Students' Algebraic Thinking and Attitudes towards Algebra: The Effects of Game-Based Learning using Dragonbox 12 + App

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Abstract

The language of algebra promotes thinking about pattern recognition and analysis, problem-solving and reasoning skills, and generalising arithmetic operations through representation with symbols. However, the high level of abstraction in algebra can cause difficulty for some students. Students who have problems learning algebra tend to show less positive attitudes toward algebra. Therefore, this study aimed to examine the effects of an android app, the DragonBox 12+, on algebraic thinking and attitudes toward algebra among eighth grade students. By using a quasi-experimental approach, comparison was made between an experimental group (n = 30) and a control group (n = 30). The instruments used were a pre-post test to test algebraic thinking and a Fennema-Sherman questionnaire to measure student's attitudes toward algebra. Results revealed that students who learned algebra using the DragonBox 12+ showed significantly higher mean scores in algebraic thinking and attitudes toward algebra compared to the control group. Findings suggested that DragonBox 12+ can provide insights into the support required for mathematics teachers to adopt effective game-based learning for teaching algebra in their schools.

1. Introduction

Algebra as one of the basic branches of mathematics has the ability to promote algebraic thinking which involves problem-solving, representation, and reasoning skills [28]. Skills learnt in algebra are based on the idea that an equation can be manipulated by performing the same operation on both sides to form another equation that has the same value but is written differently. Edwards [8] found that the most difficult aspect in developing algebraic abilities of students in the earlier stage of middle school is to master some important concepts of algebraic notation, variables, functions and properties of numbers. These four basic concepts have been classified as major algebraic ideas and need to be developed to build a solid foundation of problem solving in the classroom. These concerns are evident from Van Amerom [49]'s study which showed that many high school students have difficulty in applying the concept of basic algebra to solve an equation. In addition, lack of proficiency in mastering the properties of equality is a main factor for students who have difficulties in applying the concept of equality in solving algebra problems [44]. Martinez [33]'s study in *Trends in International Mathematics and Science Study (TIMSS)* also showed that students have difficulty in answering questions that require understanding and application of algebraic expressions to perform complex procedures.

In response to difficulties in learning algebra, Ferrucci [11] and Sinclair [41] claim that the modelling approach is a 'powerful tool' to improve problem solving skills among middle school students. According to Ferrucci [11], the modelling approach emphasizes pictorial representation to analyse and represent quantity relationships in algebra problems, such as linear relationships. This approach helps students to visualize abstract mathematical relationships in the form of a model in which students can gain a deeper understanding of the concepts and skills to manipulate symbols as variables.

According to Sensory Stimulation Theory, more learning will occur if more senses are stimulated simultaneously [29]. Sensory stimulation is achieved through colours, level of sounds, visual of facts and media consumption. Video games are electronic, interactive games known for their vibrant colours, sound effects, and complex graphics [48]. Video games stimulate learning as they allow players to experience novelty, curiosity and challenge [15]. Through video games, students learn perceptual skills [14], learn actively [27] and carry out repetitive practice [25]. Some previous research findings showed that video games help in improving students' basic mathematics abilities [18], achievement [19], [13], concepts [30], and problem solving skills [45]. According to Devlin [7], video games promote students' innovative mathematical thinking skills. As a result, past research has suggested that playing video games benefited learners by enhancing their cognitive level [5], [23], [26], [52].

On the other hand, Vygotsky's [51] Zone of Proximal Development suggests that children could perform difficult tasks successfully with the help of adults or peers who are more skilful. Video games allow players to go beyond the 'Zone of Proximal Development' because of the desire to solve a challenging problem on their own. Players could look for some guidance if they need help to proceed with the game. This will encourage players to succeed through continuous exercise either progress to the new level or repeat it. Realising the advantages of video games in learning, this study sought answers on the impact of video games in developing algebraic abilities of students.

2. Literature Review

2.1 The DragonBox 12+ application (app)

DragonBox 12+ is a powerful video game app designed collaboratively by Dr. Patrick Marchal, a professor in cognitive science, with Jean-Baptiste Huynh, a high school teacher. It is an educational video game targeting students between 12 and 17 years old. By using this app, students can learn the basics of algebra such as property of addition and subtraction, expansion, operations of variables, and factorisation or substitution. The player needs to solve algebra problems to earn points and achieve game goals. Liu [32] states that DragonBox 12+ was the top-ranked of downloaded android app in Norway in June 2013. It has won nine awards including a Gold Medal in the 2012 International Serious Play Awards, and Best Nordic Innovation Award in 2013. The six dimensions of the RETAIN design model proposed by Gunter [16] are used to support game-based learning development in DragonBox 12+. These dimensions are Relevance, Embedding, Translation, Adaptation, Immersion and Naturalisation. Each dimension can be related directly to leaning using DragonBox 12+ as described below.

In the first dimension, ***Relevance***, the DragonBox 12+ application delivers learning materials in a way that is relevant to the players and to meet their needs and learning styles. Furthermore, the unit by unit style of instruction is introduced and prepared in the context of prior learning. The second dimension, ***Embedding,*** is very closely related to another dimension in this model and can not be viewed as a single element. It shows the extent to which academic content combines with the content or fantasy stories in 12+ DragonBox application. This dimension also shows the level of student’s potential to appreciate or 'drift' in the game. The ultimate goal is to make education intrinsic in the context of entertainment games so that players can learn and play simultaneously. In the third dimension, ***Translation***, players will face similar problems to be solved, restated in a different form or in other contexts that requires them to apply existing information. The process of transfer and application of knowledge to a new situation is a part of learning.

The fourth dimension, ***Adaptation,*** is a continuation of the concept of Transfer. According to Piaget (in Silverthorn [40]), students develop cognitive structure and cognitive skills varied by assimilation and adjustments. Assimilation is associated with the process of students interpreting events in terms of what they know. Adjustments are related to the transfer and refer to the ability of students to change or establish new knowledge to ensure they match the existing understanding or idea. Prensky [39] also explained these dimensions further when describing the nature of pattern recognition in the game. Students are able to identify the original scheme which would eventually be transferred to the new learning objects in the process of constructing knowledge. ***Immersion*** dimensions could be measured in a hierarchy ranging from simple interaction or reaction to a wholly intellectual engagement in the context of the game. The dimension termed ***Naturalization*** is borrowed from Bloom's psychomotor taxonomy which is translated as the usefulness of cognitive domains. It is related to the concept of automatic or spontaneous knowledge; that is to say, students can apply the learning information without deep thinking. Recent research found the above six dimensions of RETAIN model have supported game-based learning [43].

2.2 Attitudes Towards Learning Algebra

A number of researchers have shown that video games have an effect on student’s attitudes to mathematics learning. For example, Fengfeng [9] found that games promoted a more positive attitude to mathematics learning. Kebritchi et al. [20]’s study indicated that students showed increased focus and desire to learn when playing DimensionM™ math video games because they liked to succeed at the games' missions. Students were increasingly aware of the relationship between mathematics and real life while mathematics phobias were reduced. What is true for mathematics in general is especially true for algebra since its understanding assumes knowledge of the specialised processes and language nuances associated with symbolic representations [42]. The fact that video games enhance students' mathematical learning and develop more positive attitudes in them toward mathematics is confirmed by Kebritchi et al. [21]'s study. Kebritchi et al. [21] found that a web based computer game (ASTRA EAGLE), was able to enhance 5th grade students' mathematics performance and attitudes toward mathematics. In addition, the Fennema-Sherman (1976) attitudes toward mathematics questionnaire contains scales of confidence, usefulness, fun, teacher's expectation and attitudes, and has been used by researchers to investigate the correlation between its scales and algebra achievement [1], [4], [34], [38], [46].

Understanding the benefits of DragonBox 12+ in facilitating algebraic learning, this study investigated its effectiveness among eighth grade students' algebraic thinking and attitudes toward algebra.

2.3 Student's performance in Algebraic thinking

According to Van de Walle et al. [50], algebraic thinking is about generalising arithmetic operations and operating on symbols which involves recognising and generalising patterns of relationships among symbols as noted below.

"Algebraic thinking or reasoning involves forming generalizations from experiences with number and computation, formalizing these ideas with the use of a meaningful symbol system, and exploring the concepts of pattern and functions."

(Van de Walle et al. [50], p. 262)

Algebraic thinking is sometimes thought of as being only symbol manipulation and taught only in secondary grades. However, Jinfa et al [17] agree that an emphasis should be placed on students developing algebraic thinking as a way to help them make a smooth transition between arithmetic and algebra. In Malaysia, algebraic concepts are formally introduced in lower secondary mathematics curriculum in seventh grade (age 13+). At this level, the concept of unknowns is introduced using abstract letters as variable. Students solve word problems by identifying unknowns in given situations. Students are taught how to construct, simplify, and evaluate algebraic expressions of one variable. The computations involving algebraic expressions are developed in eighth grade (age 14+ onwards). At this level, students perform multiplication and division involving algebraic terms, and addition and subtraction involving two algebraic expressions. Students are also exposed to problem-solving strategies such as simplification, working backward, and trial and error, and representing unknowns in word problems that foster the development of algebraic thinking habits.

One aspiration of the Malaysian Mathematics curriculum is to provide opportunities for students to develop problem-solving skills, which in turn can instill a positive attitude towards mathematics. However, a study by Effandi and Yusoff [53] indicate that matriculation students have a moderately favourable attitude towards problem solving in algebra and average problem solving skills in algebra. On the other research by Nasir et al. [55] found that 10^{th} grade students faced difficulties in solving algebraic problems that involved manipulation technique of dependent and independent variables. A descriptive study by Lim [54] found that 12 types of error were made by eighth grade (Form Two) students when simplifying algebraic expressions. This included misinterpretation of exponent of variables and symbolic notation, errors in simplifying algebraic expressions involving multiplication, errors in performing distributive property in bracket expansion, and in making more detachment from the negative sign. Eighth grade students were also found to perform poorly in algebra and questions that require higher cognitive ability in TIMSS 2011 [35] (Table 1). These unsatisfactory findings indicate a need to emphasize and develop students' algebraic thinking in the early grades of middle schools.

Table 1: Malaysian student's performance in Mathematics Content and Cognitive Domain in TIMSS 2011

Content Domain				Cognitive Domain		
Number	Algebra	Geometry	Data & Chance	Knowledge	Application	Reasoning
39	**28**	33	38	44	33	**23**

Source: Md. Nor et al [35]

2.4 Study Aims

While most video games appear to be effective in creating a successful learning environment when students are engaged in playing [12], little empirical evidence exists that demonstrates video games providing any more positive outcomes for algebraic thinking and attitudes towards algebra than traditional teaching methods. The majority of the studies examining the impact of video games on learning outcomes as measured by academic achievement, cognitive performance, knowledge gain or skills and performance, such as capacity for problem solving or critical thinking. Only one study explored the impact of online game-generated feedback on early algebraic reasoning among grade 6 primary school students found positive results [24]. However, it was unclear whether this impact could be generated by using video-game on student's algebraic thinking.

Hence, this research aimed to find out the extent to which the use of an android app, DragonBox 12+ could help eighth grade students' foster their algebraic thinking and attitudes towards algebra. Algebraic thinking in this study refers to abstract letters representation and manipulation and application of algebraic expressions to perform procedures in non-routine and routine problems.

This involves problem-solving strategies such as simplification, working backward, trial and error, and representing unknowns in word problems. The level of thinking required to solve the algebra problems involved the Application, Analysis, Evaluation and Synthesis classifications of Anderson and Krathwohl [3]'s Taxonomy. Attitudes toward algebra refers to the extent to which students perceive their confidence in learning algebra and the usefulness of algebra. The research hypotheses were:

- There is a significant difference between the pre-test and post-test mean scores in students' algebraic thinking within the control group and experimental group
- There is a significant difference in algebraic thinking between the control and experimental groups in pre-test mean scores and post-test mean scores.
- There is a significant difference between control and experimental groups in mean scores in students' attitudes toward algebra.

3. Methods and Sampling

3.1 Research design and Sample

This study employed a pre-and post-test quasi-experimental design. The sample consisted of sixty eighth grade students (14 years old) selected through simple stratified sampling from one secondary school in Kudat, Sabah, Malaysia. Their prior algebraic thinking was evaluated through a pre-test. Students were divided into control and experimental groups. The experimental group was exposed to the DragonBox 12+ using either a smart phone or tablet, while the control group was taught algebra using conventional methods involving imitation and repetition. The teaching and learning session lasted 16 hours. At the end of the session, each student's algebraic thinking was evaluated through a post-test. An algebra questionnaire was administered promptly to both control and experimental group at the end of answering post-test session, which lasted for 15 minutes.

3.2 Instruments

The construction of items in the algebraic thinking test were based on the Mathematics Syllabus of seventh and eighth grades. The test consisted of 15 items posed in structured formats which were designed and modified from textbooks, reference books and TIMSS 2011 released items. Anderson and Krathwohl [3]'s Taxonomy was used as a guide to develop a blueprint for the test. The items belonged to the Application, Analysis, Evaluation and Synthesis classifications of Anderson and Krathwohl's Taxonomy. A pre-test was administered to all students prior to the treatment. The pre-test was helpful in assessing students' prior knowledge of algebra and also in testing initial equivalence among groups. A post-test was administered to measure treatment effects. Both pre-test and post-test were similar; only their consecutive numbers were changed. The items were scored according to a self-developed holistic rubric. The Cronbach Alpha internal consistency was examined and the reliability coefficient for the test was found to be 0.81.

The attitudes toward algebra questionnaire was modified from Fennama [10] scale. It consisted of 20 items split into two dimensions: confidence in algebra learning and usefulness of algebra. A 5 point Likert-scale was used: Strongly Agree (5), Agree (4), Not Sure (3), Disagree (2) and Strongly Disagree (1). The test was translated by the researcher using the 'back-to-back translation' method. The test was referred to the language experts for validation and a few changes were made based upon the comments and suggestions. The Cronbach's alpha reliability coefficient of the attitudes questionnaire was found satisfactory (0.89), which means that the instrument was reliable.

3.3 Learning algebra using DragonBox 12+ video game

The DragonBox 12+ used was a 45.43MB android app installed from the App Store which could be played on smart phones and tablets. The DragonBox 12+ had a display of colourful, interactive and high resolution graphics. It was also supported by sound and background songs to stimulate learning. DragonBox 12+ provided a tutorial to introduce the set-up of the screen, the different elements of the game (e.g. The "dragon' card, the "zero" card), as well as the goal of the game. The six dimensions of RETAIN model (Relevance, Embedding, Translation, Adaptation, Immersion and Naturalisation) are described below to support game-based learning in DragonBox 12+.

Relevance

In this application, the goal of the game was to isolate the "dragon" box on one side of the gameboard. If there was more than one "dragon" box, players needed to remove it so that there was only one box. Algebraic rules were introduced in stages by introducing cards that represent monsters or dice. Eventually, the cards would be replaced with letters and numbers, and the equal sign (=) and plus sign (+) were slowly introduced. By then, the players became more comfortable with algebraic logic and eventually were able to solve equations in the game. For example in the 1-1 level, learning objectives were achieved by introducing students to the Additive Identity Property (see Figure 1). Green circles representing the number zero were eliminated simply by clicking on them. The goal was to perform the operation of Additive Identity Property with fun while creating a feeling by clicking on green circles.

$$a + 0 = a$$
$$x + 0 = x$$

Figure 1. Additive Identity Property

Embedding

The ultimate goal of the Embedding dimension was to make learning intrinsic in the context of entertainment games, so that players could learn and play simultaneously. For example, in level 1-3, players would be introduced to the Additive Inverse Property (see Figure 2). The player has to drag and drop cards on their opposite cards (night background). Opposite cards were differentiated by colors. When later on, letters and numeric expressions are introduced, the minus sign will be the differentiator. For example, numeric expressions of Additive Inverse Property, such as $5 + (-5) = 0$ would be introduced gradually to replace the letters. The properties of opposites were by then understood. In the context of this entertainment application, letters and numeric expressions were not deliberately introduced earlier because students might feel harder to distinguish letters and numeric expressions in the process of learning while playing.

$$a + (-a) = 0$$
$$x + (-x) = 0$$

Figure 2. Additive Inverse Property

Translation

The 12+ DragonBox application fully met the third dimension, namely Translation, by providing algebra questions that allowed students to apply problem-solving experiences meaningfully. This meant that students could re-evaluate their learning with real algebraic problem solving directly. For example in the level 1-19, “dragon” box would be replaced by the letter x. With help of small light particles around the box and the x, players could identify the x as the box without any problem. It usually took a “where is the box?” thought and a few seconds before the player continued playing. When transferring to paper and pencil, it will not be any trouble introducing other unknowns to students. This would indicate to teachers that transferring had taken place and the concept of the unknowns as the box had been learned.

Adaptation

Two elements were lacking in DragonBox 12+ and required the transfer to paper with teachers’ guidance. First, as the two sides of the equation in the game were updated semi-automatically, teachers needed to explain that the addition and subtraction operations should be made on both sides of the equation, and that, multiplication or division of all groups should be in equal measure. Second, the equation was always on one line and updated every time a move was made. Students needed to copy these lines down every time when 'steps' were made. For example, teachers could write equations and instruct the students to fill in the blanks with the correct answers.

Immersion.

12+ DragonBox provided interactive learning and gave students the opportunity to respond and repeat situations in a meaningful context. Thus, it enabled students to engage in the game cognitively, physically and emotionally.

Naturalisation

Students could play 12+ DragonBox repeatedly because it provided fun with actions that could become more or less automatic through repetition. Cognitively, any student would soon learn that any number multiplied by one would end up with the same number. The more that knowledge became embedded without students having to think about things much, the easier it was for students to use them in new situations. For example, if a card needed to be placed under another card (a division operation), then the other side of equation also needed the same card to be placed under another.

In this study, students were to play the DragonBox 12+ alone by finishing the level in chapter one without being given information about its relationship with algebra. The DragonBox 12+ had a ‘tips’ button’ if students needed some help to solve problem at one level. The ‘undo’ function was also created to allow players to return to the previous step if they made mistakes. To get three stars, a player must successfully solve problems at one level within some specified moves. For example, DragonBox 12+ had set a maximum number of moves for each problem.The user would have to solve each problem in a relatively efficient way before he/she ran out of moves.

The teacher acted as a facilitator to guide the session. Once the teacher found that the students were comfortable with problem solving in DragonBox 12+, the transfer would be made on paper to teach them to solve algebraic equations in a normal way.

4. **Results**

Data were analysed using SPSS version 13.0. The difference in mean scores between pre-test and post-test in the experimental group was higher (57.9) than the control group (36.1) (Table 2). The post-test mean score of algebraic thinking in the experimental group (71.1) was also higher than the mean score of algebraic thinking in control group (49.6).

Table 2: Analysis of Mean Score for pre-test and post-test

Group	Mean of Pre-test	SD	Mean of Post-test	SD	Difference of Mean	Post-test Score	
						Lowest	Highest
Control	13.5	6.1	49.6	8.8	36.1	30	66
Experimental	13.2	5.8	71.1	9.5	57.9	50	92

Analysis of the attitudes toward algebra questionnaire showed that the mean score in experimental group (3.65) was higher than control group (2.73) (Table 3). Both control and experimental groups scored higher in the confidence scale than the usefulness scale. However, the experimental group's percentage score in confidence and usefulness scale was more positive than the control group.

Table 3: Percentage Score of attitudes toward algebra in experimental group (EC) and control group (CG)

Scale	Percentage		Strongly Disagree (%)		Disagree (%)		Not Sure (%)		Agree (%)		Strongly Agree (%)		Mean	
	CG	EC	CG	EC	CG	EC	CG	EC	CG	EC	CG	EC	CG	EC
Confidence Usefulness	60.0 49.2	84.5 61.3	8.9	2.8	35.1	11.6	33.4	36.5	16.7	34.9	5.9	14.2	2.73	3.65

Hypothesis 1. *There is a significant difference between the pre-test and post-test mean scores in students' algebraic thinking within the control group and experimental group.*

A paired-samples t-test was conducted to determine the difference in algebraic thinking between pre-test and post-test mean scores within the experimental group and control group. From the Table 4, the significant value of p was smaller than significance level of 0.05, thus, there was a significant difference from the mean scores of pre-test to post-test ($t(29)=-57.7$, $p < .05$) in algebraic thinking of students in experimental group. Based on the data in Table 4, $p = .00$ was smaller than significance level of 0.05 in control group, hence, there was a significant difference between pre-test and post-test mean scores ($t(29)=-32.3$, $p < .05$) in algebraic thinking.

Table 4. Students' algebraic thinking between Pre-Test and Post-Test in experimental Group and Control Group

Variables	Group	Pretest	Posttest	Mean difference	t	df	p
		Mean (SD)	Mean (SD)				
Algebraic thinking	Experimental	13.2 (1.1)	71.1 (1.7)	57.9	-57.7	29	.00*
	Control	13.5 (1.1)	49.6 (1.6)	8.8	-32.3	29	.00*

** Significant at p < .05 level.*

Hypothesis 2. *There is a significant difference in algebraic thinking between the control and experimental groups in pre-test mean scores and post-test mean scores.*

An independent-samples t-test was conducted to compare the mean scores of pre-test in algebraic thinking between experimental group and control group. As shown in Table 5, p = .74 is greater than the significance level 0.05, thus there was no significant difference in pre-test mean scores between experimental group and control group (t(58) = -0.2, p = .74) in algebraic thinking. An independent-samples t-test was therefore conducted to compare the mean scores of post-test in algebraic thinking between experimental group and control group. The significant value of p< .05, revealed a significant difference in post-test mean scores between experimental group and control group (t(58) = 9.1, p < .05) in algebraic thinking.

Table 5. Algebraic thinking between groups in pre- and post-test.

Variables	Test	Experimental group	Control group	Mean difference	t	df	p
		Mean (SD)	Mean (SD)				
Algebraic thinking	Pre	13.2 (1.1)	13.5 (1.1)	-0.3	-0.2	58	.74
	Post	71.1 (1.7)	49.6 (1.6)	21.5	9.1	58	.00*

** Significant at p < .05 level.*

In addition, the study also analysed the findings according to the Application, Analysis, Evaluation and Synthesis classifications of Anderson and Krathwohl's Taxonomy in order to evaluate the improvements of each classification in the experimental group. Mean scores and percentages of each classification were computed to determine the effects of DragonBox 12+ lessons on each classification. Table 3 shows the comparison of means and percentages for each dimension in the experimental group in algebraic thinking using a paired-sample t-test, with significance level alpha = .05. The results show a significant positive increase from pre-test to post-test in all classifications. Based on the percentages in Table 6, the students showed the greatest improvement in Analysis followed by Application.

Table 6. Mean/Percentage Difference of Dimensions in Algebraic thinking between Pre-Test and Post-Test of Experimental group.

Dimension	Pretest	Posttest	Mean/%	t	df	p
	Mean/% (SD)	Mean/% (SD)	Difference			
Application	4.6/32.7 (0.7)	9.7/74.1 (0.6)	5.1/ 41.4	-4.7	29	.00*
Analysis	3.2/27.5 (0.4)	10.8/67.3 (0.5)	7.6/ 39.8	-3.4	29	.00*
Evaluation	1.4/3.8 (0.2)	3.1/38.3 (0.4)	1.7/ 34.5	-2.1	29	.00*
Synthesis	1.1/2.3 (0.1)	3.5/44.2 (0.2)	2.4/ 41.9	-2.5	29	.00*

** Significant at p < .05 level.*

Hypothesis 3. *There is a significant difference between control and experimental groups in mean scores in students' attitudes toward algebra.*

An independent-samples t-test was conducted to compare the mean scores of student' attitudes toward algebra. From Table 7, the p value was smaller than significance level of 0.05. Thus there was a significant difference in post-test mean scores between experimental group and control group ($t(58) = 18.3$, $p < .05$) in student' attitudes toward algebra. The mean score indicates that experimental group promoted significantly more positive attitudes toward mathematics than the control group after the intervention.

Table 7. Student' attitudes toward algebra between experimental and control group

Variables	Experimental group	Control group	Mean difference	t	df	p
	Mean (SD)	Mean (SD)				
Attitudes toward algebra	3.7 (0.1)	2.7 (0.2)	1.0	7.7	58	.00*

** Significant at p < .05 level.*

5. **Discussion**

The findings showed that DragonBox 12+ helped to enhance algebraic thinking and attitudes toward algebra among students compared to students taught using conventional methods. DragonBox 12+ provided opportunities for students to actively engage in solving algebra problems through the six dimensions of Relevance, Embedding, Translation, Adaptation, Immersion and Naturalisation compared to traditional textbook materials. The video game was able to provide entertainment and at the same time was contextually relevant. The DragonBox 12+ also involved the students mentally and emotionally when dealing with algebra problems in different levels.

Players got immediate feedback without having to wait for the teachers. Adequate cognitive challenges were provided by requiring players to think critically when using strategies to find the solution. This was not found in the 'real world' when students solve algebra problems in the classroom. As a result, students enhanced their algebraic thinking when solving algebra problems using DragonBox 12+. It was also found that students has created the most improvement in the level of Analysis and Application of Anderson and Krathwohl's Taxonomy in solving algebra problems. In other words, DragonBox 12+ helped students to improve the skills of manipulation of abstract symbols and application of algebraic expressions to perform procedures in non-routine and routine problems.

Additionally, students who were exposed to DragonBox 12+ showed more confidence towards algebra compared to students learning with conventional methods. This is evidenced when 95% of students either strongly agreed or agreed with the statements that; “I am comfortable to try algebra problem”, “I believe I can undertake further work in algebra”, and “I think I can solve more difficult algebra problems”. Similarly, students in the experimental group tended to perceive that algebra has many uses with 88% of students either strongly agreeing or agreeing with the statements, “I require algebra in my future task”, “Algebra become important in my daily work”, and “I will need a good mastery of algebra in my future work”. Bourgonjon et al. [6] shares the same view that student's preference for using video games in learning was affected by their perception of: how useful the game would be in relation to learning outcomes; the opportunities it presents for learning; and their own personal experience of gaming outside of the classroom.

However, conventional teaching methods were also found to produce a significantly difference in enhancing student's algebraic thinking. According to Kislenko [22], such effect might be caused by the teacher's teaching method and drill exercises in the control group. The method used in control group - imitation and repetition - are commonly used by mathematics teachers in Malaysian schools. Lipsey et al [31] pointed out that there is a probability that students in the control group were doing more than usual, knowing the fact that the experimental group was using a different and interesting method.

Panasuk [37] claimed that students who are able to describe, correlate and interpret representation will demonstrate the ability to solve harder algebra problems confidently. However, this claim may not necessarily be true. Based on the algebraic problem solving in DragonBox 12+, it was found that students who learnt how to identify relationships between variables in a systematic and consistent manner were able to solve algebraic problems that exist in various forms. Information gained from the application of DragonBox 12 + has to be consistent and presented directly to students in order to provide a basis for the construction of algebraic thinking. This finding supports Mosley [36] who highlights that the higher the procedural proficiency and skill of manipulating symbols to get a definitive answer for the variables x or y, the higher the ability to produce correct problem solving. This will ultimately help students develop the algebraic thinking. Furthermore, Gunter [16] states that if the teaching methods applied relate well with the content of the game design, students as players will quickly adapt to the learning because they enjoy learning mathematics using games.

6. Conclusion

The study reveals that learning algebra using DragonBox 12+ as supported by the six dimensions of Relevance, Embedding, Translation, Adaptation, Immersion and Naturalisation, can impact positively on students' algebraic thinking. This study also shows that DragonBox 12+ can help students to develop a more positive attitude to algebra learning. Students become more confident in learning algebra and find algebra useful in their daily lives.

Attributes such as being able to perform problem-solving skills and acquire a positive attitude towards mathematics could help to achieve the aspiration of Malaysian Mathematics curriculum and address the poor performance in algebra questions in TIMSS. The mathematics educators should therefore reflect on their practices and beliefs in order to optimize the use of appropriate game-based learning tools in teaching algebra.

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