal of the intervention focused on mastery learning. Khan Academy (n.d.) asserted that teachers who employ a mastery learning approach can adjust their tests by increasing the level of student expectation to cover more challenging problems. The discrimination index, on the other hand, garnered 0.30 and above, indicating that most of the test items had acceptable discriminating power. Nevertheless, appropriate actions were taken for items needing revisions before the instrument was used as the pretest. The posttest was constructed parallel to the items in the pretest with assumed equivalent difficulty and scope.

To address the issue concerning familiarity with the problems contained in the cards, I ensured that the trigonometric expressions were not duplicated in the posttest. Of the 90 problems used in the deck, only 15 out of 86 (17%) trigonometric expressions were found similar in the test. Twelve of these expressions were knowledge-based basic identities that could be used to simplify other expressions. In this regard, it can be said that the test results reflected mastery learning performance, not students memorizing answers and trigonometric problems.

Reflection and Narrative Sheets

The reflection and narrative sheets were administered during the culminating activity of the NDGBL intervention. This instrument was used to obtain qualitative data that would substantiate the quantitative results. The participants were asked to openly narrate and reflect on their experiences with the game activities. Student reflections and narratives provided *in vivo* codes and working categories that highlighted their mastery learning gains in the NDGBL implementation.

Data Analysis

In the study, the arbitrary scale (see Participants) was utilized in analysing pretest and posttest scores. The mean and standard deviation were used to describe the levels of mastery learning gains. Further, the paired samples t-test was utilized in the comparison between the pretest and posttest scores of the intact class while the independent samples t-test and ANCOVA (using posttest results as the dependent variable, student group as the independent variable, and pretest results as a covariate) were used in the comparison between developing or more developed subgroups. The selection of the identified statistical tests was appropriate based on the results of the exploratory data analysis, which satisfied the assumptions of the test, including normality (Frankfort-Nachmias & Leon-Guerrero, 2018). Data were analyzed using statistical software.

Further, the open and *in vivo* coding systems were used in analyzing student experiences with the NDGBL. The student reflections and narratives were transcribed, coded, and analyzed to identify themes and organized patterns. The coding process involved three cycles, namely (a) descriptive, (b) meaning, and (c) pattern, with a focus on before and after the NDGBL intervention. For the first cycle coding, the transcripts were individually coded by simply describing the participants' experiences and using *in vivo* codes. For the second cycle coding, the generated codes from the first cycle were re-coded to generate more meaningful codes and categories. To code, *in vivo* codes and the meaning units through first-cycle coding were identified, condensed, and assembled into codes/categories. Finally, for the third cycle of coding, the codes and categories were grouped to generate subthemes and possible themes. The condensed meaning units were read thoroughly to identify similarities and differences and sorted to further condense them to form subthemes. These subthemes were then assembled to form the themes. Both themes and subthemes focused on participants' mastery learning gains. Reflections on themes were conducted again while considering the goal of generating pieces of evidence related to the results of the NDGBL intervention. The qualitative data analysis was conducted through manual coding using word processing and spreadsheets.

Trustworthiness

To establish the trustworthiness of the qualitative research findings, the coding process was done thrice to ensure that the transcribed texts from the data gathered were carefully read and re-read, then coded and re-coded. While coding, the researcher also wrote memos. These memos served as a representation of the researcher's thoughts while coding which helped shape the development of appropriate codes and themes (Creswell & Creswell, 2018). Moreover, I reflected on my positionalities by recognizing the different roles I played during the conduct of the study so that I would not be able to influence personal views and biases in the development of the research findings.

Ethical Considerations

Upon the approval of the research request, my students were formally asked to participate in the action research study. I emphasized to them that their participation is voluntary. No students were coerced in the recruitment of the participants. Gladly, the whole class responded positively to my invitation. Then, they were given student assent and parent consent forms. The forms informed both the students and their parents about the NDGBL intervention, including the game activities that they participated in, the plan for data collection, and the actions to protect their rights to privacy. The forms, as well as the research instruments, were all evaluated and approved by the university research ethics committee.

RESULTS

Mastery Learning Gains

Intact Class

Only ten out of the 34 students (29.4%) had a satisfactory level of student mastery of the lesson before the intervention. However, after implementing the NDGBL intervention, all the participants attained a desirable level of student mastery, of which 12 out of 34 (35.3%) achieved an outstanding performance (see Table 3). The comparison between the overall mastery levels of the students before (pretest [mean=14.79, s.d.=4.42]) and after (posttest [mean=30.65, s.d.=5.79]) the implementation of the NDGBL intervention showed a remarkable improvement from fair to very satisfactory levels. Further, a statistical analysis on the comparison of means using the paired *t*-test (see Table 4) revealed that the difference between the mastery levels of the students before and after the NDGBL intervention was found statistically significant, $t=16.17(df=33), p<.001, d=2.77$.

Mastery Levels	Number of Students			
	Pretest		Posttest	
	Frequency	Percent	Frequency	Percent
Outstanding	-	-	12	35.3
Very Satisfactory	-	-	20	58.8
Satisfactory	10	29.4	2	5.9
Fair	23	67.6	-	-
Poor	1	2.9	-	-
Total	34	100.0	34	100.0

Note. Overall results for Pretest: mean=14.79, s.d.=4.42; Posttest: mean=30.65, s.d.=5.79

Table 3: Mastery levels of the students in the pretest and posttest

	Paired Differences		t	Sig.	Effect Size
	Mean	Std. Dev.			
Pair 1 Posttest Scores - Pretest Scores	15.85	.000	16.17	.000	2.77

Table 4: Paired samples test on participants' pre- and posttest scores

Developing and More Developed Learners

The mean scores of the developing group in the pretest and posttest (see Table 5) were calculated as 12.38 (s.d.=2.30) and 29.38 (s.d.=5.412), respectively. Likewise, the mean scores of the more developed group in the pretest and posttest were calculated as 20.60 (s.d.=2.271) and 33.70 (s.d.=5.774), respectively. A group comparison using ANCOVA was carried out; however, the results found no significant difference between the mastery learning gains of the two groups.

	Group	N	Mean	Std. Dev.	F	Sig.
Pretest Scores	Developing	24	12.38	2.300	1.447	.238
	More developed	10	20.60	2.271		
Posttest Scores	Developing	24	29.38	5.412	.001	.972
	More developed	10	33.70	5.774		

Table 5: Group scores of developing and more developed learners

Qualitative Evidence

Using reflection sheets, the participants shared their experiences with the game activities. Of the 34 student documents collected, 20 were evaluated as rich sources (Ravitch & Carl, 2016) that could provide supporting evidence about the mastery learning gains found in the quantitative data. However, data saturation was reached using only 11 student reflections and narratives. Qualitative analysis (see Table 6) revealed that the students gained improved mastery of trigonometric identities in a meaningful learning fun experience. But other than student motivation and mastery increases, the participants reported that they have become aware of using strategies when solving problems. Lastly, the students also perceived that they gained confidence in their mathematical abilities (also referred to as mathematics self-efficacy) after completing the NDGBL intervention.

DISCUSSION

The pretest scores have shown that most of the students had a fair mastery of the lesson at the beginning of the NDGBL intervention. However, the posttest results indicated that the students generally gained mastery learning increases and attained a very satisfactory level. The statistical significance found in the comparison between the overall mastery levels implied that the designed NDGBL intervention using the *TrigOno* card game helped the participants achieve mastery of trigonometric identities. The computed Cohen's (1988) *d* value was 2.77, indicating that the effect size was very strong or huge (Sawilowsky, 2009). The computed value means that the implementation of the NDGBL helped the participants achieve a desirable level of student mastery with more than two standard deviation units. The huge effect offers a great deal of practical application in the real world in that NDGBL environments can promote mastery learning gains in the context of remedial instruction. Ursavaş and Genç (2021) corroborated these findings, positing that students' insufficient and limited understanding of the lesson can be turned into sufficient and excellent remarks through game-based learning. To this end, this study supports the general findings in the literature regarding the positive effects of game-based learning environments (Bakan & Bakan, 2018; Liu et al., 2020), more particularly using non-digital games (Hamid et al., 2022; von Gillern, 2016) like STEM-oriented educational card games (Liu & Chen, 2013; Michael & Anugwo, 2016; Samuelson, 2018).

Both groups gained mastery learning increases; the developing group achieved from fair to very satisfactory levels while the more developed group achieved from satisfactory to outstanding levels. However, the study did not find evidence to close the gap between developing and more developed learners. While even low-to-medium-scoring students can potentially perform like their high-scoring counterparts when provided with activities that focus on student mastery (Adeniji et al., 2018), I purported that the cooperative learning structures employed in the designed game-based learning allowed both developing and more developed learners to gain mastery increases. In other words, more developed learners also benefitted from the same game activities to enrich their understanding and enhance their skills — thereby maintaining their gap with their developing peers.

Qualitative evidence suggested that while the participants generally asserted inadequate competence in the lesson, they greatly benefited from the NDGBL intervention. Given the qualitative data indicating mastery increases, we can say that the NDGBL intervention using *TrigOno* card game achieved its purpose as a remedial instruction for mastery learning. Other than mastery increases, the participants also gained awareness of the use of strategies and confidence in their abilities. Regarding self-efficacy, however, I noticed that most students who reported an increase in self-efficacy were those in the winners' bracket in the team-game tournament results. Shu and Liu (2019) asserted that students with higher self-efficacy tend to perform better in game-learning activities as they put more effort into solving problems and become more persistent in completing the task.

Limitations

One notable limitation of this work concerns its focus on the selected students bound within the context of an intervention activity. This is typical for action research in which the selection of participants is made intentional and purposive. Another limitation is concerned with the scope of the lesson covered in which the trigonometric expressions contained in the non-digital game developed were limited only to fundamental, reciprocal, quotient, and Pythagorean, identities. Other forms of trigonometric identities, such as those that involve sum and difference, even and odd, and double and half angles, were not covered. Finally, the study is also limited to its focus on student mastery learning gains. Student engagement factors uncovered in the student narratives and reflections were not further examined in the study. Likewise, other factors, such as autonomy and cooperation, which can be found in the qualitative data to help explain the quantitative results were no longer explored. Future work may delve into the interaction among these factors to gain a better understanding of the efficacies of non-digital games within the mastery learning environment.

In vivo and Other Codes (Number of occurrence)	Sample Quotes	Common Categories (Percentage of students)	Working Themes
Fun (19) Enjoy (22)	I really enjoyed playing and learning while having fun. I can clearly say that I learned a lot and enjoyed every second of playing *TrigOno* Cards.	Enjoyment (11/11=100%)	Motivation
Exciting (7) Thrilling (7) Challenging (9) Interesting (5)	I enjoyed playing and learning trigonometric measures in an exciting way. I really like the game for its unique, exciting, and challenging nature.	Interest (9/11=82%)	
Learn (31) Solve (40) Able (7)	I guess you can improve your problem-solving skills by playing [*TrigOno*]. Because of this, I will be able to answer a problem in our final exam.	Improvement (11/11=100%)	Mastery Increases
Fast/faster (6) Easy/easier (11)	Learning trigonometric functions is very hard, but with the help of *TrigOno*, [the lesson is] made easier. In the game, I learned how to solve fast with different strategies.	Efficiency (9/11=82%)	
Strategic (13) Technique (9)	After playing the game, I also learned about the strategies for solving a problem. *TrigOno* did not just only improve my simplifying skills, but it also helped me [become] strategic. We won because of our fast-solving skills and also our techniques.	Strategy development (8/11=73%)	Becoming Strategic
Confident (3) Competitive (4)	We were confident that our solutions were correct. My *TrigOno* experience is really a memorable one because, at first, I was afraid of the game, but now I can say that I am a competitive opponent.	Self-efficacy (5/11=45%)	Self-efficacy

Table 6: Codes and themes describing participants’ experiences with NDGBL intervention

Reflections

As a result of teacher reflection on this action research, the following insights were provided. These insights were translated into recommendations to offer opportunities to fellow mathematics educators who are interested in applying *TrigOno* in their classrooms. These recommendations were derived based on the activities designed for the NDGBL intervention.

- *Allow students to play in pairs*. Peer teaching within cooperative learning structures would benefit both developing and more developed learners. However, it is important to consider the dyadic relationship or social compatibility of the pairs.
- *Encourage students to play for one to two weeks*. Mathematical competencies involving numeracy are best developed through practice. Here, we can provide the class with a monitoring schedule. The games can be carried out outside of class time.
- *Participate in student games*. Teacher involvement during practice games would help support the successful implementation of the intervention. Playing games with the students can be helpful in conveying our commitment to providing opportunities for improvement.
- *Consider tournament games*. Competition is an essential component of games. Team-game-tournament can help promote interactions in a non-digital game-based learning environment. A tournament bracket, such as the King of the Hill system of play, can help facilitate the tournament games.
- *Organize a culminating activity.* A simple celebration program would be a good avenue to highlight student efforts and achievements in the intervention. Here, the teacher may provide incentives to the participants, especially the tournament winners, to recognize their motivation and commitment throughout the game activities.

CONCLUSION

This work highlights the application of a non-digital game in action research and its potential as an intervention to foster mastery learning in the context of remedial instruction. The results of the study indicated that student mastery of the target competencies significantly improved using the *TrigOno* card game in a game-based learning intervention. With high levels of interest and enjoyment with the game, students were motivated to achieve favorable mastery learning outcomes while increasing their self-efficacy and strategic thinking. Based on the research findings presented, I concluded that the designed non-digital game can be offered as a promising approach to provide students with opportunities for mastery learning of trigonometric identities. Likewise, I asserted that the designed NDGBL using the *TrigOno* card game could be a viable classroom intervention for remedial instruction. Hence, insights and recommendations, as well as the gameplay adopted (see Appendix), were provided to offer support to other mathematics teachers who wish to apply the designed game in their educational settings. I also offered this innovation with the hope of contributing to the long battle of mathematics teachers to minimize, if not eradicate, the negative impressions of many students toward the subject. Although the game designs, including materials and innovative gameplay, were registered in progress, others should not use the designed TrigOno card game for commercialization.

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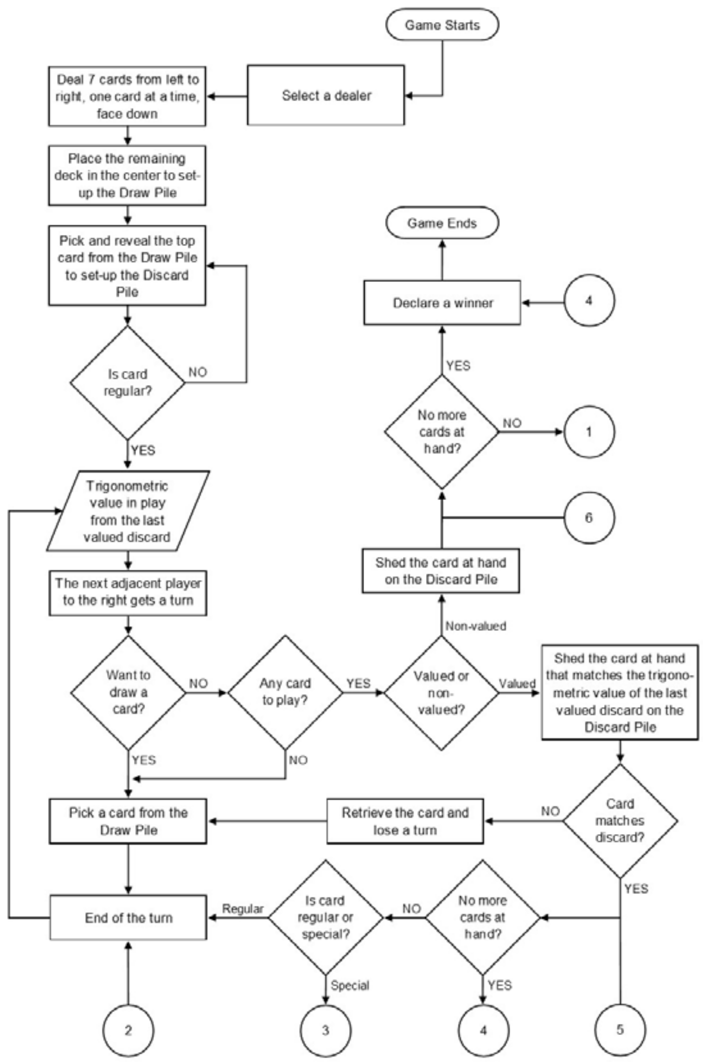
APPENDIX

Flowchart of the Designed Gameplay for *TrigOno*



Flowchart of the Designed Gameplay for *TrigOno* (continued)