

Teaching elementary mathematics with virtual manipulatives : an introduction of Magic Board

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Abstract

With the development of technology, there has been a reform in math teaching aids during the past ten years. The virtual manipulative has been created, which is a kind of assistive technology device integrating actual teaching aids and computer technology, and is suitable for elementary students in learning mathematics. Based on experience obtained in the development of virtual manipulatives, Magic Board (<http://magicboard.cycu.edu.tw>) has been created and became a well-known web-based virtual-manipulative environment for teaching elementary mathematics in Taiwan. Magic Board comprises three important components: Magic Board Software, Problem Posing Center, and Instructional Material Center. The Magic Board Software contains a virtual collection of physical manipulatives that elementary teachers can use to teach mathematics. Elementary school teachers can use this on-line virtual environment to pose and organize instructional materials for their students. Website members also have access to a variety of instructional materials that have been posed or organized by other Magic Board members. In this paper, Magic Board will be introduced and its features will be discussed. It is hoped that more teachers will enjoy the use of this resource to integrate technology into mathematics teaching.

1. Introduction

For elementary students in their first few years of school, teachers use physical objects (i.e. manipulatives), such as counters, Cuisenaire® rods, pattern blocks, geometric solids, and base-ten blocks, that are manipulated to introduce basic mathematics concepts. The use of manipulatives in teaching mathematics is based on the belief that children need concrete experiences to supplement the connection between words and symbols of mathematics (Paiget, 1952). Consequently, manipulatives have been thought to be effective tools in teaching mathematics. They provide experiences that help build clearer mental images, and help students understand mathematical ideas (Weiss, 2006). Results from research also show that students who use manipulative materials in learning mathematics perform better than those who do not (Raphael & Merlin, 1989; Carbonneau,

Marley & Selig, 2013). However, Moyer (2001) found school teachers usually thought manipulatives were fun, but not necessary for teaching and learning mathematics. Other researchers also observed that school teachers do not use manipulatives as often as recommended (Gilbert & Bush, 1988; Moyer, 2001).

Since physical manipulatives often have problems associated with implementation in the elementary classroom. These problems include lack of appropriate manipulatives, storage of manipulatives, organization and use, as well as classroom control issues. On the other hand, Hatfield (1994) indicates that teacher competency is one major reason that elementary teachers decide not to use manipulatives in their classroom. With educators' recognition of the usefulness of concrete manipulatives and other representations for teaching mathematics, two innovations have converged to form an exciting manipulative technology venue for use in early grades. They are "innovations in computer technology that allow programmers to create electronic objects, and the availability of Internet resources" (Moyer, Niezgoda, & Stanley, 2005, pp.17). Moyer, Bolyard and Spikell (2002) call these electronic objects virtual manipulatives. It is believed by many researchers that virtual manipulatives have the potential to overcome some of the main drawbacks of implementing physical manipulatives (Clements & Sarama, 2005; Sarama, Clements, & Vukelic, 1996).

Virtual manipulatives are often exact virtual replicas of concrete manipulatives. Their interactive and dynamic properties provide opportunities for constructing mathematics knowledge and developing conceptual understanding. The Principles and Standards for School Mathematics (NCTM, 2000) Technology Principle indicates that "Work with virtual manipulatives ... can allow young children to extend physical experience and to develop an initial understanding of sophisticated like the use of algorithms" (NCTM 2000, pp.26-27). Research has demonstrated that manipulating shapes and objects on a computer can be just as, or more, effective in facilitating mathematical learning (Char, 1989). Previous studies have demonstrated that virtual manipulatives can provide children with flexible representations to support mathematical explorations (Moyer, Niezgoda, & Stanley, 2005). Moyer, Bolyard, & Spikell (2002) discuss many advantageous properties about virtual manipulatives: potential for alteration, interactivity, link symbolic and iconic notation, unlimited supply, and easy to clean. Using virtual manipulatives during instruction is a new trend for integrating technology into mathematics teaching and learning. Magic Board began as a collection of virtual objects that elementary teachers use to present number concepts in teaching mathematics. The use of Magic Board and the design of instructional materials are easy. Therefore, elementary teachers do not need to worry about lack of competency to design technology integration activities. In this paper, Magic Board is described in detail and its implementation discussed.

2. Essence of *Magic Board*

Numerous virtual manipulative websites are currently available worldwide, such as the National Council of Teachers of Mathematics Illuminations (<http://illuminations.nctm.org/>) and the National Library of Virtual Manipulatives (<http://nlvm.usu.edu/en/nav/vlibrary.html>). These resources are full of applets, and each applet is designed for teaching a specific topic. Virtual manipulatives in different applets cannot be used together within the same interface. This reduces the flexibility and the need for representing different concepts. Different from these existing resources, Magic Board provides a collection of virtual objects that elementary teachers usually use to present mathematics concepts. It can be accessed at <http://magicboard.cycu.edu.tw> for free. English version of Magic Board is available from the upper right corner of the website home page by clicking the “Try English version.” button. Magic Board comprises three important components: Magic Board Software, Problem Posing Center, and Instructional Material Center. Users that register as members of Magic Board are eligible to use all of the components to construct and share instructional materials on the Magic Board platform. Users can access shared materials and adapt them to their own classes. Non-registered users (guests) can open and utilize Magic Board Software to adopt existing instructional materials for implementation into their instruction.

2.1 Magic Board Software (MBS)

MBS (Fig. 1) provides a Tool box that includes a wide range of digitalized and componentized manipulatives (19 major categories) that are frequently used in teaching elementary mathematics. Clicking the ToolBox button in the Function Button Area hides or shows the Tool box in the Display Area. Teachers can instant access and drag these objects to the Display Area. Near by the object, a right-click allows access to property variation and operation such as maximized or minimized as well as rotated. In the Function Button Area, the Text button is used to enter text to present word problems, the Draw button can be used to scribble or mark anything on the screen, and the Erase button for erasing. The Cheers Button is used to encourage students who are doing well or to motivate students who are struggling. The BK button enables a rapid change of backgrounds. Clicking the Rubbish Bin clears all components from the Display Area. A user creates his/her problem on the Display Area, he/she can save the problem by clicking the Save/Upload button to save it on the web for other users to use or clicking the Load Locally button to save it in personal computer temporarily.



Fig. 1 Magic Board Software Interface

2.2 Problem Posing Center (PPC)

Users can log into the Magic Board platform to access resources from the PPC and search for shared problems according to the level of their students and mathematical content. Users can save and upload teaching materials by clicking on Edit and Upload, and following the instructions to enter the grade of the target students and the content used in their lessons. Users can search for problems based on these pre-set search values. Clicking on My Posed Problems lists pre-designed problems uploaded by Magic Board members (Fig. 2).

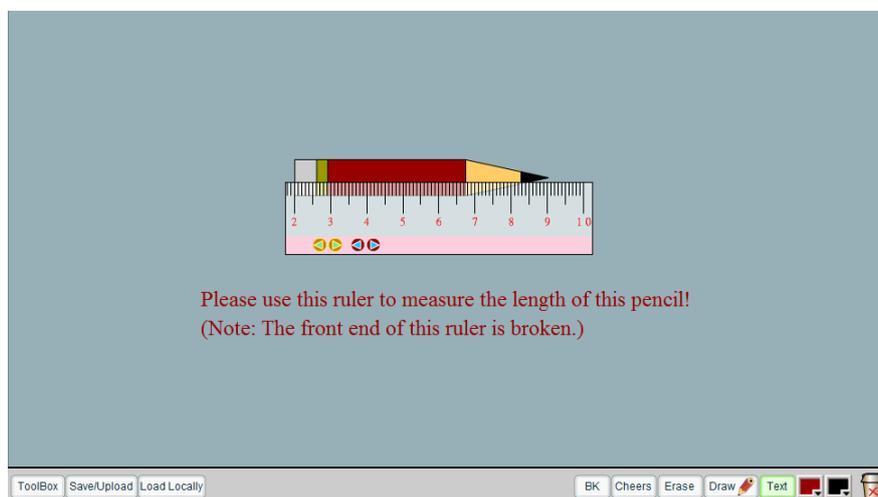


Fig. 2 Length measurement problem posed by a user

There is a sign of inadequate manipulatives as well as uncertainty during the teaching of measurements in primary schools. For instance, while teaching how to use a ruler, because of a lack of manipulatives to demonstrate its usage, teachers are required to spend more time with individual students. The same applies to scale reading and weight measuring, as the students are unable to read

the changes on the scale. Although certain teachers actually make their own manipulatives, construction is time-consuming and requires a lot of effort; there is also the problem of storage. The introduction of these measuring components after that of the basic concepts facilitates a clearer demonstration and discussion. Figure 3 illustrates the application of the weighing component. In this case, the teacher can set the weight of the items to be weighted by right-clicking the mouse, and then go on to discuss with the class how to use the balance to compare the weight of the three items.

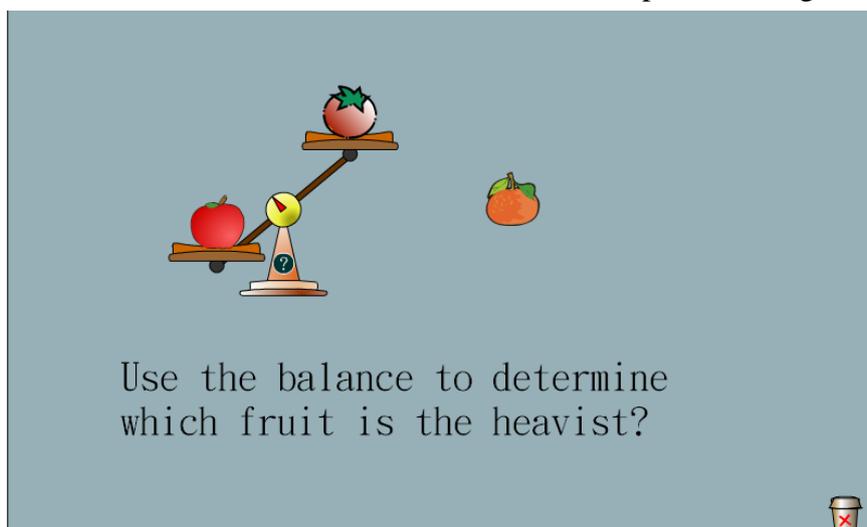


Figure 3 Using a balance to determine the weight of three items

2.3 Instructional Material Center (IMC)

The Search function enables users to search for shared instructional materials under various classifications such as the grade of the students it is intended for and the nature of the mathematical concepts being discussed. Clicking on Organize Instructional Materials enables users to browse through problems and select suitable source materials with which to personalize curriculum. My Instructional Materials reveals a list of lessons and materials previously uploaded by Magic Board members. After entering Organize Instructional Materials (Fig. 4), users search through problems numbered according to their selection order. Clicking on Set Posing Problems and entering the classification information of the instructional materials completes the compilation. The arrows in the Function Button Area control the presentation of the comprehensive instructional materials available at the IMC.

create these virtual instructional materials. For instance, mention of Flash or Dream Weaver alone is enough to put many of them off. On the other hand, there is also the problem of finding a suitable computer medium that can be incorporated in teaching. This is when Magic Board comes in. It is an efficient tool for teachers in teaching mathematics because of following features:

3.1 User-friendly

Teachers are not required to process advanced information technology training, as long as they are able to use a mouse, download ready-made and upload their own instructional materials, they will be able to operate Magic Board without any problem. In other words, teachers only need to possess the most fundamental computer skills to operate the Magic Board.

3.2 Developing Skills in Making Use of Shared Instructional Materials or Creating Your Own

A persistent problem with teachers in Taiwan is their over reliance on textbooks and a disregard of manipulative suitability. As a result, they are unable to develop suitable manipulatives based on their teaching experience. Others argue that it is too time-consuming, as it requires typewriting, art and layout designing, which far exceeds their capability. The employment of Magic Board will solve most of the problems as it provides nearly 10 kinds of backgrounds (such as forests, grasslands, the marine world, etc.). More backgrounds can be downloaded from the Internet should teachers feel the need. As to characters, there are cartoon characters, animals, plants, food, vegetables, and clothes as well as frequently seen elements in mathematical teaching. There are also mathematical signs such as whole numbers, operations and fractions. In addition, the frequently used mathematical manipulatives such as clocks, scales, balance, hundred-board, Cuisenaire rods (number rods) and geometric figures are available. Teachers only need to drag and copy to compile their own instructional materials, and subsequently upload them to share with other teachers.

The use of Magic Board helps teachers to overcome the fear in compiling their own instructional materials. It might even render teachers the feeling of being a creator or artist in teaching instead of being a passive instructor who follows the textbook. Those who are too busy to compile their own instructional materials can download those made by others, where there are currently more than 2000 set available, thus allowing learning and exchange of experience.

3.3 Individualized Evaluation of Students

A lot of school teachers dislike the mathematical computer software sold on the market or similar online resources as they find them hard to manipulate. For example, teachers may employ computer activities to show students how to distinguish proper and improper fractions, but in addition to these two types of fractions the activity might include mixed fractions, which could end up causing confusion among learners.

Magic Board features aptitude-based worksheet designing and evaluation, whereby teachers can set questions based on the capability of students to evaluate their learning progress, which eliminate generalization that is common in ordinary computer software.

3.4 May be Used in Conjunction with Primary School Mathematical Teaching

Besides the generalization that does not take into account the capability of individual students, another reason why teachers dislike employing software in teaching is that it either deviates too much from or is identical to the textbook. That is why most teachers still prefer to use textbooks. While using Magic Board, teachers are able to compile instructional materials or worksheets based on the learning progress of students, or they can even refer to those compiled by other teachers based on difficulties encountered by their students. That is why Magic Board can facilitate the solution of issues encountered by teachers in their mathematics teaching.

3.5 *Magic Board* is Equipped with Conventional Blackboard Features Allowing Dynamic Teaching

Many teachers find computer-based mathematical teaching hard to accept as it only allows students to write or choose answers (using mouse or keyboard), whereby the process that is crucial to learning mathematics is omitted. However, the Display area of Magic Board has a blackboard feature. Simply by clicking the Draw button in the Function Area, a mouse-controlled Doodle Pen will appear, allowing teacher or students to write down numbers and the calculation process, thus achieving real dynamic teaching and evaluation.

3.6 *Magic Board* Provides Students with Visual Aides

The greatest difficulty that students encounter while learning mathematics is the inability to associate numbers or mathematical signs to physical objects. Take $\frac{1}{4} + \frac{1}{4} = \frac{1}{2}$ for example; they are unable to associate this abstract equation to that of $\frac{1}{4}$ of a pizza or cake plus another $\frac{1}{4}$ is equal to $\frac{1}{2}$ of a pizza or cake. Through Magic Board, teachers can present both fractions and images of a cake or pizza in the question to reinforce student understanding of mathematical signs of operations. While teaching with the collection of cubic blocks, teachers can right-click the mouse to turn them transparent or move them around, so that students can see those stacked at bottom (see Figure 6). Such visual aides greatly benefit students in the learning of abstract mathematical concepts.

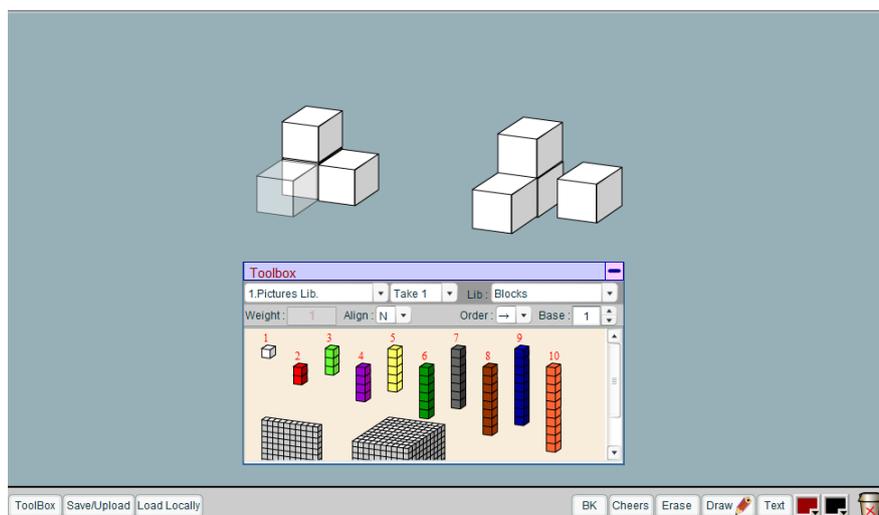


Figure 6 Magic Board clearly demonstrates individual cubic block

4. Conclusion

Magic Board was first developed at the beginning of 2005 (Yuan 2005). It digitalized and componentized physical manipulatives frequently used in current textbooks. The resulted virtual manipulatives maintain the functions and benefits of physical manipulatives while surpassing existing limitations. They also present mathematical concepts more clearly. For instance, the points on an actual 10-column board cannot be moved. However, once digitalized, each point can be moved around freely on the board allowing the possibility of change as well as a lifelike expression of the reduction concept (a superficial association).

Another example is the conventional hundreds-board, which is hard to store due to its bulky size, and it is also time-consuming to duplicate. The virtual hundreds-board takes up no physical space, its size and number patterns can be adjusted freely, and there is no restriction on the number of boards that can be retrieved. The boards can be set up in conjunction with different teaching and discarded thereafter.

Magic Board is designed only as a teaching tool and does not provide automatic teaching of the mathematics. Teachers must plan the presentation of the content, and this is what makes this software an educational one. The objective of design of this software is to save teachers time spent on manipulative preparation while meeting the need for diversified display. The Save feature allows pre-class preparation, so teachers are able to focus fully on students in class. Gathered from teachers' trial experiences and field testing, we discovered that Magic Board could indeed be applied effectively onto mathematical teaching in primary schools.

'The level of my grade 2 students this year was not so good. By introducing Magic Board in class and by making use of its images and multiple-object-presentation feature, students

were able to grasp the concept of multiplication very quickly. The amount of time required to spend on teaching was reduced as preparation time was reduced. Students were engaged and interested, and they understood better.'

'I made use of Magic Board to teach multiplication and found that students were doing very well and exam results were better than usual. Only one or two students were falling behind.'

'I let my senior students set their own questions using Magic Board, and everyone was keen to do so. Even when we were solving these questions they were all enthusiastic, which is uncommon in mathematics class.'

The above testimonies from teachers are very encouraging to the development of Magic Board, which is continuously expanding and revising. We hope to develop a set of virtual manipulatives to facilitate teachers in the teaching of numbers and quantities to students between lower and intermediate grade. It is hoped that this tool will make learning mathematics more fun for students, which will ultimately be reflected in their results.

Capable of helping teachers to present mathematical concepts clearly, virtual manipulatives can be used to provide interactive learning environments in order to help students study mathematical concepts and improve their conceptual understanding (Terry, 1996). Finding effective ways to use innovative means of teaching mathematics is essential for all students. If schools are equipped with appropriate technological equipment and such useful tools, teachers can easily integrate technology into mathematical teaching. It is hoped that Magic Board can be a good assistant for elementary teachers in teaching mathematics. It is also important to investigate problems and questions using Magic Board in real classroom and to explore effective ways to use Magic Board in teaching mathematics. This article aims to introduce the virtual manipulatives developed by a research team from Taiwan, so more teachers in other country have better understanding of their usage. Teachers who are interested and devoted to integrate information technology into mathematical teaching are welcome to join the group of Magic Board users.

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