TEACHING BASIC NUMBER THEORY TO STUDENTS WITH SPEECH AND COMMUNICATION DISABILITIES USING MULTIMEDIA

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Abstract

Under this research we developed a system destined as a teaching aid for students with communication difficulties. Our methodology examines the underlying mathematical concepts from a highly analytical perspective and derives appropriate courseware material of equivalent quality. The case-studies described in this paper deliver basic courseware on number theory and generalised mathematical concepts by presenting the geometrical meaning of the underlying concepts and providing alternative representations that enable understanding of the underlying theory. This process has resulted in the development of a visual set of case-studies that teach basic mathematical and geometrical concepts which may subsequently be extended to algorithms such as division, Greatest Common Divider, multiplication, least common multiplier, attributes and requirements for division. Interactive multimedia technologies are used extensively in the development of the teaching environment. A game-like interface aided by realistic binaural audio and animation has proved to attract user-attention for longer periods than using traditional teaching methods, aiding the educational process by providing an immersive multimedia interactive-learning alternative, for students with communication problems.

Introduction

The widespread availability of multimedia-enabled information-society technologies enables educators and researchers to develop and distribute novel learning tools and applications. Today, most teaching tools consider the underlying knowledge separated into entities, which are adaptively presented to the audience through the use of sophisticated interactive and networked technologies (Deliyannis, 2007; Dutton & Loader, 2002; Scanlon, Jones, Barnard, Thompson, & Calder, 2000; Sheizaf, Miri, Yuval, & Eran, 2004). Analysis of core knowledge and the underlying meaning are viewed as one unit, rarely being separated by their representation (Robins & Webster, 2002). Furthermore, one faces additional difficulties when designing custom educational systems. For example, students with Down syndrome can store a maximum of three concepts in their short-term memory, and may be disorientated by inappropriately synchronised sounds and music. It is important therefore to examine first the limitations of their learning development and select appropriate examples for the desired area of application that can be extended from mathematics to other areas such as reading and even the development social skills.

Our work has shown that in most cases young students with speech and communication disabilities learn more efficiently new concepts and ideas with the development of analytic examples (Deliyannis & Simpsiri, 2008). These examples describe the underlying concepts using alternative representations, for example in the case of mathematics through the use of geometrical shapes and analytical counting methods.

It is important to examine the methods through which students are introduced to mathematical concepts today. One may observe common characteristics across disparate educational units and systems as far as the teaching methodology is concerned. Natural sizes and measures are expressed through symbolic representations, which are used as a basis for the introduction of complex operations. In that respect, the physical meaning of the concepts is hidden behind symbolic representations.

A New Approach to Representation

In this paper we introduce an alternative methodology to express and demonstrate common mathematical concepts. In numerous occasions memorisation of symbols and concepts is employed to express information about the quantities involved, a representation that is usually hard to be understood by minors. For example it is common practice for students to memorise multiplication matrices, in an attempt to perform faster numerical operations, when more practical methods may be devised to enable easy multiplication.

This is not the case for all students. It is shown in the literature that learning through symbolic representations is quite a difficult task, particularly for students with speech and communication disabilities. This is particularly evident when we considering students with Down syndrome (Tien, 1997) who are particularly affected as they suffer from lack of short-term memory and they find it very difficult to work efficiently with representations.

It was found that students with communication difficulties respond better to alternative representations (Bird, 1999). Under this perspective, our work aims to describe how teaching paradigms may be developed targeting the breakdown of mathematical concepts to their essential quantitive components in order to aid the teaching process.

Figure 1: Addition of "2 + 1" represented graphically

An example is used to visually demonstrate an alternative geometrical representation of a mathematical notion. When adding two different physical measures in order to compute their sum, this is completed using the symbols "1+2" which represent the addition of a basic measure with another twice as large as the initial measure. An alternative method to display this geometrically is to use a sequence of one and two units, in an attempt to create the sum of three, as shown below in Figure 1. The image is built successively, introducing the separate elements 2 and 1, then the "sum operator" is superimposed and finally the "equal sign" is revealed together with the result, completing the presentation of the concept. In the following section we identify the number and variable complexity of examples in order to demonstrate the use of the methodology in action.

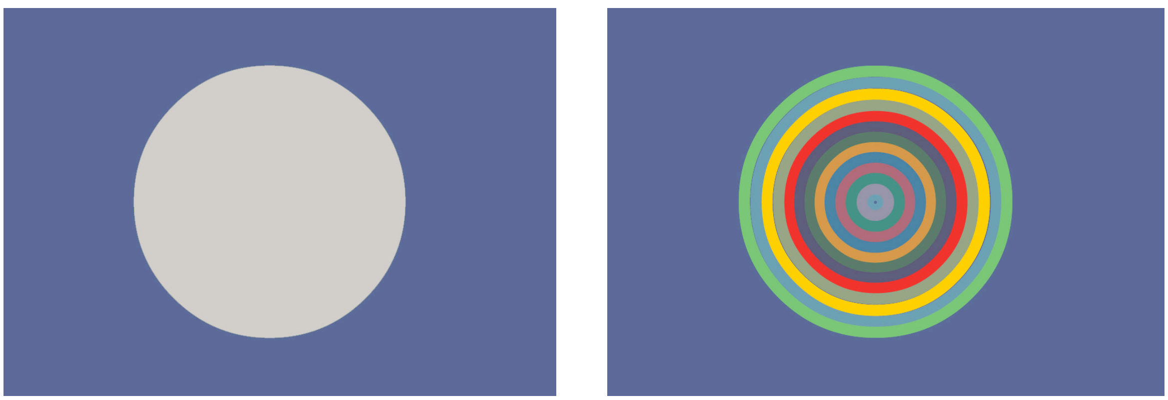
An example is used to visually demonstrate an alternative geometrical representation of a mathematical concept. Our methodology is based on the theory of G. Cuisenaire who together with the mathematician C. Categgno developed in the 1950's the manual version of the method involving 241 coloured rods which represent different lengths, from 1 to 10. We have applied this theory to more complicated examples and concepts through interactive multimedia. One characteristic and complex example is the geometrical calculation of the area of a circle described below, as now with the use of vector-based graphics and animation we are able to create virtual representations and visualisations that in reality may not be easily implemented using traditional rods.

"Adobe Flash CS3" software was used as the underlying programming environment for all the examples described in this work. This results to individual learning units featuring full Internet accessibility and functionality through Shockwave technology. A possible extension involves their organisation under a web-based e-Learning structure, enabling students to access the content from schools or their personal computers at their own time.

Case Study: Geometrical Calculation of the Area of a Circle

In order to describe and practically test our argument, we have developed a series of interactive multimedia exercises and examples, using animation, graphics and programmed behaviors. These are pictorially presented in this paper, yet in practice they are part of a full audiovisual environment complete with instructions, rules, freedom to experiment and rewards when each exercise is completed successfully. Demonstration of these concepts has been found to be more interesting even for advanced-level students as it presents alternative yet mathematically valid representation of the same concept. The first and most complex example involves the calculation of the area of a circle. First a circle is drawn which is subsequently separated into coloured bands as shown on Figure 2.

Figure 2: Calculating the area of a circle



The next step involves the deformation of bands into stripes, which are then horizontally stacked into a triangle, as shown in Figure 3. The animation process creates all the intermediate frames, resulting in a smooth visual result. Special care is given in the selection of the colour palette, to care for visual disabilities that may prevent students from differentiating the various layers.

Figure 3: Calculating the area of a circle

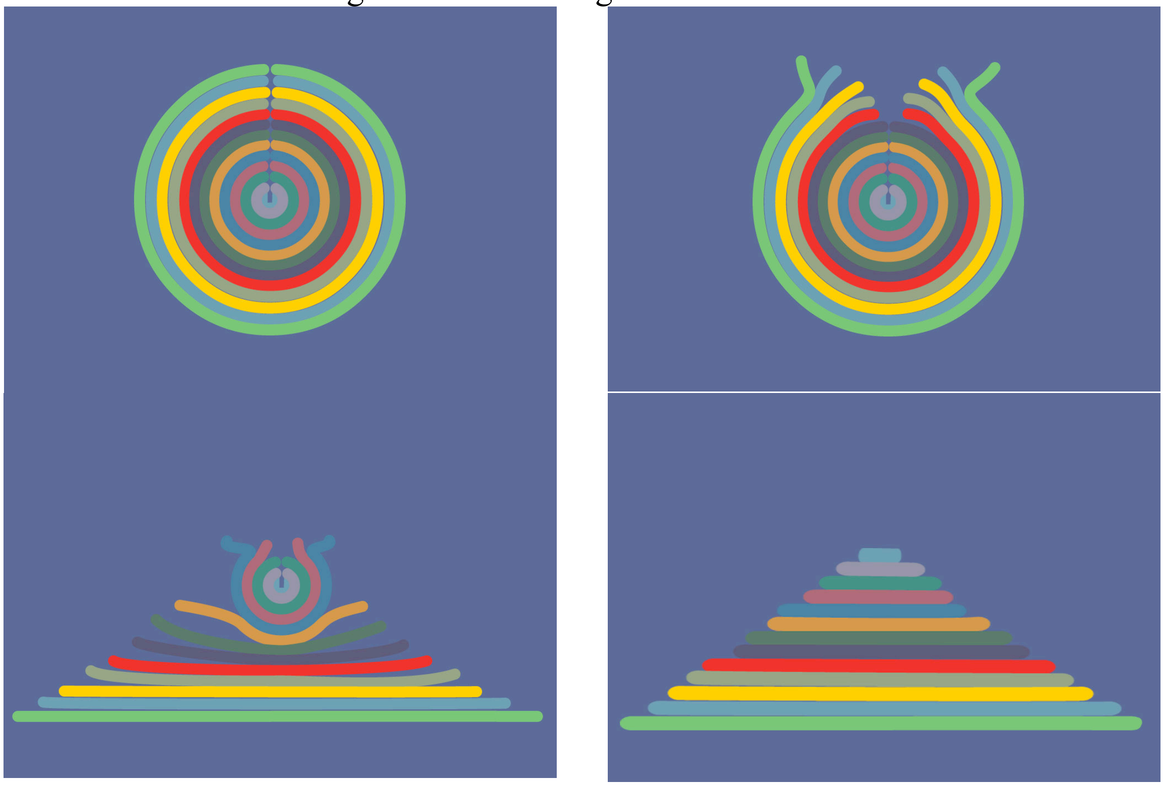
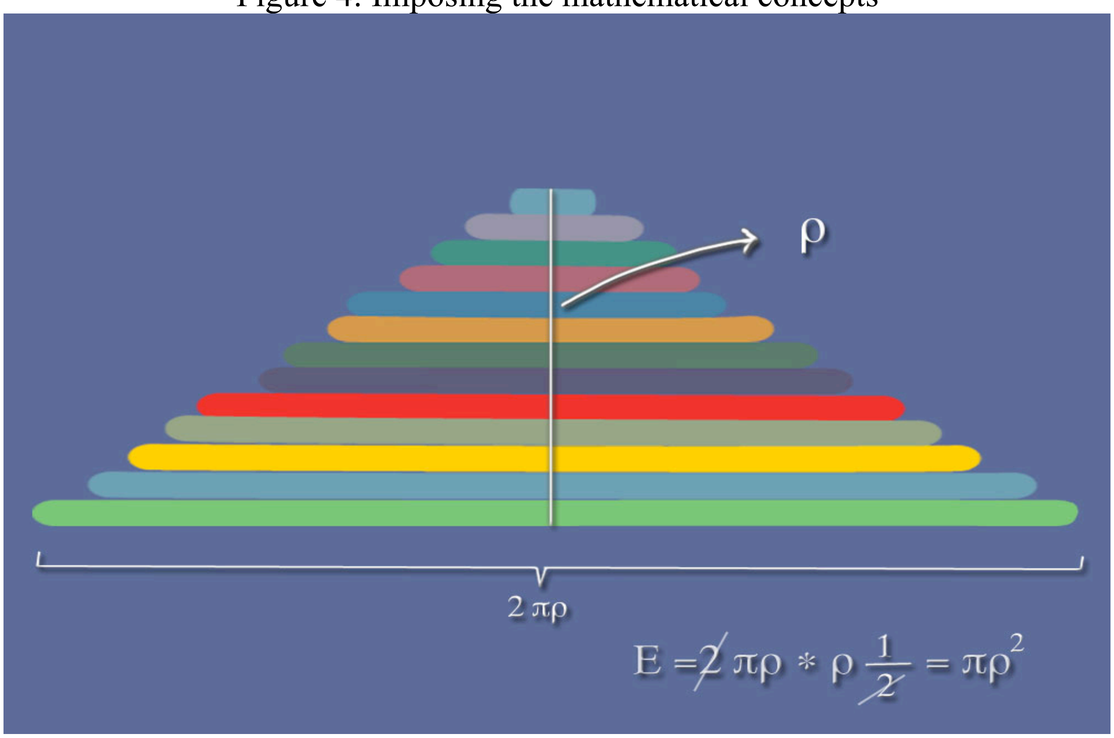


Figure 4: Imposing the mathematical concepts

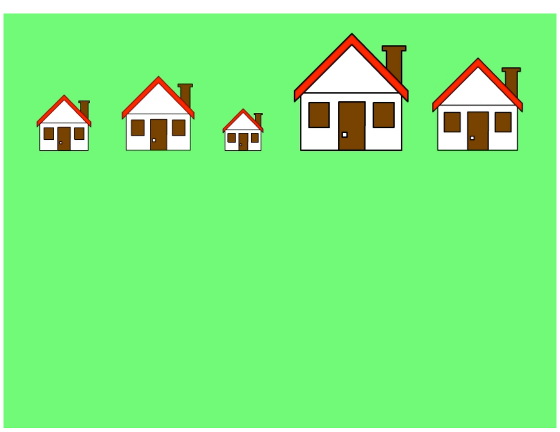


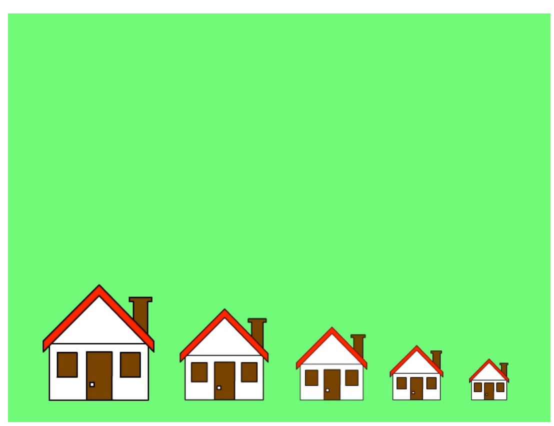
The process is completed at the next stage where the mathematical concepts are imposed, as shown in Figure 4, enabling students to appreciate the geometrical aspect of the deformation and the equation used to calculate the area. Appropriate measures such as $2\pi\rho$ and ρ are superimposed on the triangle to enable thorough understanding of the equation. The area of the triangle is presented as an approximation based on the original circle shape, via the animation, enabling students to appreciate the concepts of circle-to-triangle transformation, its relation to other geometrical shapes and the mathematical error that is introduced in the subdivision process. This permits the same example to be used as a simulation tool, in order to describe the true meaning of error and its proportionality to the number of sub-divisions. More subdivisions may be employed to reduce the error introduced in the process. Note here that the presentation may be set to run using different parameters as far as level of circle subdivision is concerned. The fact that vector graphics are used in the animation procedure enables the user to zoom-in on the edges of the triangle in order to observe the “staircase effect” that may range from clearly evident with few subdivisions to almost invisible when they are increased.

Case Study: Sorting

Sorting a series of objects according to comparable characteristics is not necessarily a matter that requires the use of numbers. Under this case study we utilise a series of house icons with different attributes, each may be displayed using different size or colour. The objective involves placement of these objects in size, smaller to larger and the opposite, or colour order. As shown in Figure 5 and for the size example, the user begins with five freely moving objects that have to be placed in appropriate free positions.

Figure 5: Sorting example using objects of different sizes



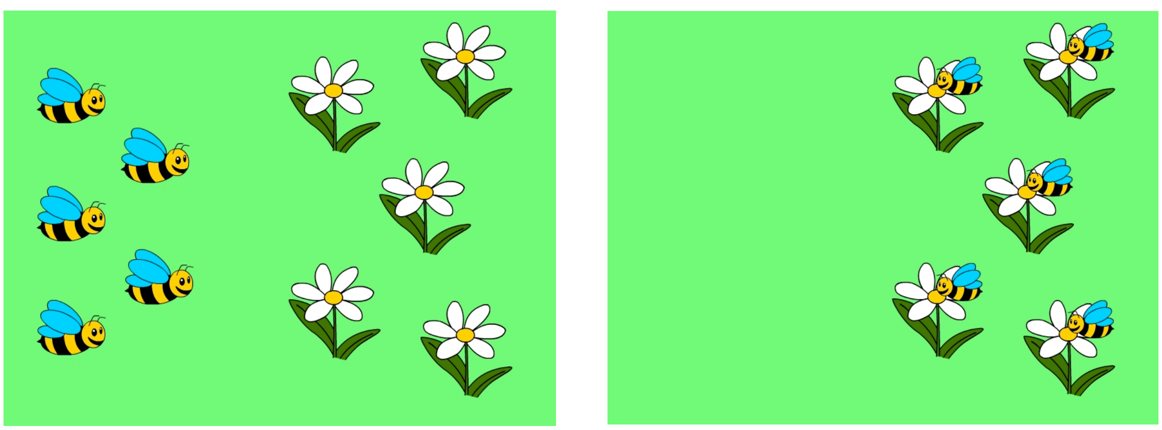


All case studies are accessible through a web-interface. User-profile information provided at the initial registration stages is used to select the appropriate range of examples from the central multimedia database. Principal factors of the selection process are the specific user requirements and minimum system-capabilities, instructing the presentation system to use appropriate video, audio or text information relevant to the learning task. If the user finds it difficult to complete the assignment within the designated time, then the correct setting is displayed for a few seconds, and the user is then instructed to continue. Upon correct placement, the user is rewarded.

Case Study: One to One Representation

In order to describe the one to one representation a series of flowers and animated bees is employed. The user is instructed to place each bee over a flower. When all bees are placed on all flowers the task is completed. A movement algorithm is used for the bees, which creates a random motion path. Sound is also used to attract the user's attention.

Figure 6: One to one representation

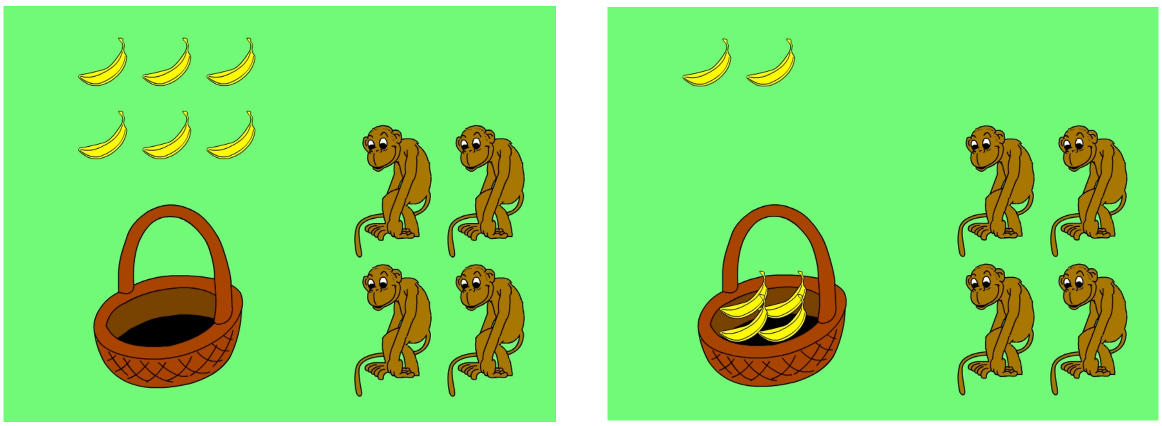


The use of a touch-screen and displaying the case studies in full-screen with speakers and on-line instructions have proved to act as an attractor to students who often compete and take turns to use the system. Figure 6 displays the visual setting of this action before and after the task is completed. The use of binaural audio added more realism in the presentation environment (Tsakostas, Floros, & Deliyiannis, 2007).

Case Study: Grouping

In this case study the objective is to demonstrate grouping of different objects in the same quantities. Two sets exist on screen, 6 bananas and 4 monkeys, which have to be connected. When each monkey possesses one banana the task is complete. Figure 7 presents the setting of this action.

Figure 7: Grouping

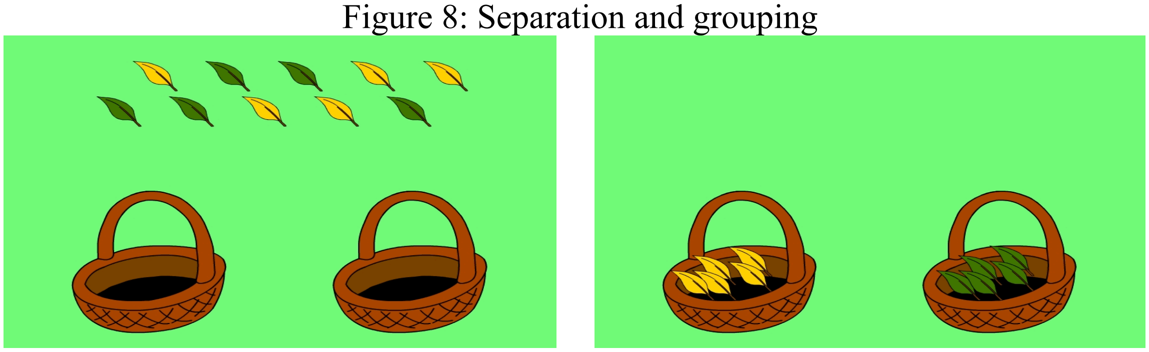


Case Study: Separation and Grouping

Separating two groups according to their particular characteristics is the objective of this action. Figure 8 depicts ten leaves separated into five yellow and five green, which have to be placed in different baskets. The student can place all leaves in the baskets but the task is only completed when the separation is performed appropriately.

The realisation of the above series of examples has introduced the need for standardisation of the production process. This is necessary for various reasons, both functional and aesthetic. Starting from cultural issues, it is important for the developer to study the profile and cultural background of the students, in order for the teaching representation to be successful. In other words, the environment has to utilise recognisable representations, in order for the user to be concentrated on the task in hand and not on interface learning.

Figure 8: Separation and grouping



Standardisation for Courseware Development

In order to design new actions, one has to clearly identify the learning objective. For each objective there are various complementary tasks and alternative approaches that need to be selected according to the technological proficiency of the students. For example, a young student that has never used a mouse before may be discouraged by the difficulty of using this particular pointing device. A suggested solution to this problem is the use of touch-screen, which permits a hands-on approach to be implemented.

The above have resulted in the development of a standardisation document in the form of “guidelines” that specifies both technical and aesthetical capabilities, constraints and conventions. Its purpose is to present the findings and observations that were collected throughout the development of this project, and provide alternative solutions to practical problems in the development of new case-studies and learning units.

Conclusion

Interested parties may further extend the functionality of existing paradigms, according to specific user needs. This development is necessary for further use and adoption of the methodology (Heikki, 2001). As mentioned in the introduction, the same base components may be used as the basis for the development of new examples, which may then be shared as fully functional units over the Internet. The vector-based nature of the implementation enables each learning unit to be used in a variety of devices such as mobile devices, permitting further platform integrations to be realised. The methodology discussed is not system-specific, permitting a wide array of multimedia authoring tools and game environments to be employed for further courseware development.

Interactive multimedia is clearly the tool for the development of courseware, as these technologies allow user-immersion and increased interest. The overall observation of the learning process has revealed that students are keen to utilise interactive multimedia learning examples. Particular attention is required in the planning stages as the particular needs and capabilities of students need to be taken into consideration.

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