The Elements of Computational Thinking in Learning Geometry by Using Augmented Reality Application

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Abstract—Augmented Reality (AR) technology has now become a growing trend within the education field. It has the capability to combine both digital and reality world that subsequently leads to the emergence of new possibilities in improving the quality of teaching and learning activities. The objective of this research is mainly to analyse the Computational thinking elements in solving Geometry topic after the intervention of AR application. Qualitative data analysis was employed as the research methodology of this study that involved interview protocol with 10 pupils enrolled in Form 1 Mathematics class at one of the selected schools in Johor Bahru, Malaysia. Content analysis was then administered using the ATLAS.Ti Version 8 software to identify the codes, themes, and meaning conveyed by the pupils' answers in the Computational thinking test. Based on the interview and Computational thinking assessment show the pupils' ability to solve Geometrical problems using Computational thinking elements. The researcher found that Computational thinking elements do exist in problem solving pertaining to the topic of Geometry. However, the order of usage of these Computational thinking elements differs among the pupils. This leads to the conclusion that pupils who utilise the AR application with Computational thinking successfully solve Geometrical problems through the help of the Geometrical thinking process that comprises the elements of Abstraction, Generalisation, Decomposition, Algorithmic, and Debugging.

Keywords—augmented reality, computational thinking elements, geometry, qualitative

1 Introduction

4.0 Industrial Revolution consists of various new technological findings namely automation, *Internet of Things* (IoT), Augmented Reality (AR), Virtual Reality (VR), data analysis, artificial intelligence, system integration, the use of robotic and cloud computation [1], [2]. Augmented Reality (AR) is one of the blooming technology which has potential in the educational field. According to [3], in this state-of-the-art era, AR is a popular technology which is widely used in the educational field. The use of smart device gives positive impact in the learning process [4]. The present young

generation, including kids and teenagers, is known as 'digital natives' since this generation has been exposed to technology from early age [5], [6].

AR technology can help tighten the boundary between reality and virtual world. In this scenario, [3] found some research which show the potential of AR being implemented in the educational topic such as Geometry, planet movement and chemistry molecule structure. Based on the research by [7] stated that AR can help upgrade their visualisation skill. This assumption is identified due to AR characteristics which can upgrade digital information value in the learning content [8]. In fact, the result of studies [9] have shown that Augmented Reality technology can improve the effectiveness of the learning process.

2   Literature review

According to [10], Computational Thinking is generally meant as problem solving, to design system by describing basic concept in Computer Science. [11] believed that Computational Thinking term can be identified as thinking process in solving the problem in order to ensure the result can be implemented effectively. [12] describe the computational thinking concept is a problem-solving skill that starts by understanding a complex problem with a holistic approach and analyze the problem, then solve large problems step by step and make it easy to manage and fix. Besides, this research uses Computational Thinking element that has been implemented according to Computational Thinking framework as mentioned by [13], by which it emphasizes on several elements of *Abstraction*, *Generalization*, *Decomposition*, *Algorithms* and *Debugging*.

There were several previous research which used Computational Thinking for solving problem in the learning process [14]–[16]. According to research by [16] has shown that the use of Computational Thinking in learning strategy is an essential factor that can influence pupil's learning activity. For an instance, [17] found out that cognitive and metacognitive components via learning strategy has an important influence to successfully solve problems related to academic environment. The use of Computational Thinking is one of the core strategies to solve matters in Mathematics lesson.

[18] emphasized about the importance of using various teaching methods for Mathematics lesson. The obvious challenge for Mathematics lesson is Geometry topic. The research of *Trends in International Mathematics and Science Study* (TIMSS) 2011 showed that Geometry topic is the weakest one [19]. Research by [20] portrayed that the achievement of Malaysian pupils was low in the year 2007, 2011 and 2015 that contributed Malaysia to be at the low level of international benchmark for Geometry topic. Hence, [19] criticised the use of traditional method for Geometry topic and claimed that the available intervention treatment is not enough for the learning activity.

[21] informed that technology in Mathematics lesson can simplify and upgrade pupil's skill in solving problems. While [22] stated that the characteristics in the technology tools can help assist pupils to apply and use for solving Geometry topic [23] [24]. According to the research conducted by [25], AR is able to give better understanding on spatial and it helps pupils to get better score for their individual writing assessment compared to conventional method. [8] stated that AR characteristics are beneficial from the visualisation perspective as they can be a reference for shape and

additional information when cognitive has limitation to process and understand ideas in the application of learning. Besides, AR can boast motivational level, confidence and satisfaction for the use of AR mobile device for learning activity [26].

3 Problem statement

According to [27] in their research, they have identified that Computational thinking has significant relation for solving problem in Geometrical topic. Their opinion is similar with [28] who have elaborated that pupils have more interest on Mathematics which is relevant to be studied for the learning activity that uses solving problem method in the real context. One of the approaches for solving problem is applying Computational thinking skill as the process to break problems in learning process [29]. The implication of not using learning strategy in solving problem effectively will cause pupils to feel bored and experience difficulties in learning [30].

 [31] has mentioned that pupils with low visual ability will experience difficulties to develop mental visualisation. Research has proven that mental relation with Visualisation Spatial ability will be more quick and precise for Augmented Reality user in comparison with non Augmented Reality interface [32]. Moving on, the implementation of Augmented Reality in learning will provide skill to pupils towards cognitive thinking in solving problem [33]. While [34] has explained that some pupils face difficulty to solve problem of Geometry topic since the topic content can be considered as abstract that can influence low academic achievement for Mathematics subject.

4 Research questions

The study is conducted to investigate;

What are the elements of pupil's Computational thinking for solving Geometrical topic by using Augmented Reality application?

5 Methodology

Research methodology that uses qualitative design emphasizes on exploratory method as recommended by [35] which is consisted of two research methods for data collection. First method uses semi structured interviews data protocol to 10 selected pupils who are learning Mathematics in Form One class in one of the schools of Johor Bahru, Malaysia by identifying code, theme, sub-theme and meaning according to Thematic analysis [36]. Table 1 shows the examples of semi structured interview conducted. Second method uses content analysis to identify code, theme and meaning from pupil's answer in the Computational thinking assessment by using ATLAS.Ti Version 8 software. Computational thinking assessment conducted is the adaptation of design and principle guidelines to develop Computational thinking assessment by [37] of the programming topic. Researcher has modified the design and principle guidelines to Geometry topic. Analysis is conducted to identify pupil's Computational thinking elements

to solve problem of Geometry topic. Sample selection has been conducted based on purposive sample after doing Computational thinking assessment and the selection has been done to the pupils who achieve the highest score. There are 31 pupils who participate in Computational thinking assessment, those pupils who have been selected for the interview are chosen ranging from the highest to the lowest score. During interview session, researcher has to stop the session for the tenth pupil since the answer of the interview shows saturated pattern. All 10 pupils who have been interviewed are represented by the alphabets of P3, P4, P7, P9, P11, P14, P15, P17, P24, P28.

Table 1. Semi structured interview questions

No.	Computational Thinking Elements	Examples of The Questions
i	Abstraction	Q1 : *What did you do after you get question on Geometrical problem solving?* Q2 : *Beginning from understanding the given problem, what are you going to do as refer to the entity information or available important and relevant object?* Probes : *Does the given information is comprehensive? Does the information need to be added or aborted or amended?* Q3 : *How are you going to determine the given information is only the important and needed items, while the unimportant is ignored for solving Geometry problem? Please explain.*
ii	Generalization	Q4 : *Can you identify the formula for some similar problems while solving Geometry problem?* Q5 : *Can you use that Geometry problem solving when you are given different problems of Geometrical learning?*
iii	Decomposition	Q6 : *How are you going to break complex problem to the smaller parts which can be easily understood and solved in the Geometrical problem?* Q7 : *Are you able to solve each of the smaller parts problem?*
iv	Algorithms	Q8 : *How do you draft or plan the step-by-step actions for Geometrical solving problem method?* Q9 : *Do you solve Geometrical problem by using systematic step-by-step problem solving?*
v	Debugging	Q10 : *Do you recheck the answers of Geometrical problem solving after completing and answering those problem?* Q11 : *What is the method that you use to fix the mistake of Geometrical problem solving?*

6   Research procedure

Research procedure related to the implementation of Computational thinking in AR application has several phases of activities that pupils will experience as refer to teaching and learning session in the classroom. The activities prepared is according to the duration of Mathematics learning period in school. As per Table 2, Geometry topic learning that uses Computational thinking in AR technology consists of 4 subtopics. Moving on, as per Table 3, pupils are able to visualize polygon virtually for
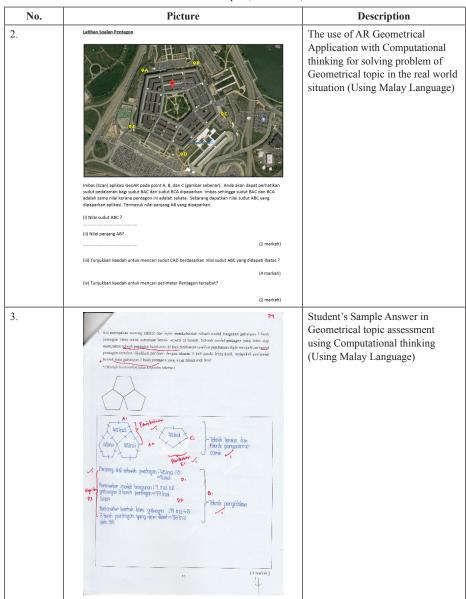
Geometry topic in the real situation and minimize the difficulty to imagine Geometry. AR application is also used together with the implementation of learning strategy by using Computational thinking as the process that pupils apply during and after using AR application. This approach is a thinking process method that is able to formulate formula of the problem, thus, problem solving effort can be represented in more effective way especially for any research related to Geometry topic. Pupils will use Computational thinking elements by adopting from [13] namely Abstraction, Generalization, Decomposition, Algorithms and Debugging elements during the process of solving Geometrical topic problem. The implementation of Computational thinking in Geometry topic of Mathematics subject is similar to [38] who has suggested the application of Computational thinking in Mathematics field since it is well-structured approach.
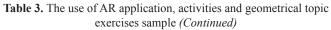
Table 2. Timetable for research on teaching and learning practice

Week	Content
1	SubTopic 1 : Line & Vertex – The use of AR application with Computational thinking • Virtual content (AR) know, compare and contrast plus explain vertex of the angle for parallel lines, reflect angle, and complete corresponding angle.
2	SubTopic 2 : Basic Polygon – The use of AR application with Computational thinking • Virtual content (AR) labling and naming, number of sides, vertex and vertex of the polygon. • Virtual content (AR) Geometrical elements for various types of triangular and square.
3	SubTopic 3 : Perimeter & Space – The use of AR application with Computational thinking • Virtual content (AR) determine various types of perimeter when long parallel lines is given or needs to be measured. • Estimate various types of space by using any suitable methods.
4	SubTopic 4 : Problem solving for Combination Geometrical Problem – The use of AR application with Computational thinking • Solve problem for any matters related to triangular and square, perimeter and triangular space, square space, parallel square, kite, trapezium and combination any types of shape.

Table 3. The use of AR application, activities and geometrical topic exercises sample

No.	Picture	Description
1.		Student uses AR Geometrical Application

(Continued)

Table 3. The use of AR application, activities and geometrical topic
exercises sample *(Continued)*

No.	Picture	Description
2.	Latihan Soalan Pentagon Imbas (Scan) aplikasi GeoAR pada point A, B, dan C (gambar sebenar). Anda akan dapat perhatikan sudut pedalaman bagi sudut BAC dan sudut BCA dipaparkan. Imbas sehingga sudut BAC dan BCA adalah sama nilai kerana pentagon ini adalah sekata. Sekarang dapatkan nilai sudut ABC yang dipaparkan aplikasi. Termasuk nilai panjang AB yang dipaparkan. (i) Nilai sudut ABC ? .... (ii) Nilai panjang AB? .... (2 markah) (iii) Tunjukkan kaedah untuk mencari sudut CAD berdasarkan nilai sudut ABC yang didapati diatas ? (4 markah) (iv) Tunjukkan kaedah untuk mencari perimeter Pentagon tersebut? (2 markah)	The use of AR Geometrical Application with Computational thinking for solving problem of Geometrical topic in the real world situation (Using Malay Language)
3.		Student's Sample Answer in Geometrical topic assessment using Computational thinking (Using Malay Language)

7   Data analysis

This research has used qualitative design and data analysis by applying thematic and content analysis [36].

7.1 Data thematic analysis (interview data)

Table 4. Thematic analysis

Main Theme	Sub-Theme	Pupils
Abstraction	Identifying important and relevant object (A1)	P3, P4, P7, P9, P11, P14, P15, P17, P24, P28
	Identifying unnecessary object (A2)	P3, P7, P14, P17, P24
Generalization	Determining similarities for some problems (B1)	P3, P4, P7, P9, P11, P14, P15, P17, P24, P28
Decomposition	Breaking complex problem to smaller parts (C1)	P3, P4, P7, P9, P11, P14, P15, P17, P24, P28
Algorithms	Drafting one operating set or step-by-step action for solving problem method (D1)	P3, P4, P9, P11, P14, P15, P24, P28
	Operating action in correct order (D2)	P3, P4, P7, P9, P11, P14, P15, P17, P24, P28
	Showing instructional control stream namely instruction or solving problem action (D3)	P3, P4, P7, P9, P11, P14, P15, P17, P24, P28
Debugging	Recognize (Identifying), remove, and fix errors (mistake) (E1)	P3, P4, P7, P9, P11, P14, P15, P17, P24, P28

This research has used qualitative design and data analysis by applying thematic and content analysis [36].

Referring to Table 4, pupils report the use of Abstraction element in solving problem of Geometry topic by identifying; searching; drawing; writing; watching; entity or object identifying such as shape; number; sentence, measurement or important value.

"While reading question, I identify essential value and rewrite namely pentagon measurement and sketching pentagon shape." [Pupil, P3]

Pupil also reported the use of *Generalization* element to solve problem of Geometry topic by showing code or theme outcome namely making; searching; identifying; using; changing; identifying number or formula.

"I identify Mathematics formula of the same measurement by knowing the length for every side. I can use the formula to cater different types of problems, for example similar side concept can be used for other problems too." [Pupil, P4]

Besides, pupils mention the use of *Decomposition* element in solving Geometry topic problem by showing code and theme gainings namely divide; separate; separation; be separated; item separation such as pentagon and Geometry problem.

"Three pentagons are divided to only one pentagon to help ease counting. I complete one by one, for instance, I get the length of the sides first. Then, finding the perimeter." [Pupil, P7]

Besides measuring the length, pupils mention by using *Algorithms* element in solving problem of Geometry topic by showing the finding of code and theme such as to design; to plan; to do something; to make; to solve; to perform; to use item systematically, organization; action; systematic; one-by-one; proper step; correctly.

"I plan my step-by-step actions for the method to solve Geometry problem. Then, I try to solve and draw the figure to ensure my choice of answer is correct. If the arrangement of problem is not organised, it will cause misunderstanding and make me confuse. Therefore, I will solve all problems by using correct and systematic steps." [Pupil, P24]

For the last stage, pupil elaborate by using *Debugging* element to solve Geometry topic problem. The result has shown code and theme earning namely check; checking; examining; ensuring; recounting; redoing work processing; answering; counting number and sketching.

"I recheck the answers written. I observe the calculated number especially perimeter and formula such as plus, minus, divide and multiply." [Pupil, P11]

7.2 Data content analysis (computational thinking assessment)

Table 5. Content analysis

Computational Thinking Elements							
Pupil	**Abstraction**		**Generalization**	**Decomposition**	**Algorithms**			**Debugging**
	A^1	A^2	B^1	C^1	D^1	D^2	D^3	E^1
P3	✓	✓	✓	✓	✓	✓		
P4	✓	✓	✓	✓	✓	✓	✓	
P7	✓	✓	✓	✓	✓	✓		
P9	✓	✓	✓	✓	✓	✓	✓	✓
P11	✓	✓	✓	✓	✓	✓		✓
P14	✓	✓	✓	✓	✓	✓	✓	✓
P15	✓	✓	✓	✓	✓	✓	✓	✓
P17	✓	✓	✓	✓	✓	✓		✓
P24	✓	✓	✓	✓	✓	✓		
P28	✓	✓	✓	✓	✓	✓		

Table 5 clearly state that all pupils have shown *Abstraction* element namely 'Identifying information on essential and relevant entity or object' (A^1) and 'Identifying information on unimportant entity or object' (A^2) . Besides, all pupils have also portrayed *Generalization* element namely 'Determining similarity characteristics for some problems in order to ensure the identified solving method formula can be applied to different types of problem' (B^1). All in all, the analysis also shows that all pupils are exposed *Decomposition element* (C^1), 'Separating complex problem to smaller parts in order to be more understood and able to be solved'. On the other hand, *Algorithms* element which is (D^1) 'Planning one operational set or step-by-step action for solving problem method' and (D^2) 'Performing organised action according to correct step' show that all pupils have portrayed that element, but (D^3) element 'Showing command control flow such as instruction or action for solving any problem' by which only pupils P4, P9, P14 and P15 using that element in doing mathematical calculation. P3, P7, P11, P17, P24 and P28 do not show the calculation for (D^3) but the final answers are still correct and according to the feedback given during the interview, those pupils are able to straightly

give answers since the calculation for (D^3) is just an imagination which is not shown on the answer sheet. The final element is *Debugging*, only pupils P9, P11, P14, P15 and P17 show the use of (E^1) element 'Recognize (Identifying), remove, and fix errors (mistake). P3, P4, P7, P24 and P28 do not show the calculation for (E^1) but the final answers are still correct and based on the pupils' feedback during the interview, they are confident with their final answers and do not show the answer checking process for (E^1) in the answer sheet.

8   Discussions

According to clear data analysis, it shows that pupils have applied Computational thinking elements namely *Abstraction*, *Generalization*, *Decomposition*, *Algorithms* and Debugging in the process of solving Geometry topic. For solving learning problem, the choice of model or certain solving problem design is a vital aspect to complete any task. With the emergence of technology field like Computer Science, to some extent, it helps promote the most suitable solving problem method for technology related field like Computational thinking [39].

Referring to [40], Abstraction element in Computational thinking can help assist pupils to understand the learning of Mathematics subject. In Mathematics subject, pupils will learn abstract numbering and emphasize arithmetic algorithm as well as building arithmetic system [41], thus, it shows how importance the use of Abstraction element to solve problem as per stated in this research. The finding of this research is also similar to meta-analysis as per suggested by [41] by which there is positive correlation between Computational thinking and academic achievement with one of the elements used which is Abstraction in supporting the learning of Mathematics subject. In addition, the results of a study [42] have proven that the digital education environment in mathematics learning has shown an increase in the level of Abstraction element for Computational thinking.

Pupils' elaboration by stating formula shows that essential information is identified from the previous phase, it enables pupils to produce formula for solving problem of the given Geometrical topic. This opinion is approved and parallel to the research conducted by [43]–[45] by which their research has stated the process of using Generalization to solve problem within pupils' ability to formulate solution for the general form which can be applied for different problems and finally to be used as variables for solving problems.

Pupils' elaboration by resketching simplify pentagon in comparison with original complex pentagon that is given in the question as a method to simplify Geometrical problem solving which gives meaning pupils understand the method to solve Geometrical topic easily. This opinion is supported and relevant with the research by [44] whereby it is clearly stated in the research that the process of using Decomposition element for solving problem is related to pupils' ability to break complex problem which finally becomes something that is easily understood and solved. Based on the research conducted, it is found that pupils who can use Decomposition element are able to solve complex problem easily and able to answer correctly according to work process.

Pupils elaboration by drafting correct calculation process as an important method to solve Geometrical problem indicates that the step-by-step calculation of organised and systematic work process will assist pupils to solve problem in Geometrical topic. This idea is relevent to the research by [44] by which it explains that the use of Algorithms element for solving problem indicates pupils' ability to plan the step-by-step operation or to act upon problem solving method. Based on the research done, it is found that pupils who can use Algorithms element can finalize their answer correctly according to work process by using organised and systematic steps. For [40], they have stated that the importance of Algorithms element as a tool to develop and to successfully solve the problem by using Computational thinking approach.

As per interview analysis, pupils explain and witnessing the awkwardness during or after answering the questions by rechecking the sketch, work process and answer. Besides, pupils are also explaining about number checking and doing recount upon work process and answers. Debugging is identified as one of the four major elements within exercise dimension that using useful Computational thinking for various design activities [46]. In fact, [47]–[49] have stated that finding and correcting mistakes, representing, and analysing are essential elements for Computational thinking that are shared in various knowledge disciplines.

[50] stated that Geometry is one of the vital topics in expanding pupil thinking process for solving problem. Geometry topic learning gives wide opportunity to pupil to expand the skill of visualisation spatial and reasoning for achieving higher order thinking skill [51]. Summarily, Computational thinking approach in solving problem of Geometry topic with the assistance of AR technology provides more benefits to pupil in the process of solving problem. In fact, the use of AR technology with Computational thinking for solving problem of Geometry topic is relevant to the statement given by [52] that proposed Computational thinking skill should be upgraded in terms of teaching aids for pupil learning process.

In this regard, the discussion of research finding is according to all five Computational thinking elements that consist of solving problem for Geometrical learning topic with the help of developed AR application which is successfully evident as a tool to help solve problem for Geometrical learning topic. There are various research show that the use of software for Geometry topic can help enhance the achievement of Geometry topic as per research conducted by [53], [54] that uses GeoGebra software. In fact, there is one research states that the use of AR application in Geometry topic for primary school has increased the achievement of Geometry learning. This view is highly recommended by [55] that mentioned clearly the use of AR application in learning strategy can be implemented for effective teaching and learning process.

9   Conclusion

This research is mainly to identify Computational thinking elements of the pupil on how to solve Geometry topic by using AR application. To sum up, pupils successfully portray Computational thinking element namely Abstraction, Generalization, Decomposition, Algorithms and Debugging to solve Geometry topic. According to this research, it is a wish that Computational thinking approach with the assistance of AR

technology can highly promote the use of technology in the lesson as well as boasting the advance research on technology and pedagogy approach for solving problem in the learning activity.

10   Acknowledgement

11   References

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