A FRAMEWORK FOR DESIGNING COMPUTER ASSISTED CONSTRUCTIVIST LEARNING ACTIVITIES[1]

Erol KARAKIRIK, Soner DURMUS
Abant Izzet Baysal University, Turkey

ABSTRACT
Constructivist learning approaches emphasize student's active involvement during learning process by engaging them with meaningful activities. The interest on alternative tasks, which give the most of control to the students in order to increase their participation and to provoke divergent thinking, has recently significantly increased. Hence, it is very important to devise appropriate tasks from closed tasks with strict rules to flexible open-ended tasks in order for students to build their knowledge and to improve their metacognitive skills. Promoting and implementing open-ended tasks require much more effort and time than widely used traditional drill-and-practice learning tasks. In addition, alternative tasks need to be carefully designed around the conceptual features of the domain such as mathematics by taking its specific knowledge into consideration. Well-designed tasks could enhance students' abstraction of mathematical concepts and procedures. Current computer technologies as educational tools give us the opportunity to integrate such tasks to the learning setting. Computer assisted math activities may provide an interactive environment where students could pose and solve their own problems to form connections between mathematical concepts and operations, and get immediate feedback about their actions. A few computer based activities aiming to teach mathematical concepts and procedures such as digit value and permutational calculations were developed. In this paper, the guidelines to design such computer assisted activities will be discussed and developed computer based activities will be presented.

INTRODUCTION

Students construct mathematical structures that are complex, abstract, and powerful actively in a constructivist learning environment. In such a setting, they explore mathematical ideas by thinking, participating, and reflecting. They take the responsibility of completing assigned tasks and controlling and creating their own mathematical ideas. The role of teacher is to guide and support students' invention of viable mathematical ideas rather than correct expert way of doing mathematics (Battista & Clements, 1990). Teachers should provide an environment in which students can discuss, defend, and reflect on the specified tasks. Well-designed tasks may enhance students' abstraction of mathematical concepts and procedures. Available computer technologies give the opportunities to teacher to integrate such tasks to learning setting. This paper aims to give guidelines of designing such computer assisted constructivist mathematical activities and exemplify a few such activities.

GUIDELINES FOR DESIGNING CONSTRUCTIVIST LEARNING ACTIVITIES

Clements (1997) claims that there are five myths about constructivism that may affect the design of activities: i) Students should always be actively and reflectively constructing. Students' active involvement should be promoted, but there might be some constructions which our minds may act without working with the concept/procedure at hand. Students may work with a problem which aims for students to gain certain concepts or procedures, but while students are working with the problem, they may unconsciously construct other constructs that may become explicit in other occasions. ii) Manipulatives make learners active. Although manipulatives may help students construct knowledge, the way they are being used may lead students to rote learning. iii) Constructivist learners are lonely voyagers. Students develop mathematical ideas with and/or without with their peers. They discuss their own mathematical constructs with others to modify, to reflect on, and to make of its own unique construct. iv) Cooperative learning is constructivist. Cooperative group works are important but do not necessarily make teaching more constructivist. v) Everybody is right! Students are given chances to defend their own mathematical ideas in constructivist learning environment, but it does not necessarily mean that all mathematical ideas are right at the same time. Each effort are important and should be respected, but the goal should be to find solution(s) which make sense within the mathematics and may be better than other.

Students' ideas should be used as the starting points for instructions (Cobb et. al., 1988). The main reason for that is to regard mathematics as a human endower which should be valued. The wide range of thinking strategies of students should be taken into the considerations. The tasks should be designed in a way students may work in groups or on their own.

Mathematical concepts and procedures contain abstract and concrete elements. There are different representations for the same mathematical concept and procedures. Teachers should make judgment calls to balance concrete and abstract features of the mathematics. Physical and computer manipulatives, pictures, spoken and written words may be linked to abstract mathematical ideas (Lesh, 1990). Especially manipulatives should relate abstract mathematics to students' intuitive, informal understanding of concepts and translate between different representations at all points of their learning (Clement, 1996). Example of physical and computer manipulatives are cubes, tangram pieces, geobords, colored rods, etc. There are a few studies confirming that students using manipulatives outperformed to those not using manipulatives (Driscoll, 1983; Sowell, 1989; Suydam, 1986). Manipulatives also increases scores on retention and problem solving tests. Similarly, students' attitudes toward mathematics may be improved when they use manipulatives (Sowell, 1989). Although these findings suggest to use manipulatives, there are also a few study suggesting that using manipulatives do not guarantee the success (Fennema, 1972; Baroody, 1989).

Mathematical ideas can be visualized by computer or physical manipulatives. Computer programs allow students to manipulate on-screen. Computer manipulatives are more manageable, clean, flexible, and extensible if they are compared to physical ones (Harvey, McHugh & McGlathery, 1989). Many computer manipulatives have the ability to change the arrangement of representations. Different representations such as pictures, tables, graphs, and symbols enable teachers to reach to wide range of students. The effect of a change in one representation may be related to the other. For example, any stretch of rectangle on computer geobord can result change in measures of the sides, perimeter and area of the rectangle. This dynamic links may help students to connect different aspects of mathematics and construct rich mathematics.

[1] This paper is presented at the Fourth International Educational Technologies Conference, Sakarya / Turkey

Students can save their work for one project and use it for another (Clements, 1989). Every action of students may be stored and later retrieved. Later, these actions may re-played if desired, and be analyzed for different purposes. This enables students and teachers to explore real world mathematics. Students can draw rectangles and squares by hand but miss some important aspects of the figures. In LogoTurk, students should decide the sequence of commands to figure rectangle or square. That forces students to reflect on their decisions. This way of analyzing rectangles forces to see a rectangle as one of many that could be made rather that as just one rectangle. This approach may help students during problem solving process by breaking problems into parts by disembedding, planning and programming each piece of complex picture separately (Clement, 1989).

Slides, flips, and turns of different geometric objects can be performed with Logo by using specific commands. Students will see immediate effect of commands, reflect on and correct them. That enables students to discuss motions themselves not just the shapes (Butler & Close, 1989).
Computer manipulatives and programs can be integrated to constructivist tasks. They are not sufficient alone, teacher guidance and support is needed. Clement recommended the followings while integrating programs and manipulatives. Selected computer programs should

- ✓ allow have uncomplicated changing, repeating, and undoing actions;
- ✓ students to save configurations and sequences of actions;
- ✓ dynamically link different representations and maintain a tight connection between pictured objects and symbols;
- ✓ allow students and teachers to pose and solve their own problems; and
- ✓ allow students to develop increasing control of a flexible, extensible, mathematical tool.

Such programs also serve many purposes and help form connections between mathematical ideas. In addition, for computer manipulatives, teachers need to

- ✓ use computer manipulatives for assessment as mirrors of students' thinking.
- ✓ guide students to alter and reflect on their actions, always predicting and explaining.
- ✓ create tasks that cause students to see conflicts or gaps in their thinking.
- ✓ have students work cooperatively in pairs.
- ✓ if possible, use one computer and a large-screen display to focus and extend follow-up discussions with the class.
- ✓ recognize that much information may have to be introduced before moving to work on computers, including the purpose of the software, ways to operate the hardware and software, mathematics content and problem-solving strategies, and so on.
- ✓ use extensible programs for long periods across topics when possible.

Two examples of computer manipulatives will be introduced (Figure 1 and Figure 3).

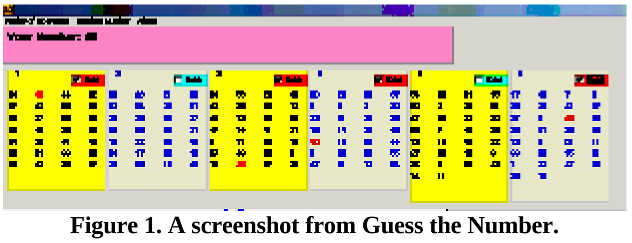

Figure 1. A screenshot from Guess the Number.

The goal of this computer activity is to help student see how base 2 number system can be applied. There two modes of operations that teachers may utilize. In the first mode, numbers are arranged randomly. In the second mode, numbers are sorted in an ascending order. One keeps a number and other tries to guess this number by asking whether this number exist in each column or not. After all the columns are considered, the guessed number is revealed by the program. The second mode of the system provides hint and explanations about how the system found the number. In this mode, the first number in each card represents the digit value in base 2 namely 1 for the first card, 2 for the second card, 4 for the third card, 8 for the fourth card, etc. One could put 1 in front of a card when the guessed number exists in a card and put 0 when it does not exist. Then, the representation of the guessed number in base 2 could be obtained by combining these values in an order from left to right (Figure 2). The representation of number 45 is 101101 in base 2. Figure 2 shows the clues of getting 45 within base 2 number system. The rationale behind finding the hidden number by the system may be discussed in the class and application of different base systems might be seen. This activity could be extended to other base systems by adding new layers to each column.

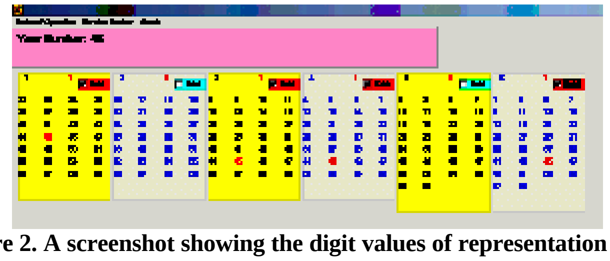

Figure 2. A screenshot showing the digit values of representation of 45.

Second computer activity is about explaining the difference between permutation and combination concepts. The main idea of the activity is to give different colors to each item used in the computations by simulating the task of painting a wall. The wall could be painted in two different ways, different parts with different colors or as a whole with a mixture of colors. The first one refers to the idea of permutation (Figure 3) while the second one demonstrates the idea of combination (Figure 4). One could arrange the number and content of the boxes to be used in the computations.

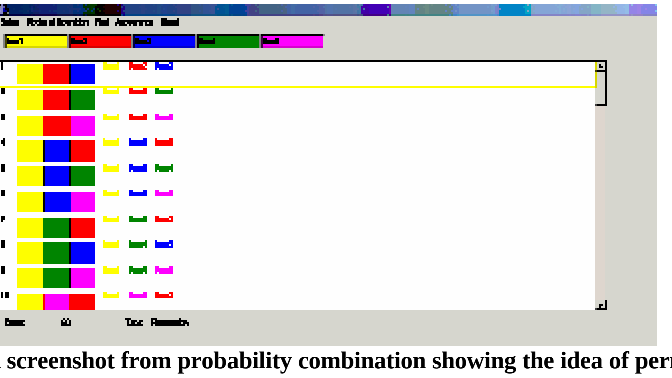

Figure 3. A screenshot from probability combination showing the idea of permutation.

Although the order of the colors of the items is important in permutational calculations, it is not significant in combinatory calculations since their mixture produces the same paint. Hence, some of the color combinations in permutation produce same paint in combinations. The system may help users visualize in a way showing the mixture of the paint produced by the same permutation (Figure 5). The second and seventh color combinations produced the same paint as a mixture although they represent different permutational pairs.

There are also two different modes of operations in the system. In the first mode, system displays all alternative combinations for the selected operation. In the second mode, users are required to drag-and-drop items to produce different combinations (Figure 6). The system prevents the usage of the repeated combinations.

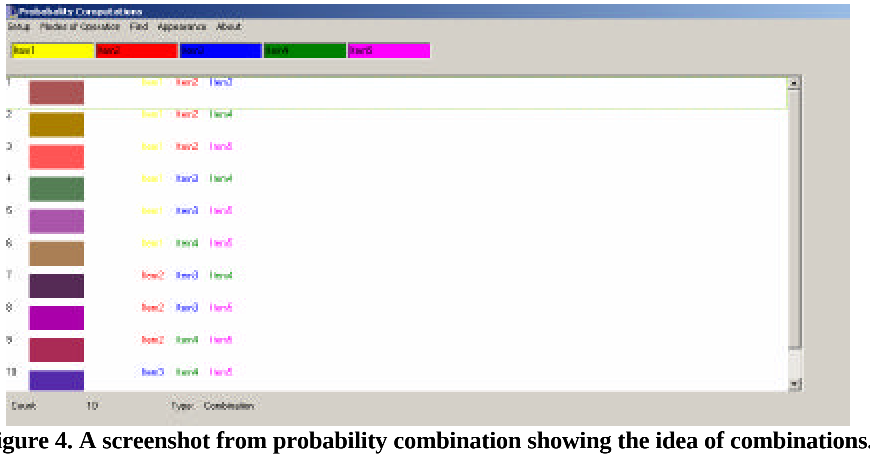

Figure 4. A screenshot from probability combination showing the idea of combinations.

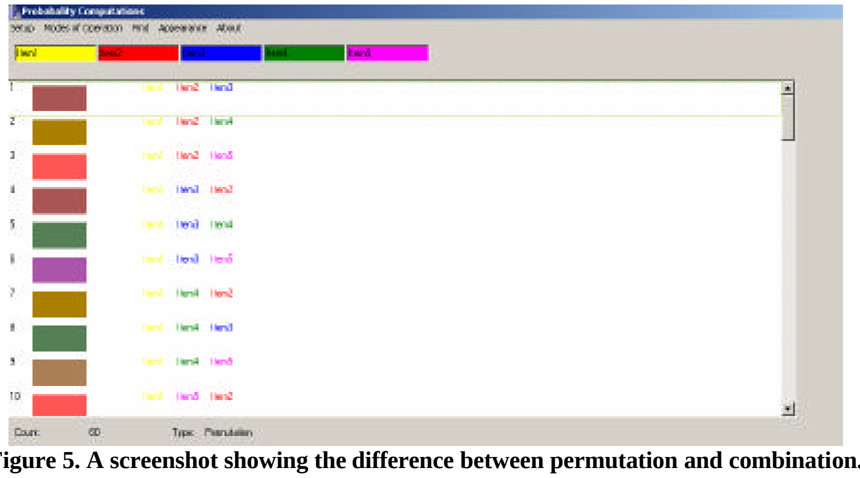

Figure 5. A screenshot showing the difference between permutation and combination.

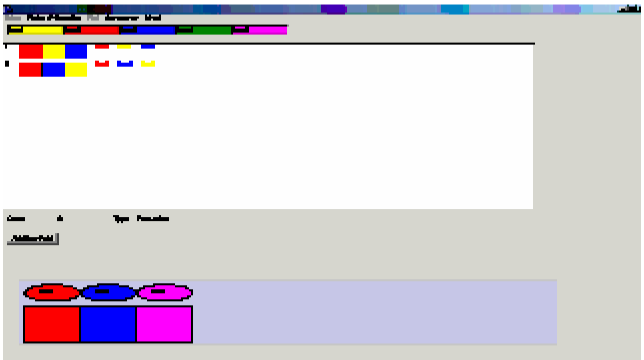

Figure 6. A screenshot showing the activity mode.

CONCLUSION

Technology enables teacher to facilitate constructivist environment in which students uses computer programs to construct mathematical concepts and relations. In this paper, it is exemplified two computer assisted constructivist activities. Availability of different modes of operations gives teachers opportunities to help students visualize the main ideas of the concepts at hand and to provide users opportunities to construct their own understanding by interacting with the concepts. Developing computer-based activities may enhance constructivist learning environment as it is proposed in this paper.

REFERENCES

Baroody, Arthur J. (1989). One Point of View: Manipulatives Don't Come with Guarantees. *Arithmetic Teacher*, 37, 4-5.

Battista, M. T., & Clements, D. H. (1990). Constructing Geometric Concepts in Logo. *Arithmetic Teacher*, 38(3), 15-17.

Butler, D. & Close, S. (1989). Assessing the Benefits of a Logo Problem-Solving Course. *Irish Educational Studies* 8, 168-90.

Clements, Douglas H. (1989). *Computers in Elementary Mathematics Education. Englewood* Cliffs, N.J.: Prentice-Hall.

Clements, D. H. (1997). (Mis?)Constructing Constructivism. *Teaching Children Mathematics*, 4, 198-200.

Clements, D. H. & McMillen, *S. (1996).* Rethinking Concrete Manipulatives. *Teaching Children Mathematics, 2(5), 270-279.*

Cobb, P., Yackel, E., Wood, T., Wheatley, G., & Merkel, G. (1988). Creating a Problem-Solving Atmosphere. *Arithmetic Teacher* 36, 46-47.

Driscoll, Mark J. (1983). *Research within Reach: Elementary School Mathematics and Reading.*St. Louis: CEMREL.

Fennema, Elizabeth. (1972).The Relative Effectiveness of a Symbolic and a Concrete Model in Learning a Selected Mathematics Principle. *Journal for Research in Mathematics Education* 3, 233-38.

Harvey, Wayne, McHugh, R., & McGlathery, M. (1989). *Elastic Lines. Pleasantville (Software)*, N.Y.: Sunburst Communications..

Lesh, Richard. (1990). Computer-Based Assessment of Higher Order Understandings and Processes in Elementary Mathematics. In *Assessing Higher Order Thinking in Mathematics*,edited by G. Kulm (pp. 81-110). Washington, D.C.: American Association for the Advancement of Science.

Sowell, Evelyn J. (1989). Effects of Manipulative Materials in Mathematics Instruction. *Journal for Research in Mathematics Education* 20, 498-505.

Suydam, Marilyn N. (1986). Research Report: Manipulative Materials and Achievement. *Arithmetic Teacher* 33, 10, 32.