Teaching Table: A tangible mentor for pre-K math education

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ABSTRACT
In this paper, we describe the design and implementation of Teaching Table – an interactive tabletop audio-visual device aimed at enhancing the learning experience for pre-kindergarten children by involving them in physical activities. Using electromagnetic sensing technology, the table can track tagged objects placed on its surface, accurately identifying their type and location while providing a coincident visual display and audio feedback. Teaching activities that are aimed at developing early math skills have been created for the table in alignment with standard curriculum guidelines for pre-K schools. Additionally, we include software based assessment tools for mentors/teachers to easily track an individual child's progress during the process of interacting with the table.

Author Keywords
Tangible computing, education, tabletop sensing, physical manipulatives, learning toys.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces---input devices and strategies, interaction styles, evaluation/methodology; K.3.1 [Computers and Education]: Computer Uses in Education---computer-assisted instruction.

INTRODUCTION

The computer as an educational medium is being explored in many research arenas to impart interactivity to and augment the learning process. But the ability to use computer interfaces by very young users, with limited literacy and developing motor and cognitive skills, is often a major hurdle in learning. There is a growing body of research related to studying the hardware and software interface issues encountered by children when using computers [1, 2, 3].

Additionally, past education researches have emphasized the importance of interaction with physical objects for overall development of a young child's mind. There has been good evidence to support the fact that through touching, manipulating, exploring and testing, children find out and learn about the world around them [4, 5]. Piaget and other developmental psychologists have also emphasized the importance of using physical objects for young children's cognitive development [6, 7].

New paradigms in computer interaction have made promising advances in this regard, redefining how physical toys can be used for both play and learning. Broadly categorized as 'tangible interfaces', these advances in computational and sensing technologies have greatly impacted the field of educational technology. Tangible interfaces provide ways of interacting with a computer through real objects that are relevant to the task instead of through the keyboard or mouse [8, 9].

The augmented tabletop environment - a distinct theme within tangible computing - has demonstrated its potential for educational purposes [10, 11, 12]. The aim of our project has been to explore tabletop environments to teach early math fundamentals to children in the age group of 3-5 years, giving them a concrete platform to learn and understand abstract concepts through interaction with physical manipulatives. We also include various assessment and progress tracking tools within the table software for effective integration with the result-based curriculum approach of the present class environment.

RELATED WORK

There have been a number of researches aimed at developing digital manipulatives for educational or entertainment purposes. The most notable of these are TICLE, Block Jam and Topobo [13, 14, 15]. The 'Read-It' tabletop environment at the University of Eindhoven [12] is a similar setup with a focus on developing reading skills for children from 5-7 years of age.

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The present project differs from the above approaches in that we also try to incorporate assessment tools for the mentors/teachers to keep track of an individual child's performance. This feature not only helps in further enhancing the learning environment for the child, but also increases the chances of making the table more acceptable in the present day school environment.

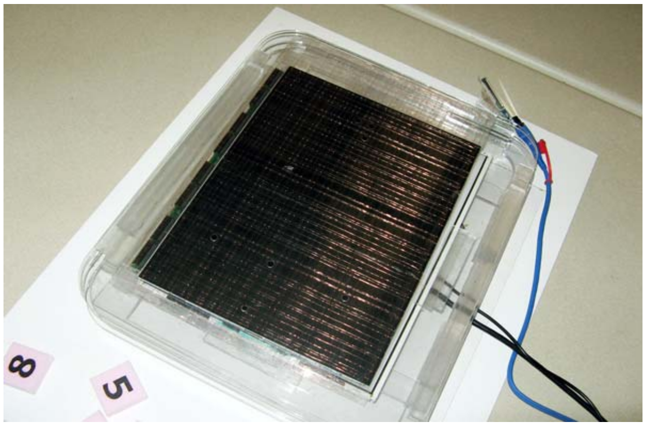

Figure 1. The current prototype of the Teaching Table.

IMPLEMENTATION

The Teaching Table system couples wireless object tracking technology with a graphical display and audio feedback in order to create a complete tabletop interaction setup, as shown (Fig. 1 & Fig. 2).

The screen provides graphical output that coincides with the movement of the objects on an electromagnetic sensing pad, enabling real-time visual feedback for a child's interactions with the physical pieces. Speakers are incorporated into the table setup to provide an additional audio feedback channel. The basic sensing technology is based on one of the author's prior research on tabletop sensing [16].

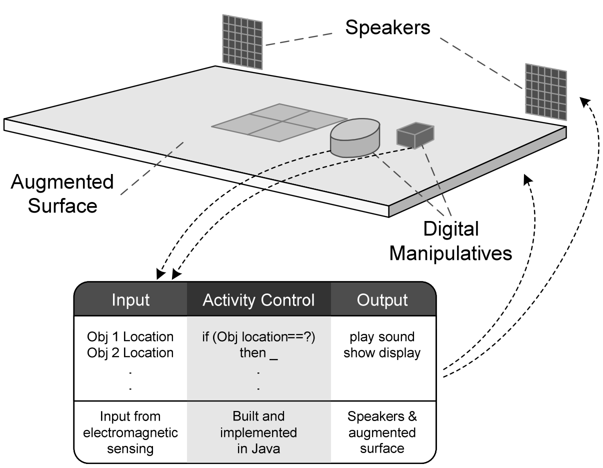

Figure 2. A schematic diagram of the Teaching Table.

Software

The Teaching Table software is implemented in Java and consists of separate modules that handle the communication with the positioning hardware, the control of the learning activities and the audiovisual output. The position sensing module reads tag ID and position information via the serial port and transmits this information to the activity module, which updates its current state. The system then responds to a child's interactions with the appropriate audiovisual feedback. The playback of the different learning activities can be controlled from a separate desktop PC-based console, which allows the teacher or mentor to monitor a child's learning progress.

EDUCATIONAL ACTIVITIES

The main aim in designing the activities was to employ the interactive capabilities of the system in a way that is informative and fun for the child, all the while fostering maximum understanding of mathematical concepts. The activities attempt to involve a child by providing friendly voice feedback and cues coupled with visual feedback on the table's surface. The child is expected to respond by placing tagged objects (in the form of numbered blocks, geometric shapes, etc.) at appropriate places on the table.

In our continued efforts to align the system with the needs of present-day schools, the activities were built in accordance with the Georgia State Content Standards for Pre-K curriculum, which specifies the minimum level a child should attain after completing pre-K classes [17].

Scaffolding

To ease the process of learning during the activities, we use a 'scaffolding' technique to reveal incremental information to the child in case s/he makes mistakes. For example, consider a scenario where a child is asked to identify the number 5 and put it on the table. Now, with the scaffolding technique, we give increasingly informative hints to the child every time s/he makes a mistake, as follows:

Try 1: (The child puts the wrong block)
<System Voice> *"Uh Oh! This is not the number 5. Try Again!"*

Try 2: (The child puts 8 instead of 5)
<System Voice> *"This is not the number 5. This is the number 8. Please find the number 5 and put it in the bin"*

Try 3: (The child again fails to put the correct block)
<System Voice> *"This is not the number 5. The number 5 looks like this…"*
<Table Display> 5
<System Voice> *"Now find the number 5 and put it in the bin"*

<REPEAT until correct block detected>

Figure 3. An example of the scaffolding structure.

Categories of Activities

We now describe five main categories of activities we are developing based on the Georgia State Pre-K Content

Guidelines [18]. Each category is illustrated by a sample activity:

Category 1: Developing an understanding of numbers

Topics Covered: Counting by rote; identifying numbers etc.

Sample Activity: Putting the numbers 1-10 in order on the surface of the table

Category 2: Creating and duplicating simple patterns

Topics Covered: Repeating patterns; completing incomplete patterns etc.

Sample Activity: Recreating a pattern (displayed on the screen) by placing blocks in the appropriate places.

Category 3: Sorting and classifying objects

Topics Covered: Identifying/sorting alike objects (all red together, all squares together) etc.

Sample Activity: Putting all the red blocks together, and all the blue blocks together.

Category 4: Developing a sense of space and an understanding of basic geometric shapes

Topics Covered: Recognizing, describing and comparing basic geometric shapes etc.

Sample Activity: Similar to Category 1, only difference is that geometric shapes are used instead of numeral blocks.

Category 5: Learning to use a variety of non-standard and standard means of measurement

Topics Covered: Sorting, Ordering etc.

Sample Activity: Finding the block which is the largest among a given set of blocks.

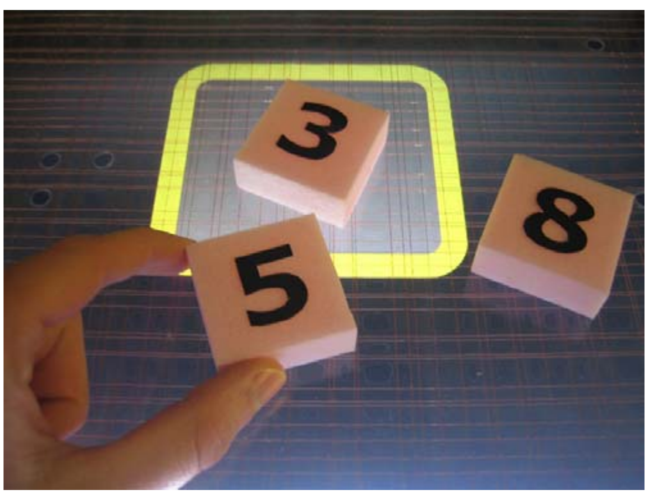

Figure 4. A sample activity using number blocks.

ASSESSMENT TOOLS

As stated earlier in this paper, we also include software-based assessment tools that track the progress of a child interacting with the teaching table and display this information for evaluation by the teacher. The main parameters recorded by these tools are:

1. *Success/Failure* – If the child was able to complete a given activity in a pre-determined period of time. (Note that a child would be able to continue playing nonetheless.)

2. *Time taken* – The amount of time the child took to complete the activity (for success/failure).

3. *Number of unsuccessful attempts* **–** The number of times the child had to be given hints for the completion of an activity.

4. *Average time taken* – The average of total times taken by all the students to complete an activity. This also helps the teacher in setting an appropriate completion time limit.

5. *Adaptive activity selection* – The system can keep track of the kinds of activities in which the child performs below average. This information aids both the teacher and the system in determining overall progression structure (*viz*. a sequence of activities towards a goal) for each child.

USER STUDIES

An important part of the project is to ascertain whether the design of the Teaching Table meets the requirements and expectations of the stakeholders involved, and to evaluate whether the product is usable in the classroom environment. To this end, we have developed a three-phased user inclusion strategy described here. The first phase was completed as part of our initial design process. The second phase is currently in progress and should point to the next round of refinements in the Teaching Table design. The third phase will involve deployment of a fully functional prototype in the classroom.

Phase 1: Reviewing the classroom environment

This informal study involved visits to a pre-K school and observation of classroom activities by one of the authors. During the visits, the author served as a volunteer at the school, gaining first-hand experience of the class environment and making observations of student/teacher interactions and learning activities.

The school visits helped in better understanding the pre-K classroom environment. This included observing the present learning activities and how they are conducted by the teachers in the classroom. Since the Teaching Table would be primarily assisting the teachers in this task, the observations helped in deciding the right features for the table that would create easy division of work between the teachers and the table. Also observed were various other classroom functions of a teacher, like distribution of resources, handling different skill-levels of the students and other management and administrative activities.

This background research provided useful insights that informed the design of the first Teaching Table prototype. It also helped frame the subsequent user evaluation methods for the project.

Phase 2: Focus group with teachers

We are currently conducting a study with eight pre-K teachers to identify common issues around using early-education computational devices (and Teaching Table in particular) to effectively augment their classroom math teaching. The main objectives for conducting this study are:

a) To determine the feasibility of using the Teaching Table system in a classroom setting, and

b) To determine the preferred ways of assessing a child's progress in acquiring basic math skills.

The results of this study will inform the next round of developments for the Teaching Table system. Objective (a) seeks to identify the necessary design changes to the physical interface toward Phase 3 deployment in the classroom. Objective (b) seeks to evaluate the on-screen assessment tool for teachers and determine any necessary refinements to the set of parameters that are currently recorded by the interface.

Phase 3: Constructive Interaction with Children

After the next stage of system design, we plan to conduct a usability study of the Teaching Table with the primary user group. This study will be an on-site evaluation, observing children using the system in their regular classroom environment. The main objectives of the study are:

a) To evaluate whether the system is physically usable by kids (ages 3-5 years) in a typical classroom setting, and

b) To evaluate whether the interaction activities are appropriate for the age group and are understood by the children.

CONCLUSION AND FUTURE WORK

In this paper, we have presented the Teaching Table system for basic math learning for pre-K children. The system is designed to integrate into the classroom environment, and provides both learning activities for children and assessment tools for teachers that fit with the existing pre-school curriculum. We have discussed our system design and three-stage research and evaluation approach.

The power of the Teaching Table platform lies in its generic nature, which allows activities that aid in the development of a variety of different skills to be constructed and supported. While our current research has focused on the development of math skills, it would not be difficult to extend the activities to cover concepts in other areas, such as language and literacy, science, and creative development. We also plan to develop collaborative activities for small groups of children to interact with the table together.

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