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The Effectiveness of Kinesthetic Approach in Developing Mathematical Function Graphs Recognition and Understanding at University Level

Mohamed El-Demerdash[1, 2], Pedro Lealdino Filho[1], Christian Mercat[1]

[1]S2HEP EA4148 Université Claude Bernard, Lyon 1 (France), [2]Menoufia University (Egypt)

Corresponding author e-mail: m_eldemerdash70@yahoo.com

Abstract

This research paper investigates our belief as educators that kinesthetic approach can be used to develop students' recognition and understanding of mathematical function graphs with the help of a competitive dancing game.

Given that some students need to use other senses as a preparation to abstract and symbolic thinking, we developed ***Augmented Reality kinesthetic digital resources*** *around standard mathematical function graphs using Microsoft Kinect sensor and some programming of Unity 3D Development Kit, Microsoft Kinect (SDK) - Software Development Kit - and CindyScript the programming language associated with Cinderella - Dynamic Geometry Software, linked through a UDP (User Datagram Protocol) connection. The software recognizes students' body gestures as input representations for mathematical function graphs.*

Aiming at verifying the resources effectiveness in developing recognition and understanding of mathematical function graphs, a quasi-experimental design, a pre-experimental one group (pretest - intervention - posttest), is considered. The test consists of 40 items that are equally distributed among the two levels of achievement: recognition and understanding. 20 items are designed at each level in isomorphic pairs that are administered randomly as whether pretest or posttest. The items type for the test are multi-choice questions of 4 choices. The test items were written in verbal and nonverbal, symbolic and graphical ways.

The setting of the experimental study was at CFAI Savoie Chambéry - a training college for careers in industry for young people - with 51 students of the first year of BTS Maintenance of Systems and BTS Technical Assistance engineers.

The quantitative data collected through the pre and post test does not allow us to draw a clear conclusion on the effectiveness of using the kinesthetics resources in developing students' recognition and understanding as the means difference was negative. However, the reason of that is not related to the data itself but on how it was collected. On the other hand, the qualitative data gathered from the students and their teacher shows that the resources were very engaging and pleased students as they played. The results are not conclusive, the experimentation needs to be repeated in a context where the didactical contract ensures the

motivation for the post test in order to investigate the resources effectiveness in terms of both recognition and understanding.

Introduction

The emergence of motion-controlled technologies within the increasing usage of embodied cognition and augmented reality environments opens new doors for students to use their different senses into the learning process (Mercat, 2015). The goal besides making them more motivated to pay attention to the information presented and better retain the information (Tsai & Yen, 2013) is to let students experience an alternative way to build concepts.

The concept of function is unifying idea in mathematics. It plays an important role throughout mathematics curriculum (NCTM, 2000). Like many concepts in mathematics, developing a thorough understanding of mathematical functions is challenging for many students (Clement, 2001). Students have learning difficulties with mathematical functions include operations with functions and recognizing functions in different context.

Tall and Viner (1981) identified some difficulties that students faced while using graphical methods on functions. Aspinwall, Shaw and Presmeg (1997) asserted that in many cases the graphical representations can cause cognitive difficulties, because the perceptual analysis and synthesis of mathematical information presented implicitly in a diagram often makes greater demands on a student that any other aspect of a problem. For students to develop a holistic understanding of the concept of mathematical functions, they have to be able to identify the connection elements of a functional dependency and to combine these (Nitsch et al., 2014). The ability to translate between various functional representations is essential for this purpose (Ainsworth, Bibby & Wood, 2002; Seufert, 2003).

Method and Procedures

The Development of Kinesthetic Digital Resources

In order to get kinesthetic feedback from the students, we used the Microsoft Kinect sensor and some programming, using Unity 3D Development Kit, Microsoft Kinect (SDK) - Software Development Kit - and CindyScript the programming language associated with Cinderella - Dynamic Geometry Software, linked through a UDP (User Datagram Protocol) connexion. The software recognizes students' body gestures as input representations for mathematical function graphs. As shown in the Figure (1), Cinderella software plots two function graphs, the red one

corresponds to body gestures, and the green one corresponds to the goal graph which the student should perform to obtain the positive score during the game. On the left side of the figure above we show Cinderella plotting the functions in accordance with what the player (right side) is performing in front of Kinect sensor.

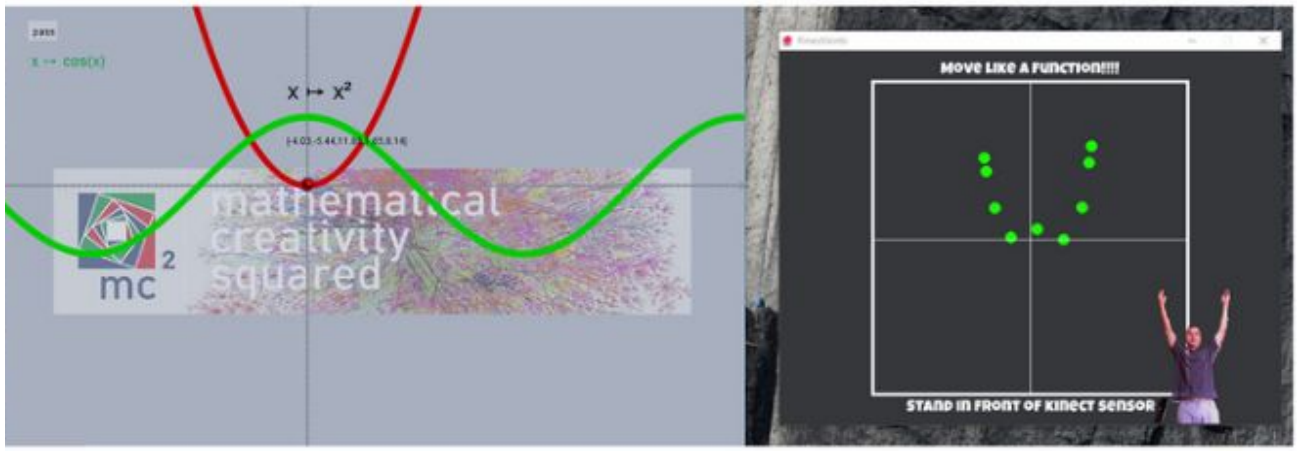
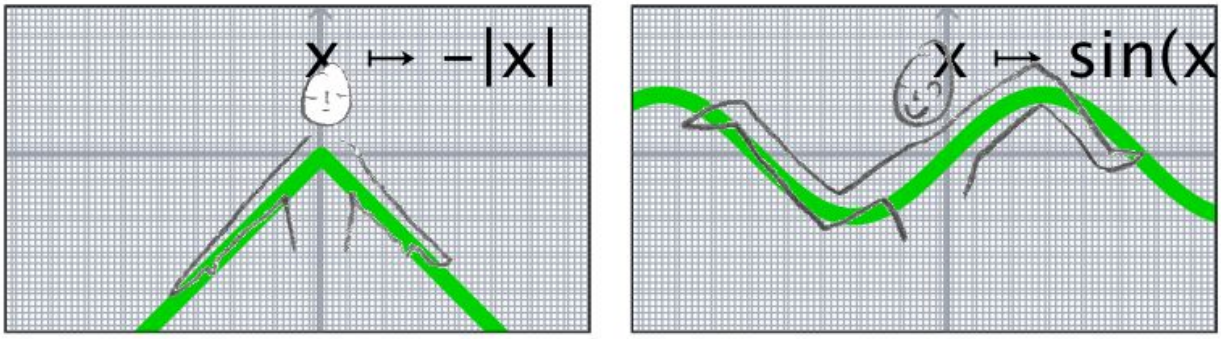


Figure (1): Cinderella plots the function graph in accordance to body gesture detected by the Kinect sensor.

The developed kinesthetic digital resources include a wide range of mathematical functions: Constant function, linear function, quadratic function, cubic function, absolute value function, fractional function, trigonometric functions, exponential function, logarithm function.

In order to provide students with different ways to perceive mathematical function graphs, Three main modes of games were considered using embodied motion as a fundamental strategy in designing these resources:

- **An exploratory game mode:** Where a list of functions was entered and the body gestures allowed to identify the closest function in the list matching the points and the derivatives defined by the eight points (left and right arm, wrist, elbow, shoulder). The player can be given a task to perform, in the form of a paper card such as in Figure (2).



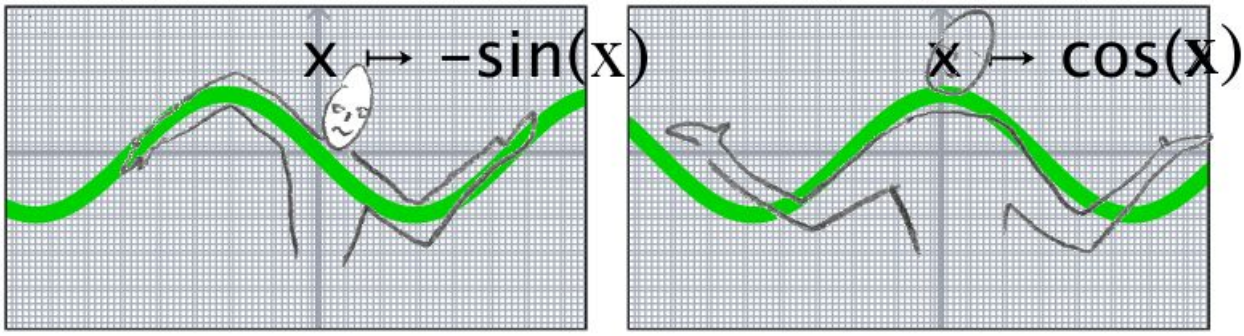


Figure (2): Matching body gestures to some mathematical function graphs.

- **A choreographic game mode:** Where a predefined list of about six functions is given to students and a score is computed for each function, according to the distance between the eight control points and the graph, and according to the comparison of the slope of the joint and the derivative of the function. An overall score is assigned to each player after three rounds of repetition.
- **A dance battle mode** where players team together in order to setup their own elaborated choreography by writing down a set of functions themselves. Then each team compare their own achievement on each choreography with the score of the other group.

The Development of Achievement Test

Since the purpose of the present study is to develop students' recognition and understanding of mathematical function graphs, we designed an achievement test[1], that can be used in assessing students' performances before and after administering the prepared kinesthetics digital resources.

Table (1) shows the test specification in terms of mathematical function types that covered in the prepared kinesthetic resources with respect to recognition and understanding levels of mathematical achievement. The test consists of 40 items that are equally distributed among the two levels of achievement: recognition and understanding. 20 items are designed at each level in isomorphic pairs that will be administered randomly as whether pretest or posttest.

The items type for the test are multi-choice questions of 4 choices to eliminate the guessing issues from the students' side. The test items were written in verbal and nonverbal, symbolic and graphical ways.

The total score of this test is set to be (40) marks. One point mark is given to each correct item response.

[1] It is available as a download from: https://dl.dropboxusercontent.com/u/5761672/AchievementTest.pdf

Table (1): Specification of the Achievement Test

Achievement Level	Recognition		Understanding		Sum	%
Function Type	**No. of Items**	**Items Numbers**	**No. of Items**	**Items Numbers**		
Constant function	2	11, 12	2	23, 30	4	10%
Linear function	2	9, 10	2	21, 24	4	10%
Quadratic function	2	1, 15	2	27, 37	4	10%
Cubic function	2	2, 16	2	28, 38	4	10%
Square root function	2	3, 6	2	32, 36	4	10%
Absolute value function	2	17, 18	2	29, 35	4	10%
Fractional function	2	7, 8	2	22, 31	4	10%
Trigonometric function	2	19, 20	2	39, 40	4	10%
Exponential function	2	4, 13	2	25, 34	4	10%
Logarithm function	2	5, 14	2	26, 33	4	10%
Sum	**20**		**20**		**40**	
%	**50%**		**50%**			**100%**

Procedure of Experimental Study

Subjects

The setting for the experimental study was at CFAI Savoie Chambéry (http://www.pole-formation-savoie.fr). CFAI is a college training for careers in industry for young people, employees and companies. The CFAI (Apprentice Training Centre of Industry) and AFPI ASP (Association for Vocational Training in Industry) Savoie offer quality training to industrial trades. The enrollment of this college is approximately 280 students. The sample of the study were 51 students of the first year of BTS Maintenance of Systems and BTS Technical Assistance engineers.

Experimental Design

As for the experimental design of the study, the pre-experimental one-group (pretest – intervention – posttest) design was used to investigate the effectiveness of the prepared kinesthetics digital materials in developing the students' achievement of mathematical function graphs.

Before the intervention

Before starting the experimental study, the researchers prepared two computers connected with two Microsoft Kinect sensors in order to get kinesthetic feedback from the students. Cinderella and Unity 3D Development Kit are also installed so that the software recognizes students' body gestures as input representations for mathematical function graphs.

Finally, and more importantly, the researchers met with the subjects of the study explaining to them the aims, the nature of the study, what is required from them during the study (Starting from the pretest, going through administering dancing as a function hero game, and ending with the posttest) and what is expected from them by the end of the study.

Administering the Pretest

The pretest was administered to the study subjects as a pretest at the beginning of the experimental study to assess their achievement of mathematical function graphs. The subjects were informed that the duration of the pretest is ten minutes.

Administering "Function Hero" Game - Intervention

The class was divided into two groups according to their side in the classroom (left or right). At first, as a warm up, two different sets of functions were used and each group was subjected to a given set then to the other one. Each student got a score according to his performance. This took about half an hour.

Then, the researchers let the student edit the choreography and enter the functions of their choice. This took more time than anticipated because of some technical issues. We had to clarify some syntax issues as well, for example the system needs the * sign between operands of a multiplication, which is usually implicit. Students used their handheld calculators in order to propose functions to their group. They tried to enter complicated functions that the other team would not know or would not be able to "dance". But it appeared to be complicated and difficult to them as well, so most of them went back to elaborations of simpler functions.

After half an hour, students began the battle, a first team presenting their own choreography first, the second team then trying to get comparable scores. The process of selecting functions and dancing in battle mode was repeated the day after. A comparison of the scores for the two teams elected a winner team and an overall winner of the game. Small prices were then distributed.

Administering the Posttest

The recognition posttest was administered to the study subjects as a posttest at the end of experimental study to assess their achievement on mathematical function graphs after administering the Hero Function game. The subjects were also informed that the duration of the posttest was ten minutes. We should have waited for the completion of the post-test before giving away the prices because the students lost interest and were eager to stop and leave the school therefore they admitted to have rushed the posttest.

Researchers' Notes During the Experimentation

The students tested during this experimentation are in a technical school. They are not particularly interested in maths, but the playfulness of the activity proposed engaged them in the action, even very weak students, usually very passive, tried to play and they all enjoyed the game. These students have generally difficulties with abstraction, they are not used to create mental representations. The challenge has stimulated their curiosity, they explored new representations and they were happy to discover their algebraic expressions, according to one of their teacher. Moreover, they were not that interested in the post test because they had their break just one or two minutes before this test, they were hurry to go out. Then, they confessed that they didn't actually care of their answers, hence the results of the post test didn't bring anything to the fore.

The students began to use their hand-held calculator in order to graph functions. The most bizarre were tried, for example sin(x^2). But actually trying to get a high score on these deterred them from using them in the choreography. They fell back to simpler functions and whereas the two groups were subjected to different warm-up functions (circular for one, polynomial for the other), some of their findings were common. During the practice, they nicknamed some of the functions, for example "sinus, that's the Egyptian" for the sine function because they had to turn sideway in order to bend their arms in the right concavity.

The students were overall very motivated by the experimentation but not at all by the post-test, which was performed once the prizes were distributed. This was clearly a mistake because they were eager to adjourn for recess and didn't pay attention to the post-test. The data is therefore not usable as it is.

Results

Results of the Pretest

Table (2) shows students' performance on the pretest on terms of mean and Standard Deviation (SD).

Table (2): Results of Pretest

Number of students	Mean (M)	SD
22	6.62	2.26

Results of the Posttest

Table (3) shows students' performance on the posttest on terms of mean and Standard Deviation (SD).

Table (3): Results of Posttest

Number of students	Mean (M)	SD
22	4.48	1.83

Results of the Pre-Post Results

Table (4) shows the statistical analysis results of the pre-post measurements of students' performance.

Table (4): Pre-Post Tests Results

	Mean	SD	Mean difference	Significance Level
Pretest	6.62	2.26	-3.94	0.05
Posttest	4.48	1.83		

The quantitative data collected through the pre and post test doesn't allow us to make conclusions about the question on recognizing functions. Therefore, based on these data analysis, we should

conclude that they unlearnt what they knew, which is clearly not true, moreover students engagement does not show in their achievement in terms of learning gains. The reason for that situation is related to the way data was collected.

Conclusion

We cannot conclude that there was difference in terms of learning gains based on the pretest and posttest because the experimentation was not sufficient. A new experimental protocol is being considered in order to investigate resources effectiveness in terms of both recognition and understanding. Nevertheless the motivation was extremely high in students, which is an achievement in itself and we will attempt to measure this in further research.

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