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MULTIFUNCTIONAL COUNTING TABLET (MCT) AS A TEACHING TOOL TO LEARN BASIC MATHEMATICS AMONG MALAYSIAN PRIMARY SCHOOL PUPILS

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ABSTRACT

Parents, school administrators and teachers who want to find the best teaching aids for their children or pupils may face the problem of selecting the best teaching and learning tools in particular to manipulatives as they can be expensive. For the learning and teaching of Numbers and Operations in Primary schools, for example there are many to choose. However, having to learn to use and master the uses of the different aids or manipulatives, it does pose a problem for pupils and teachers alike. In addition, there is the cost of multiple purchases and storage of these teaching tools. McT provides the perfect solution to overcome these problems. McT is a multifunctional counting tool i.e., manipulative specially designed for the teaching and learning of Numbers and Operations in Primary schools for Year 1-3 pupils where traditionally these topics require the use of different teaching tools. The feasibility study indicated the McT has its theoretical foundation to be successful as a potential teaching tool to replace some of the presently used manipulatives in the classrooms. In conclusion, the product design process suggested can be considered a possible conceptual framework to run a research to validate McT.

Keywords: Counting tool, mathematics, primary school, manipulatives, abacus

1. INTRODUCTION

"When I hear, I forget.
When I see, I remember.
When I do, I understand."
(An old Chinese proverb)

This summarized the importance of hands-on activities in primary classes. Children in their early years of cognitive development need to use their 5 senses to learn – sight, taste, touch, hearing and smell to gather information situated in their environment. This is very true of children learning early mathematics. Moyer (2001) commented on Jean Piaget's work about young children learn primarily in concrete mode and that the abstract mathematical ideas or concepts are better understood through hands-on activities. Later educational psychologist like Zoltan Dienes developed the Dienes blocks; Caleb Gattegno and Georges Cuisenaire designed the Cuisenaire rods while Bruner's thesis on enactive, iconic and symbolic stages explains the role of the concrete, representation stage before progressing to the abstract. More recent work by constructivist theorists reinforced the benefits of concrete manipulatives to progress to the abstract symbols that make sense to these pupils. Students use mathematical manipulatives, not only does it increase their mathematical achievement scores, but it also provides them with additional methods or strategies that are critical to building problem solving skills (Liggett, 2017).

What then are 'manipulatives? Moyer (2001) defines them as "objects designed to represent

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explicitly and concretely mathematical ideas that are abstract. They have both visual and tactile appeal and can be manipulated by learners through hands-on experiences. (p.176)" In today's Malaysian classrooms, one may find different types of teaching tools and manipulatives like Multilink cubes, Dienes blocks, Lego, counters, place value counters, bead strings, Cuisenaire rods, base-ten blocks., place value cards, 10 x10 squares, digit cards, dice, dominoes and so forth in the learning of Numbers and Operations.

Abacus is a well-known counting tool throughout history and predecessor to a modern calculator. There are many versions of the abacus, but the build concept is still the same. A compact frame that holds columns of beads that slides on a stick. Generally, the traditional abacus was made with high-quality wood for durability, ease of material access and the organic features of wood product. these features are still commonly used in most modern abacus production. This does come with a drawback. High quality wood does have high durability but it is also heavy and expensive especially during current times. These factors would be not sustainable for the usage, especially for primary students.

Counting tokens consist of any object that is capable for counting individually. For this study, there are LEGO, building blocks, coin tokens, counting cubes and counting sticks that are used for teaching aid. These counting tokens are mostly made of plastic, usually ABS, acrylic and PVC plastic through an injection moulding process and no assembly required. Due to that, these tokens are very cheap, durable, lightweight and easy for mass manufacturing. They are also available in plenty of colour variations like Lego and the Cuisenaire rods. One particular benefit of LEGO construction, Lego games or Cuisenaire rods, is that it helps to improve students' involvement, problem-solving and motivation in learning mathematics. Apart from that, Cuisenaire rods help students to master abstract concepts using colored cardboard or wooden strips of varying lengths (Kurumeh, 2009).

However, these manipulatives also come with their own drawback. Overall, most of this token are not environmentally friendly as it is made from plastic. Other hazardous factors are depending on the size of the token. For small token such as LEGO and coin token, the tendency to lose, swallowing hazard is quite high. While token such as counting sticks, it also has high tendency to lose and also sharp object hazard. For large token such as building blocks and counting cubes, they need large storage and can lead to an increase in weight, where it will be difficult to carry.

Therefore, in order to have a viable product, the product needs to have good durability, compact, easy to carry, environmentally friendly material and at the cheapest price.

Table 1. The pros and cons of selected manipulatives

Product	***Pros***	***Cons***
Abacus	Durable Compact Environmentally friendly (material)	Heavy Difficult to produce Expensive
Counting tokens (LEGO, building blocks, coin token, cubes, sticks etc)	Durable, Lightweight Colourful Easy to produce Cheap	Hazardous (swallowing, sharp end) Not environmentally friendly material (ABS plastic) Large storage needed Easy to lose

Thus, introducing so many teaching tools or manipulatives is that pupils, teachers and administrators face many challenges like i) coping with learning how to use the different tools, ii) adjusting to the different learning styles and manipulative skills, iii) cost of manipulatives.

On the first challenge, Moscardini (2009) demonstrated that manipulatives can be effective tools to help pupils make sense of the concepts, encourage mathematical thinking and provide opportunities for reasoning but if used as an adjunct where pupils are asked to follow a fixed procedure then it serves only as a crutch and not a tool. Manipulatives should develop "pupils' fluency with mathematical procedures as well as the development of ability to solve problems and to reason mathematically" (Moscardini, 2009). Following the argument presented above, it is clear that to make the best use of a manipulative requires a pupil to develop a number of learning styles, as well as a set of good manipulative skills. Thus, the time and effort expended would be beneficial to the pupils' mathematical learning process.

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Another factor to consider is the cost. It is one of the most important determinants on what type of manipulatives to use in the classroom. Larkin (2016) compared the usage of a physical teaching tool with a similar online manipulative while learning addition and subtraction math concepts and found that those using the physical manipulative showed a better understanding of the math concept compared to those using the online manipulative. It is much cheaper to get online manipulatives and definitely they are easy to store. However, he found that the students loved the physical manipulative the best. Although research has shown that cost is factor in using manipulatives in the classroom, there are creative ways to keep the cost of manipulatives low (West 2018).

In the Malaysian primary mathematics curriculum (Dokumen Standard Kurikulum Dan Pentaksiran Tahun 1 (2016), 'the teaching and learning process of mathematics gives priority to the mastery of knowledge and understanding which enables pupils to apply concepts, principles and the mathematical processes learnt' with emphasis to mathematical thinking i.e., problem solving, reasoning, communication, representation and connection and use of technology in mathematics.

For the primary level, the use of teaching tools and manipulatives like abacus, Multilink cubes, Dienes blocks, counters, Lego, place value counters, bead strings, Cuisenaire rods, base-ten blocks., place value cards, 10 x10 squares, digit cards, dice, dominoes and so forth are recommended in the learning of Numbers and Operations. However as discussed above, the cost of buying such a vast variety of manipulatives is not only high but particularly difficult for pupils to master every one of them. This paper sought to recommend an alternative solution to address this issue.

2. PROBLEM STATEMENT

Learning of mathematics in primary schools cannot be well understood nor mastered without the use of specific teaching aids or manipulatives (Hughes, 2003; Smith & Pellegrini, 2008). Cognitive theories over the centuries have taught us that children need to touch, feel, smell and manipulate these physical objects to understand mathematical concepts and it is also a prerequisite to acquire skill sets for advancement to more complicated concepts later (Smith & Pellegrini, 2008; Muddin, 2013). However, the need to manipulate a variety of teaching aids must surely require pupils to adapt to a variety of learning styles as well as those of the styles of their teachers (Online, 2013). Herein lies the crux of the problem pupils are facing i.e., pupils are required to learn to use and master the uses of different aids on a regular basis. In addition, there is the cost of multiple purchases of these teaching tools that could be discouraging to the school administration. It is thus, proposed that the use of a multifunctional counting tool to solve the above problems.

3. OBJECTIVE

1. To investigate the different learning styles and skill sets required of pupils when using the various teaching aids to learn specific content standards in Malaysian primary school mathematics.
2. To design and develop a teaching aid known as a Multifunctional counting tablet (McT) in place of the various teaching aids to learn similar content standards in the Malaysian primary school mathematics
3. To test out the teaching aid known as Multifunctional counting tablet (McT) among pupils and teachers in selected Malaysian primary schools.

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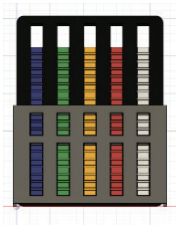
4. PRODUCT DESIGN PROCESS

Table 2. Many to One

Manipulatives		McT
	Abacus Base-ten blocks Colored counters Cuisenaire rods Multilink cubes Lego Dienes cubes Colored chips	

The development of McT followed a product design process used by our Research and Development Department as explained below:

a. Feasibility study

Based on Table 1 approach, a feasibility study was done on commonly use counting tools for pupils to study early mathematics. A detailed account on these manipulatives can be seen in the Introduction section above as well as the rationale for developing McT as an alternative to replace the many manipulatives. A feasibility study was carried out with a few respondents in May 2021 to gauge the acceptance among the pupils and parents about the relevance and use of McT as well as to look at the design and physical attractiveness of the manipulative. For that purpose, a series of interviews on the efficacy and relevance of McT in the primary school classrooms was conducted in Kuching, Sarawak involving two pupils and a parent.

The pupils tried out the teaching aid (McT). The sessions were recorded for analysis. Suggestions for further improvement were also elicited from the parent. Interview findings indicated that the respondents found the McT made the learning process much more fun and easier. They could use the regrouping concept in doing the addition and subtraction of whole numbers.

The interview from a parent showed that the McT was innovative - it looked difficult, but after the explanation from the interviewer, the child could do it easily and enjoyed it very much. As the sample size is small, it is suggested that full research is carried out to comprehensively test out if McT does achieve its purported functions and uses as listed in the table below:

Table 3. Coverage of mathematics content and functions of McT

MULTIFUNCTIONAL ABACUS TABLET (MAT) for Numbers and Operations	DESCRIPTION (YEAR / SUBJECT / TOPIC)	USAGE (SKILL/ KNOWLEDGE/ CONCEPT
MULTIFUNCTIONAL ABACUS TABLET (MAT) for Numbers and Operations	Mathematics Yar 1, 2 and 3 Topics: i. Number within 100, ii. Number within 1000 iii. Number within 10 000 iv. Addition and Subtraction, v. Multiplications vi. Division vii. Problem solving	A. It helps teachers and pupils to learn the concepts of the following topics: i. Number ii. Addition and Subtraction, iii. Multiplications and Divisions iv. Problem solving The following skills can be acquired –ordering, number line, place value, regrouping for additions and subtractions, counts in 2s, 3a, 5s, 10s, comparison of 2/3 numbers as well as learning basic mathematical concepts including addition, subtraction, multiplication, division, number sense, place value and counting. B. it can be adapted to become a traditional abacus of 4:1 or a SOROBAN while the more complex one is the 5:2 sempoa.

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		C. It allows for creative and problem-solving activities by helping young children to form insights about the logical relations among the chips and color grouping D. At the more advanced level, it can be used for Math Competition or challenges in class. Its main utility is to replace the many manipulatives to teach the same topics or skills with just one manipulative. Some examples of teaching aids commonly used in the classrom are abacus, Multilink cubes, Dienes blocks, Lego, counters, place value counters, bead strings, Cuisenaire rods, base-ten blocks and others.

b. Products Conceptualization

Based on the feasibility study results, a product concept was developed based on these features: multifunction, durable, compact, lightweight, easy to produce, environmentally friendly and cheap. At first, it was seemed impossible to achieve as some of the criteria contradict with each other, such as durability. Durable material is usually not lightweight and if it can be lightweight, usually it would be expensive. With 3D printing technology, all of the criteria can be achieved as 3D printing is able to print the product with variation of internal structure that can optimize the strength and the weight of the final product. 3D printing also capable of printing in a variation of materials such as plastics (PLA, ABS, TPU, PC and etc), composites (wood-plastic, glass-plastic, fibre-plastic, plastic-metal, etc) and clay. For this product design, the chosen material is Polylactic Acid (PLA) as it is the most environmentally friendly material of all 3D printing material. It is derived from lactic acid which is commonly found in yogurt. PLA is commonly manufactured from a plant-based source such as starch from corn. It is known to be environmentally friendly as in terms of manufacturing, it comes from renewable source and in terms of disposal, it is biodegradable and also capable for closed loop recycling process.

c. Products Design

As the product concept is decided to be based on 3D printing technology, the design is also will be subject to 3D printing manufacturing. A CAD software was used to design the product and the design was mostly based on tablet size as it is a well-known modern shape especially the current generation. The product is around 220mm x 250mm x 3mm size, capable of being on its own or can be merge to be covers for books or files. This design is also capable for single print manufacturing. What that means is the product can be printed in a single print and still maintain its movability. in other words, the product can be used right away after print. This is a huge advantage in manufacturing as it eliminates assembly stage for the production. This technique can only be implemented in fuses deposition modelling manufacturing (FDM) and most 3D printer are based on this type of process.

d. Tooling Support

Based on the design, a FDM 3D printer is used as a tool to make the prototype of the product and may also use for small-scale manufacturing. this tool and technology do a great help in reducing the time gap from design to prototyping and manufacturing. for this design, it only took a total of 3 days from the designing phase to the working prototype that would look very similar to the final product.

e. Mass production Support

As this product is a design based on 3D printing technology, the capability of mass production is relied on what kind of 3D printer that would be used and how many that are available for printing. One printer

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can produce 4 units of this product in one day, 250 units in one month. Typical 3D printing farm would have more than 1 printer, usually 10, which is more than capable to achieve mass production quotes.

5. DISCUSSION AND CONCLUSION

Research has provided good evidence that the manipulatives offer an effective way for pupils to learn math concepts and master skills in different ways. Manipulatives if used constructively can have a significant outcome on the pupils' math skills and motivation (Hurst & Linell, 2020). This paper examines the current manipulatives that are in use in our Malaysian classroom. Literature has shown that though they are important as a learning tool they also posed problems in terms of coping and adapting to the different learning styles and manipulative skills in addition to the high cost of purchasing them. In the longer term, this paper suggested the use of one manipulative (McT) in place of they need to utilize too many teaching tools serving the same functions. Although McT has not been demonstrated to be a better alternative in the teaching and learning process, it is proposed that well-planned research is carried to look at its effectiveness and limitations by using a good sampling size and appropriate methodology. In conclusion, McT offers a promising alternative for the children to learn the related topics in Numbers and Operations but evidently, it needs to be trialed and validated through user acceptance.

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