A MICROWORLD FOR THE LEARNING OF BINARY REPRESENTATION BY PRIMARY LEVEL EDUCATION PUPILS

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Abstract

This paper focuses on the design of a microworld for the learning of binary representation by primary level education pupils. The proposed microworld has been constructed within the theoretical framework of modern social and constructivist perspectives of knowledge construction. In the context of the constructed microworld, pupils have opportunities to construct the concept of coding a piece of information represented in systems used in the real world, such as visual drawing information, in binary representation systems used by a computer. Pupils also have the opportunity to construct the concept of decoding a piece of information presented in a binary form to information represented in a system used in the real world. In the context of the proposed microworld, pupils are helped to construct these concepts by exploiting the following opportunities: a) to draw a picture by coloring in each cell of a grid, b) to use 0s and 1s to represent the picture in focus, c) to experiment in order to discover by themselves the encoding system implied by the system in their pictures, d) to use different coding systems to represent a picture, e) to observe the automatically-created binary representation corresponding to a picture they have constructed and f) to draw a picture by using a binary code and to observe its representation automatically created by the system.

Introduction

The conceptualization of Computer Science (CS) in K-12 education as 'the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications and their impact on society' is widely accepted by many researchers and educators as well as scientific and professional organizations. Within this framework, a model curriculum for K-12 CS has recently been proposed (ACM, 2003). One of the four goals of this curriculum is to introduce the fundamental concepts of CS to all students beginning at primary level. Level I (recommended for grades K-8) of this curriculum is geared to provide primary school students with fundamental CS concepts by integrating basic technology skills with simple ideas on algorithmic thinking. At this level of education, pupils can begin thinking algorithmically as a general problem-solving strategy to accomplish a task in a step-by-step manner. It is clear that whatever is achieved in high school depends upon the effectiveness of student access to technology and achievement of computer-related learning milestones at the primary level. Understanding how the representations of information used in the real world must be represented in order for them to be understandable to a computer is fundamental for a preliminary understanding of how a computer works. Thus, understanding how Os and 1s can be used to represent information, such as binary images and numbers, is a basis for the achievement of the goals of CS curriculum at this level of education. Understanding of binary representation of information is also critical for a fundamental understanding of how a computer works. It is worth noting that both students in secondary education and adults also have

difficulties in understanding how a computer works (Soloway & Spohrer, 1989). It is what the pupils do - not what they see - that has the greatest impact on learning at the primary level (Papert, 1991). The role of engaging learners in meaningful and enjoyable learning activities is also acknowledged as crucial for the learning of fundamental CS concepts and skills at this level (Jonassen, 2000; Bell, Witten, and Fellows 2002). The positive effects of constructivist educational software on student understanding of a variety of learning subjects, including CS, has been also acknowledged (Papert, 1991; Noss and Hoyles, 1996; Jonassen, Carr. & Yueh, 1998; Kordaki, 2005).

Based on the above, we designed a computer microworld to encourage primary level education pupils to be actively engaged in their learning regarding binary coding of information. The context of painting was selected as the context for the possible learning activities. This was chosen to provide students with opportunities to develop strong motivation and to be happily involved in the specific learning activities to be set (Bell, Witten, and Fellows 2002). The design of this microworld was based on modern constructivist and social theories regarding knowledge construction (Vygotsky, 1978; von Glasersfeld, 1990; Crawford, 1996a, 1996b; Noss and Hoyles, 1996). These modern theories acknowledge the active, subjective, constructive and social character of knowledge, with an emphasis on the significant role of tools in student learning. The role of multiple and linked representation systems in the construction of educational software is also considered critical (Dyfour - Janvier, Bednarz, & Belanger, 1987; Kaput, 1994). In addition, the role of appropriate feedback on student actions when they use the tools provided for self correction in specific tasks was taken into account in the design of the proposed microworld. Providing students with the chance to explore specific binary representations and to conjecture about the internal logic that governs their structure is also considered essential (Mariotti, 1995). In the design of the proposed microworld, the representational capabilities of the computer were considered ideal for student learning of binary representation of information (Kaput, 1994). A microworld providing primary education pupils with opportunities to construct the concept of binary coding in a constructivist learning context meaningful for students has not yet been reported.

In the next section of this paper, the basic features of this microworld are presented. These features are discussed in terms of the tasks that could be performed by students and proposals for future research are set out.

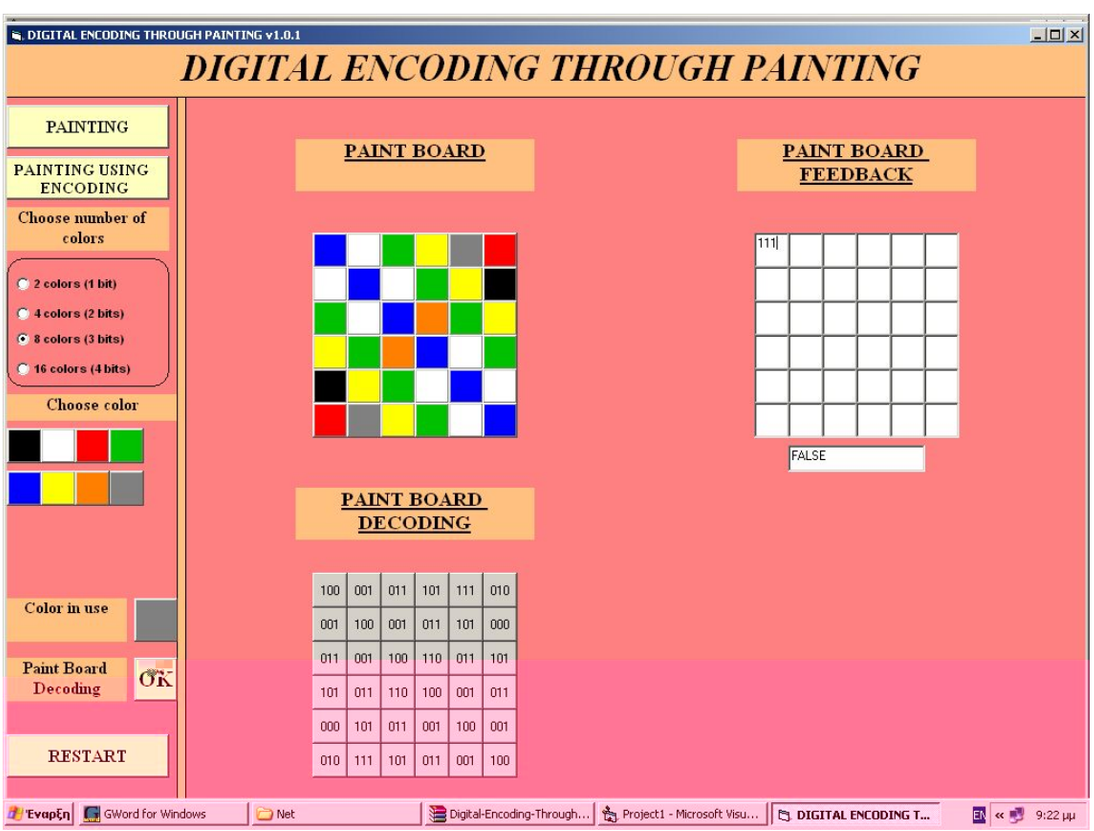
The educational software: features and possible tasks

In the context of the constructed microworld, pupils are given the opportunities to: a) draw their own pictures by coloring each cell of a grid with nxn (n=6, 12) cells, b) use 0s and 1s to represent their pictures, c) experiment in order to discover independently the encoding system implied in their pictures, d) use different coding systems to represent a picture, e) observe the automatically created binary representation corresponding to a picture they have constructed and f) draw a picture using specific binary coding systems and observe its representations automatically created by the system.

Drawing and observing the use of a binary coding system. Students are provided with the opportunity to draw their own pictures, in order to both make sense of the task at hand and be motivated in the procedure. The grid used is in the form of a square grid divided into square cells. Pupils can color each individual cell of these grids in order to produce their drawings. Two different grids can be used: a) a small grid with 6x6=36 cells and a larger grid with

10x10=100 cells. The small grid was selected to give pupils opportunities for fast drawing. By using this grid, pupils can produce primitive drawings and then have the opportunity to focus on coding them using binary representation systems. The larger grid provides pupils with the opportunity to produce more sophisticated drawings. This is welcome for those pupils with special preferences in drawing. Even larger grids were not used as they were considered unsuitable for use on a computer screen. Pupils have the option of coloring in their drawings by selecting from four different sets of colors, e.g. 2, 4, 8 and 16. After choosing the set of colors they prefer, pupils can select a specific color and then use it to color in a specific cell of the grid by clicking on it. Consequently, pupils have the opportunity to be engaged in meaningful and pleasant work drawing their own pictures. Next, the pupils have two options; to code their picture on their own using a binary system, and to view the binary representation of their picture automatically produced by the system. By providing pupils with the opportunity to view this coded representation, they can make primary sense of how their own representations can be viewed in their transformed versions where a binary representation coding system is used. Pupils are also given the opportunity to change the colors of their drawings and simultaneously observe the immediate transformation of the binary-coded versions. In Figure 1, you can see an example, where 4 colors are used to draw a picture on a grid of 6x6 cells. In this Figure, you can also see the binary representation of said picture.

Figure1. Drawing and binary representations of a picture in the context of the proposed microworld



Experimenting with the use of 0s and 1s and discovering binary codes. After pupils draw a colorful picture, they have the opportunity to experiment and to discover the coding system that the computer uses to represent this picture in its memory. Pupils can actively use 0s and 1s to binary represent their own

drawn representations. In fact, students can begin writing the code they think corresponds to each cell of their picture. They can write this code in each of the cells included in another grid identical to the grid they used to produce their colored pictures. Actually, pupils can fill the empty cells of this grid with combinations of 0s and 1s. When pupils use 2 colors (black and white), they have to fill the empty cells with single 0s and 1s. However, when the number of colors increases, the pupils have to develop combinations of 0s and 1s in order to represent the specific colors used. In any case, the system automatically sends a message to the individual pupil to inform them if the code they wrote is the code used by the system. By using this feature, pupils have the opportunity to express their own coding systems and to correct them. Students also can discover different coding systems such as the ones produced by the use of 1, 2, 3 and 4 digits. Here, the teacher can explore the generation and the patterns of their students' binary coding systems and take appropriate actions. Teachers can also exploit students' primary binary coding systems to help them progress to the construction of more sophisticated coding systems consisting of the same number of digits and using the minimum combinations of 0s and 1s.

Decoding. Finally, the system provides the possibility of automatically transforming a binary picture constructed by a student into a colored one. This transformation could be essential for pupils as this can enable reversible thinking (Piaget, Inhelder & Szeminska, 1981). In particular, when the binary codes used are limited, pupils can easily create a meaningful picture in its binary form and can be enabled to make useful reflections on their observations of the two identical pictures of different representations.

Based on what has been discussed above, students can use the provided features by the proposed software to experiment with the coding and decoding concepts in digital worlds. This experimentation can become a significant factor in pupils' primary understanding of how information is coded in the computer.

Technical Information. The microworld constructed using Microsoft Visual Basic V. 6.0.

Conclusion and Future plans

This paper presents a microworld providing pupils at the primary level of education with opportunities to construct the concepts of coding and decoding using binary representation systems. The microworld provides pupils with opportunities for active, subjective and constructive learning. In the context of this microworld, reversible thinking can also be enabled. Pupils can study the previously-mentioned concepts in the meaningful context of drawing. The learning activities that pupils can perform are open, as they can exploit the boundaries of their imagination. It follows that pupils can be fully engaged in drawing activities they prefer while simultaneously learning about coding and decoding. Pupils can also study their colorful pictures in relation to binary coding automatically produced. In addition, pupils can attempt binary coding of their pictures by themselves and receive immediate feedback from the system so that they can self-correct them. Finally, pupils are provided with the possibility of describing a picture using a binary code and automatically translating it in a colorful mode. It is worth noting that the teacher can exploit the tools provided by this microworld to investigate their pupils' primary ideas about binary coding and to make appropriate interventions. Based on the above, we can state that the proposed microworld could become a meaningful, friendly and resourceful context for pupils to learn concepts related to the use of binary coding. However,

more research is needed using the proposed microworld with real pupils to investigate their learning behavior with the system and to make appropriate improvements.

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