International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169
Volume: 5 Issue: 6 865 – 870

Hybrid TUI Abacus Model: An Advance Tool for Learning Math

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Abstract:- In the world of changing technology, the speed of development using new technology has increased and so has the learning rate. Modern software helps new generation of kids learn new things easily but lack the practicality of touch and feel, and kids also become less physically and socially interactive. There always has been an argument about which way is better for learning for kids. Hence, a test was conducted to evaluate whether practical learning or learning through software resulted in faster learning. The test involved 20 kids of the 4-7 year age group, where kids were divided into two sets, each set consisting of 10 kids. One set of kids where taught mathematical operations such as addition, subtraction, multiplication and division using a physical abacus tool while the other set was given a mobile application of the Abacus Tool. Both the sets of students were given one week learning time and a paper pen test was conducted for both the set of kids. They were allowed to use the same version of Abacus on which they were trained for a week. The results of the kids that used the mobile application surpassed those who were given the physical Abacus tool. Thus, we may conclude that learning Abacus virtually using software helps kids learn faster and much better but makes kids physically and socially inactive. We propose a hybrid model where kids experience the physical touch and feel, socialize more, while also getting the motivation of self-praise and leveraging modern software Abacus. This hybrid model is implemented in the form of Abacus.

Index Terms—*Abacus, kids, TUI, Phixels*

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I. INTRODUCTION

The world is progressing continuously with new inventions by the day. Hence, it is equally important for the younger generation to learn quickly. The major brain development for kids happens between the age group of 4 to 7. It is quite important that they are provided with the right teaching so as to catch up with the advent of new technology. This can be achieved using existing software or by developing new generation software especially for kids. Physical and social development of a kid is equally important just as cognitive development. For assessing the thesis of whether new software tool or the actual physical tool is better for kid's development, we conducted a small experiment using software Abacus [1] and an actual physical Abacus.

The term Abacus has been acquired from a Greek word 'abax' or 'abakon' which means 'tabular form' that is possibly extracted from a Semitic word 'abq' which means 'sand. An arithmetic technique based on the fundamental of abacus calculation, abacus maths is evaluated to be one of the fastest ways of calculating and learning maths. Faster than a calculator, not only does abacus maths gift young learners the opportunity to shine in the language of maths from a really young age, but also helps to learn the language of maths giving a solid foundation in primary and high school.

1.1 Invention of Abacus

The Abacus is the most primitive form of calculation which was invented somewhere in the 300-500 BC. The Abacus has travelled a long way and has had transitions as it travelled in different countries over the world.

1.2 How does it work?

The Abacus in ancient days was used purely as a calculation tool. Every bead was assigned a value starting from a units place moving towards the left. The beads in the upper deck had different values than those in the lower deck. The calculation process necessitated the use of both the hands. All the calculations were based on the movements of the beads. This was probably one of the greatest inventions of the ancient days that helped the merchants and traders in their accounting. Abacus training for children is becoming a popular way to improve mental math skills, around the world. It helps the kid learn basic as well as advanced mathematical skills that include addition, subtraction, division and multiplication. The basic principle involves assigning values to the beads and then moving them up or down, or left or right depending on the kind of abacus being used.

The Japanese technique of using the Abacus is known as the Soroban technique. In a Soroban, one bead is placed above the beam, and has a value of 5, and four beads and below the beam have a value of 1 each. Every third rod is marked with a dot, to denote the unit number. The designation of the unit number is up to the operator. The beads are moved up and down using the thumb and the index fingers respectively and the number of beads touching the beam signifies the value. The Soroban technique employs a rule which requires you to work from left to right.

The Chinese version, known as Suan Pan on the other hand, though quite similar in structure, uses a slightly different approach. The beads in the lower deck are known as earth beads or water beads and have a value of 1 each, and the beads on the upper deck are called heaven beads and have a value of 5 each. Following the place value system based on Arabic numeral system, which is a standard in almost all forms of the Abacus in use today, the rightmost column represents the ones place and then it moves gradually forward, increasing by 1 unit as you move to the left. The Suan Pan is very closely interlinked to the number system of the Chinese, known as "huama".

ISSN: 2321-8169
865 – 870

1.3 Why Abacus??

It is important to accept that early childhood is the most critical growing period in terms of emotional, intellectual, physical and social development. While it's a scientific fact that human brain growth is at its peak potential in early childhood, it's also a fact that all children process information differently. No child is the same, and while some children learn better through reading, others learn better through doing – which brings us to the topic of maths.

Interestingly, many adults feel that if they could have been exposed to a smarter way of learning maths as a child, then their outlook would be a far more pleasant. For most kids, maths is extremely difficult and boring, and unless interest is taken in learning it from a young age, they will always have a love-hate relationship with it. So how do we get kids interested in learning maths? One of the best and most successful ways to make the subject of maths more attractive and interesting is with Abacus.

It is difficult to imagine counting without writing numbers, but there was once a time when all we had were our hands and fingers. And as numbers became larger, many started using stones, beads and sticks, and this is how abacus maths was born.

2.1 Learning Approach

2.1.1 Learning Development phases

There are three dimensions of learning styles - Visual, Auditory and Kinaesthetic. Majority of the population (65%) are visual learners, 30% are auditory learners and 5% are kinaesthetic learners. Visual learners learn better using pictures or visualization; auditory learners prefer hearing to understand the contents and kinaesthetic learners prefer experiment or hands on activity. The best result to gain interest of learning from majority of masses is to combine these three learning technique together.

The ages between 3 and 6 are often called the preschool years. During these years, children change from clumsy toddlers into lively explorers of their world. A kid progresses in these main areas:

- **Physical development.** In the development years, a child becomes capably stronger and starts to look taller.
- **Cognitive development.** The world is progressing continuously with new inventions by the day. Hence, it is equally important for the younger generation to learn quickly. The major brain development for kids happens between the age group of 4 to 7. It is quite important that they are provided with the right teaching so as to catch up with the advent of new technology. This can be achieved using existing software or by developing new generation software especially for kids. Physical and social development of a kid is equally important just as cognitive development. For assessing the thesis of whether new software tool or the actual physical tool is better for kid's development, we conducted a small experiment using software Abacus [1] and an actual physical Abacus.
- **Emotional and social development.** Between the ages of 3 and 6, children gradually learn how to manage their feelings. By age 5, friends become important.

  Studies have shown substantial differences between children who experience frequent intercommunication with parents and children who are raised with less encouragement. Up to the age of 3, your child's brain produces an excess of synaptic connections—many more than he will ultimately need.
- **Language.** By age 2, most children can say at least 50 words. By age 5, a child may know thousands of words and be able to carry on conversations and tell stories. In the prior years, a child reacts to all communicating language, and by the preschool years, a child may ignore or appear confused by foreign tongues. Child's communication skills take a huge leap during these years. The child becomes a much better listener and responds more readily when spoken to. It's not just their sentences that get longer and more sophisticated; they can follow directions with more than one step. They even begin to think out loud and talk in situations and feelings.
- **Sensory and motor development.** As a kid develops it becomes more agile i.e. running, jumping, climbing, and learning to perform ever more sophisticated feats. Its brain continues to sharpen the processes that are keen to coordination and balance. In the course of the preschool years, kids also enhance their executive functions, which control memory, timing, and sequencing—these abilities are essential for more complex physical activities.

2.1.2 Learning through Play

Play is considered an activity where children smile, laugh and enjoy themselves. Mobile games are considered as modern play. Children spend up to 30% of their time and energy in play. Thus, learning and playing should be consolidated together so that the learning process is most delightful. The cognitive behaviour theory revealed that when children feel happy in their learning, they tend to absorb the contents faster and understand information easier.

Studies have shown that learning via playing at home is a preferred way for students and the percentage of subject understanding is higher when students learn through playing.

2.2 Technology

2.2.1 Current technology trend

A few decades ago, the 'web' and 'surf' were the popular, fanciful, and yet revolutionary terms that we all loved to drop in our conversations and writings. The year 2017 too will see a lot of these two terms and its countless derivatives. One such notable encroachment of the term "mobile" is in eLearning. It's called mobile learning or mLearning.

Mobile learning obviously enjoys all the benefits of traditional eLearning and along with it also provides ample scope to fully utilize the blended learning approach.

2.2.2 Mobile Application

With huge improvements in technology, the mode of playing games has changed to digital. Digital gaming includes computer games, mobile games and many more. Mobile applications as well as games are now being identified as a constructive and efficacious tool to teach or further solidify concepts by many researchers as mobile games are more likely

 ISSN: 2321-8169
865 – 870

to learn actively. Besides, mobile games are interactive because mobile games enable players to interact with the game's environment and thus make the games more interesting. The players have a sense of engagement which draws their attention.

The mobile application that we used in this research is 'Know Abacus'. It is an Android application available on Google play store developed by 'Lookkid Software'[7]. It is an application that can be used to learn Abacus for Children of the age group 5 and up. The application helps kids learn counting on Abacus. It has the functionality to teach kids addition, subtraction, multiplication and division up to two digits. The application on its default mode helps to calculate up to 9 crore counts and up to two decimal places. There are also other sections like mental math, review lessons and random lessons which will really help children learn. Distinctive feature about this application from the actual abacus is interface. It shows the real time count on the screen itself and the child could understand if he/she did the count wrong instantly and can try to correct it. The application also has the option to turn off this feature so that kids can do calculation like an actual abacus. The application, just like other games is self-motivating, it praises the learner if they did well with a visually attractive graphical interface and shows the score and time in which the user completed the test. It also saves the record and shows the best time in which anyone has completed the test. The saved records in application can also be used to track the progress of the user.

Other characters that make the 'Know Abacus' application attractive to children is its sound, colour beads of Abacus, multi touch and hints or help messages. The application gives a very authentic sound of Abacus while moving the beads on the application, providing a sense of using an actual Abacus. The colour beads on the application Abacus makes it attractive for children and the application has colour highlighting feature that helps perform application calculation step by step. The multi touch feature helps to move the multiple beads on the application interface together at the same point of time as an actual physical Abacus may allow. When the help message option in the application is turned on, it helps the user when there is a complex calculation that has to be performed. There is also a left hander option which can be used by left handed or differently abled kids to use this application with ease. The 'Reset Button' on the right top of the application makes it very handy for the user to make a new calculation on the application since all the beads need not be reset manually.

3. Learning and Test

To test the theory on which method of learning is better for kids we conducted a test on 20 kids of age group 4 to 7. These 20 kids were divided into two sets, set 'A' and set 'B', each set consisting of 10 children. This assessment was conducted in three phases: pre-test, training and post-test.

3.1 Usability Pre Test:

Students were given 30 basic mathematical questions on a paper and were asked to solve as much of the question as they could. The time given to complete this test was one hour. These questions included **3 digits** addition and subtraction and **2 digit** multiplication and division. The children were allowed to use which ever method they found comfortable to solve the question and at the end of the test, the scores of the test were recorded.

3.2 Training:

Training was the second segment where the kids were training for mathematics using 'Abacus'. The 'Set A' kids given with an actual physical abacus in hand and 'Set B' kids were given an Android Application of Abacus called as 'Know Abacus' [7].Both the set of students were given training on Abacus, how to use abacus, counting on Abacus, 3 digit addition and subtraction, and 2 digit multiplication and division on abacus. This training was given to 20 participating kids for one week, one hour a day.

3.3 Usability Post Test:

Post Test was the third segment of our assessment where the Set A and Set B kids were given 30 basic mathematical questions again and were asked to solve the question. The set 'A' kids were asked to use the Physical Abacus tool, the abacus on which they were trained for a week to perform mathematical calculations, similarly Set B kids used the Android application. The questions in the post test were similar to the type of questions used in Pretest i.e. 3 digits addition, subtraction and 2 digit multiplication and division. At the end of the test the score of the kids were recorded.

4. Result Analysis:

The analysis of the performance was done on factors based on the accuracy, time and performance efficiency. Individual marks were recorded for each student as well as their respective time taken to solve the test was tracked down for the both tests.

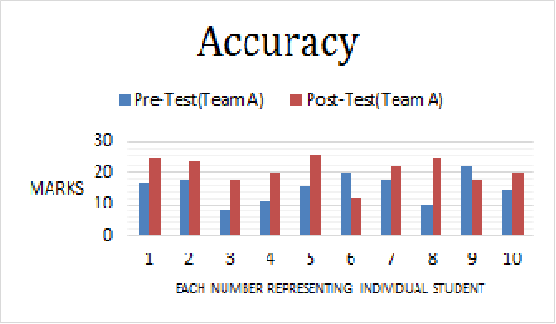


Fig.1 representing marks obtained out of 30 by students before and after learning through abacus toy.

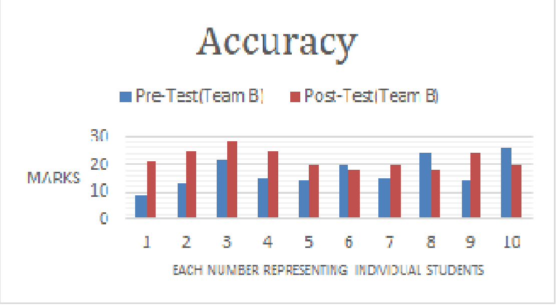


Fig. 2 representing marks obtained out of 30 by students before and after learning through abacus mobile application.

The above graph indicates that the students performed better after learning through the abacus toy as well as the mobile application. The improvement can be clearly seen through the evaluation of result on the basis of pre and post-test belonging to their respective team.

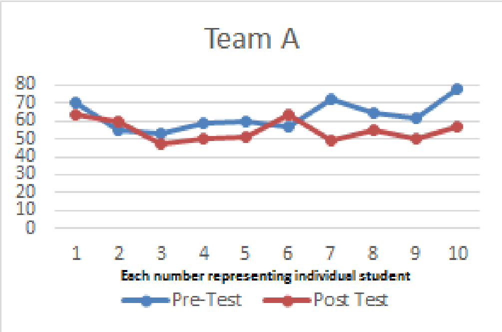


Fig. 3 representing time taken (in minutes) by each student

In team A before and after using the abacus toy.

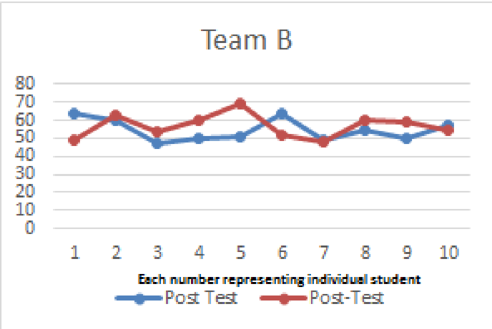
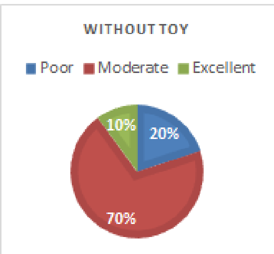


Fig. 4 representing time taken (in minutes) by each student

In team B before and after using the abacus mobile application.

While conducting the test, students were asked to take as much time as they needed to complete it. It was observed that students were able to finish the test a bit early when they were taught using the abacus (toy or application) as compared to the pre-test in which they had no knowledge. The conclusion can be made from the above graph that students from both the group got an advantage after learning through the abacus method and hence they were able to complete their test quickly.



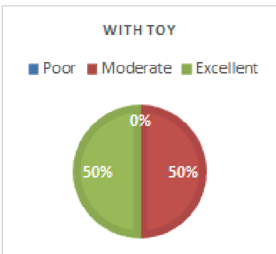


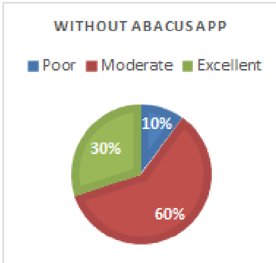
Fig. 5 representing the percentage obtained

Fig. 6 representing the percentage obtained

By students of team A in pre-test (no knowledge of by
students of team B in post-test (after Abacus toy whatsoever)
knowledge Abacus toy)

The third element on which the students were tested was that how good or bad the abacus learning affected them in their performance. An analysis was made by grouping the marks of students based on three categories such as *poor, moderate and excellent.* The range for each category was decided by the marks obtained by students i.e. student scoring marks between 0-10 will fall in the category of poor, marks between 10-20 falls in the category of moderate and rest were grouped under

Excellent. Fig. 5 describes the performance of students belonging to team A in pre-test whereas fig. 6 indicates their performance in post-test. Interpretation made on analysing both the graph states that there was an improvement in their marks after gaining knowledge of abacus.



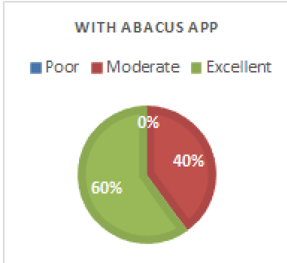


Fig. 7 representing the percentage obtained

Fig. 8 representing the percentage obtained

By students of Team A in pre-test (no knowledge of by
students in Team B post-test (after Abacus application whatsoever) knowledge of Abacus application)

The same can be concluded from the above graphs that, there was an increase in marks obtained by students after familiarizing themselves with the abacus application.

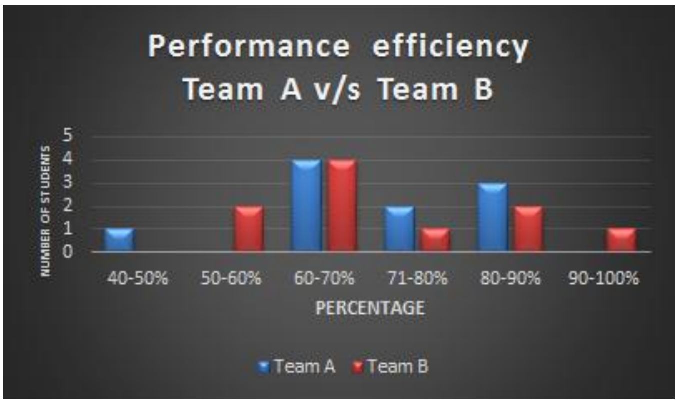


Fig. 9 representing the percentage obtained by Team A and Team B in post-test

The observation that has been made after conducting the pre-test and the post-test of the students belonging to the Team A and Team B is that, students who were made to learn the methods of addition, subtraction, multiplication and division using the abacus mobile application (in our case, the application used is 'Know Abacus') outperformed those students that were taught mathematical operations using the abacus toy. The percentage was calculated of the marks obtained by both the teams in post-test, and the above graph (fig. 9) reflects that students of Team B obtained higher percentage when taught using the application as compared to the students of team A taught using the toy.

The efficiency of which learning tool is better can be concluded from our post-test, noting that when students are exposed to mobile games with the suitable learning concepts, they are interested in learning and are motivated.

5. Future implementation

After the test was conducted and results were analyzed, a discussion session involving the same set of students was conducted to explore what they like while studying and what they don't. Findings are summarized as follows:

- Children don't like sitting at the same place for longer time, they prefer freedom of movement
- They like to be rewarded for their performance
- They like to use interactive tool to learn, such as mobile and tablet
- They like to have fun while learning supported by games and stories
- They like working together

Children like to play, and playing facilitates learning. Based on these findings we theorized that using TUIs could enhance their learning by supporting interactivity, collaboration, embodiment and pleasure. Designing TUI for children's learning has its practical and scientific relevance.

6.1 Why TUI??

A **tangible user interface** (**TUI**) is an interface in which a human connects with information through the real environment. The purpose of TUI development is to empower collaboration, learning, and design by giving physical forms to digital information, thus taking advantage of human abilities of grasp and manipulation of physical objects and materials.

Human-Centered design promotes involving potential future users into the design process. Children are involved in effective exploration by creating imaginary and rich artificial life through play. TUIs provide children with useful support for exploration and knowledge acquisition.

TUI provides a playful environment that facilitates children's overall development and learning. Providing such playful entities increases children's engagement, offers freedom, motivation and also learning through natural activities that fit into children's everyday contexts. TUI helps in collaborative learning which increases productivity levels, boosting confidence and self-esteem of children.

When considering the technique for teaching mathematical operations using physical and virtual abacus, they both have some advantages as well as disadvantages when observed thoroughly.

Keeping in the mind the advantages of both the tools that our experimental study shows, we also present a HYBRID model, a tangible user interface which will contain selective benefits of physical and digital interfaces rather than all the benefits of individual entities alone.

6.2 Hybrid Model for Abacus

We want to suggest a plausible future tangible user interface for performing basic mathematical operations using the existing Abacus. The TUI technology used in making this model is ***'Phixels'.***

'Phixels' is one of the Tangible User Interface projects developed by "Luke Vink Artem Dementyev Hiroshi Ishiji" in 2016. According to it, Phixel is a single element that embeds localized actuation, sensing and control to move itself along a given path. When combined, Phixels enable not just the representation of data, but also the bidirectional physical interaction with that data. Because Phixels can talk to each other, they can be arranged in any given pathway expanding their application to a variety of forms such as in a musical instrument, architectural space or for artistic expression. Phixels are an initial step towards a vision to have single elements capable of transforming physical properties in response to physical interaction, without the need for an external system for actuation.

The technology of "Phixels" can be used to implement a TUI (Tangible User Interface) Abacus. Since Phixels are small spherical elements having cords attached to it which can communicate to each other, it has bidirectional physical interaction with data and can be remotely controlled by a system. It can be used to make "Advance TUI Abacus" which can be implemented like an actual physical Abacus combined with the power of technology. Using Phixel technology, we can make an Abacus which can move its beads automatically based on the computer program fed into the computer system. Thus using the TUI Abacus we can train the students on how counting, addition, subtraction and other operations can be performed by automatically moving the beads to show the steps of operations performed on Abacus and we can improve the understanding skills of the students by adding an external audio to it. Each correct step performed for a calculation can be indicated by a green color of the Phixels while red color Phixels can be used to show misplaced beads on the Abacus. We can also include suggestions into the TUI Abacus by adding a blue color blinking Phixel so that if a student is confused on which is the next correct move to perform the calculations ahead the TUI Abacus can itself show the suggestion for it.

To support TUI Abacus we will require a strong software application that will store data of tutorials which has to be automated on TUI Abacus by moving it Phixels according to the steps of tutorial. Adding audio feature in the software application will improve the understandability of the TUI Abacus. Since the TUI abacus is not a hand held mobile application it is bound to be used by multiple users hence the software application requires a profile module to store the score of each students training on it differently according to profile. Other features that the software application may require are the ability to generate questions for multiple operations like addition, subtraction, multiplication and division, test series and ability to change the color indicators of the Phixel and different language support.

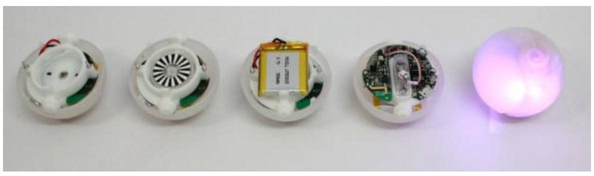


Fig 10 Interior structure of Phixel

 ISSN: 2321-8169
865 – 870

The figure depicts the light emitting phixel which can be used similar to that of beads in traditional abacus.

Fig 12 Phixels when attached to the cords

Fig 13. A projected model of a TUI abacus

7. Conclusion

The paper has discussed on the benefits of learning using Abacus as well as which is the best learning tool for children when compared with the traditional abacus and its software application. It also serves as an alternative to encourage and assist the users in knowing and learning basic Abacus calculating methods. This paper proposes a hybrid model using Tangible User Interface which overcomes one of the most controversial aspects i.e. lack of physical and social activity. So we illustrate how a tangible user interface can be provided for this kind of a problem domain using one of the TUI project called "phixels" as future improvement to the current abacus model

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