MATHEMATICS EDUCATION REINFORCED THROUGH INNOVATIVE LEARNING PROCESSES

Michela Tramonti

Institute of Mathematics and Informatics – Bulgarian Academy of Science (BULGARIA)
European Training and Research Association for a Cooperation Key to business – EU Track (ITALY)

Abstract

Nowadays, society becomes more and more based on ICT and advanced technologies. As a consequence, the need for experts with a scientific and technology background is constantly increasing. Nevertheless, according to the latest studies the interest and motivation towards science is decreasing among students and consequently their interest in careers based on science and technology is decreasing as well. Mostly, it is caused by the fact that some teachers still use traditional teaching and learning methods even for an up-to-date curriculum for their science teaching.

The current situation is confirmed also by the results achieved by the worldwide surveys, such as Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). They show that, especially, European students often lack mathematical competences and key basic competences in science and technology. In fact often their scores are below the Organisation for Economic Co-operation and Development average (OECD) average while the best performances are achieved by Asian countries.

In this context, starting from the analysis of the state-of-the-art of the current learning processes used, this paper aims to describe an innovative learning and teaching approach, currently in the development phase, regarding the mathematics education for 14-16 years old students.

The innovative learning and teaching approach, to be developed, will exploit new potentialities emerging from a complex combination of the current approaches used in Europe and the Asian one, in particular the Singapore's method based on three phases, concrete-pictorial-abstract.

Moreover, this learning approach will converge, further, on the discovery from the students of the challenging connections between math and reality, especially through the use of the artworks, such painting, music, dance, theatre and on the strengthening of learning process through the use of emerging technologies.

As a result, this innovative combination will allow to create and develop a more effective educational environment for teachers and students by guaranteeing an active involvement and a creative inclusion of learners to let them test the interconnection of different languages, such as visual, sensory, verbal and nonverbal. This will favor, from one side, the development of both cognitive and emotional dimensions by promoting even an intercultural approach. From the other one, they will be able to benefit from the use of more attractive and fun pedagogical tools, in particular, in the study of mathematics sometimes considered difficult.

Keywords: Mathematics education, learning by doing, inquiry-based learning, arts, technology-enhanced learning.

1 INTRODUCTION

On the base of the initiative “Grand Coalition for Digital Jobs” launched in 2013 by European Commission to favour the rapid development in ICT sector in collaboration with enterprises, public authorities and training organizations aims at encouraging the implementation of concrete actions to increase professionals by improving digital competences [1] to lead the knowledge economy towards a new Europe in smart, inclusive and sustainable way [2]. However, the statistic data show over 16M low skilled jobs are expected to be lost because of an economy increasingly requires high skills and an received non-adequate education in digital skills in-line with job needs.

On the other hand there are other international challenges, such as globalization, resource exploitation and human aging which Europe should face. In this context, research, development, education and

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skills are the keys words for Europe of the 21st century despite the obvious national and international barriers that limit the development and strengthening of the European Research.

Among causes can be found the decreasing of interest in careers based in science and technology as consequence of the decreasing motivation of young students towards any scientific subject. These data are well-shown by results emerged from international and national surveys, such as Program for International Student Assessment (PISA) [3] and Trends in International Mathematics and science Study (TIMSS) [4].

Indeed, concerning the last PISA survey realized in 2015, the mean scores achieved for mathematics are below the OECD average, even if in Italy the pupils performance has reached the OECD average (490) in math, but at the 34° place in the complete classification, as shown in the Figure n.1:

	Mathematics	
	Mean score in PISA 2015	Average three-year trend
	Mean	Score dif.
OECD average	490	-1
Singapore	564	1
Japan	532	1
Estonia	520	2
Chinese Taipei	542	0
Finland	511	-10
Macao (China)	544	5
Canada	516	-4
Viet Nam	495	-17
Hong Kong (China)	548	1
B-S-J-G (China)	531	m
Korea	524	-3
New Zealand	495	-8
Slovenia	510	2
Australia	494	-8
United Kingdom	492	-1
Germany	506	2
Netherlands	512	-6
Switzerland	521	-1
Ireland	504	0
Belgium	507	-5
Denmark	511	-2
Poland	504	5
Portugal	492	7
Norway	502	1
United States	470	-2
Austria	497	-2
France	493	-4
Sweden	494	-5
Czech Republic	492	-6
Spain	486	1
Latvia	482	0
Russia	494	6
Italy	490	7

Figure 1. OECD processing based on database PISA 2015.

However, these collected data show that the Asian countries are placed at the best positions of the ranking such as Singapore, Chinese Taipei, Macao (China), Republic of Korea as follows:

1° Singapore	564
2° Chinese Taipei	542
3° Macao (China)	544
...	...
34° Italy	490

Figure 2. OECD PISA 2015 - Performance in mathematics, reading and science.

1° Singapore	621
2° Korea, Rep. of	606
3° Chinese Taipei	599
...	...
19° Italy	494

Figure 3. IEA's TIMSS 2015 - Distribution of Mathematics Achievement (Grade 8)

Most of these differences is caused by the fact that some teachers still use traditional teaching and learning methods even for an up-to-date curriculum for their science teaching based on:

1 contents mastery, the discipline and knowledge and on the completeness of the message communicated,
2 learning deductive mode,
3 teacher-centered.

In this context, the research project proposal aims to investigate new strategies for math teaching and learning and to analyze how the combination between meaningful learning and mastery learning can stimulate motivation and interest in young students for the study mathematics and to obtain a relevant improvement of their final performance.

2 RESEARCH METHODOLOGY

Considering the best performances achieved by Asian countries through the international mathematics surveys, this research project will proceed with the analysis of the Western and Eastern learning and teaching approaches in order to underline their strengths and weaknesses. In particular, for the Asian side, the learning/teaching approach investigated is Singapore's method spread already in countries like USA, Australia and England and for a few years also in Europe.

The research is focused, mainly, on the combination of the mathematics approaches set in Western and the Singapore's method characterized by the use of visual and model-drawing strategies which underline mathematics and word problems and leave out the memorization occurring through repetitive exercises [5]. This approach consists in the introduction of mathematical concepts through three phases process: concrete, pictorial and abstract. This means using a symbolic representation to ensure that the concrete mathematical experience allow students to reach an abstract representation [6].

The theoretical framework referred to this research work is developed on the base of the theory of didactical situations in mathematics exposed by Guy Brousseau [7] aiming to define the conditions in which a "learner" is led to "do" mathematics, how to use it and how to invent it. He identifies three types of situations: a-didactical, non-didactical and didactical.

The first one, "a-didactical", refers to the context containing all the conditions which allow students to establish a relationship with a specific knowledge. The second one, non-didactical, is the not-organized context in which students can learn specific knowledge. Finally, the third one, didactical, is the situation in which all the activities are well-organized and designed by teachers. It is an example the tasks to be carried out in a typical lesson in a classroom [7].

However, these three situations can be imagined like interaction systems between one or more subjects with a "milieu" that is a context or means. In order to synthesize the different situations occurring, the Author refers to *Polygons of didactics* with the introduction of this crucial element, the "milieu", as shown in the following figure:

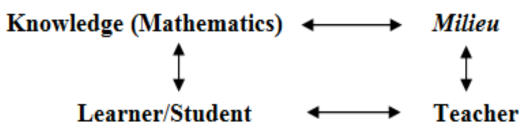

Figure 4. The didactical quadrangle of Guy Brousseau.

The "milieu" in the research model will be represented by the art which will be the "context" to reach knowledge and the fundamental element to combine the Western and Eastern approaches.

2.1 Arts as unifying element

The arts help students connect better scientific subjects and reality, and in particular, between mathematics and arts, such as music, painting, dance, theatre rediscovering their usefulness and their application in everyday life. Therefore, the learners become active in their learning process by constructing own knowledge in "meaningful" context through the objects manipulation, tools and through the observation and interpretation of their actions' results. In these terms the meaningful learning gets contextualized and complex. The students learn more and better if they cope with authentic tasks directly connected to the real world, where they met their everyday lives' "real problem". The same thing occurs when student approaches to mathematics studies. Actually, people often forget that reality as well as all disciplines known by man are based on mathematical concepts: math is in human being, in architecture, plants and animals, and as part of them it regulates also their characteristics.

With the introduction of the Fibonacci series [8], made by the Medieval great mathematician Leonardo da Pisa, it is possible to observe how the growth of flowers, leaves and branches of a plant follows specific patterns. In crystals [9], the symmetry elements regulate the arrangement of the various faces and of the various edges, so that there are determinate to form solid systems, for example the cubic form in the minerals such as halite or trigonal form in the dolomite.

Despite this strong presence of mathematics concepts in the reality, their connection doesn't appear so evident during the learning process and often teachers offer to students a too theoretical approach causing the perception that maths is abstract and far away from everyday life. This can influence the way to learn the maths privileging more storage capacity than problem solving skills [10].

3 TOWARDS IMPLEMENTATION OF THE COMBINING MODEL IN A LEARNING PROCESS

The new model achieved allow students to develop and improve their mathematics knowledge through the use of the specific art-works, which will help them, in turn, develop systems reasoning based on applicable knowledge, imagination, creativity and problem solving skills by dealing with mathematics problem with variations. This means that even if the mathematics formula/concept to be studied remains constant, the background/the contest or, in this case, the art-work referring to them will be changeable context in which students will approach and to learn in depth the mathematics concepts.

Moreover, with the introduction of the arts works students will proceed through the three phases of the Singapore's method. In the concrete phase of the proposed method, students will learn and familiarize with tools and modalities useful to construct specific objects such as a dodecahedron.

In the pictorial phase, they will learn how to recognize math in the art exploiting the potentialities to work in group and in individual study. For example, they will be asked to find the art works containing dodecahedron form, such as "The Portrait of Luca Pacioli" of Jacopo de' Barbari (around 1500).

Figure 5. "The Portrait of Luca Pacioli" of Jacopo de' Barbari

Finally, they will create their art work, using their creativity, started from the mathematics formula studied. In addition, in order to make the learning process more effective, the technology of modelling programs for the objects creation and of 3D virtual environments will be used during the whole phases [11].

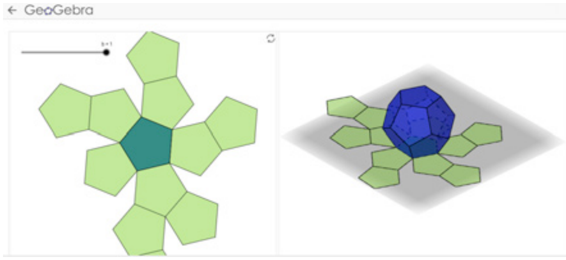

Figure 6. Visual Modelling Programming in 3D – Geogebra

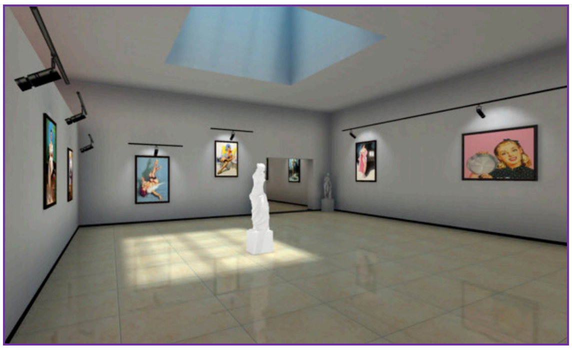

Figure 7. An example of 3D virtual environment using Unity 3D [7].

4 CONCLUSIONS

The result of this innovative combination will favor the creation and the development of a more effective learning environment for teachers and students by ensuring an active involvement of learners through the use of different languages, such as visual, sensory, verbal and nonverbal. This will encourage the student development of both cognitive and emotional dimensions by promoting even an intercultural approach. In addition, with the use of the art work, they will benefit from the testing of more attractive and fun pedagogical tools, in particular, in the study of mathematics sometimes considered difficult and boring.

REFERENCES

[1] European Commission, “The Secretariat of the Grand Coalition for Digital Jobs – Final Report,” March 2016. Retrieved May 08, 2017 from URL http://cordis.europa.eu/docs/projects/cnect/5/620985/080/reports/001 Finalreportforpublicationfinal.pdf

[2] European Commission Communication, "Europe 2020 – A strategy for smart, sustainable and inclusive growth, Brussels, 3.3.2010.

[3] OECD, “PISA 2015 Results in Focus, OECD, 2016. Retrieved May 08, 2017, from https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

[4] Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M., “TIMSS 2015 International Results in Mathematics”, Retrieved from Boston College, TIMSS & PIRLS International Study Center, 2016. Retrieved May 08, 2017, from http://timssandpirls.bc.edu/timss2015/international-results/

[5] Sami F., “The Singapore system: An example of how the US can improve its mathematics education system, in MathATATYC Educator, n. Issue 3(2), pp.9-10, 2012.

[6] Witzel B.S., Riccomini P.J., Schneider E., “Implementating CRA with secondary students with learning disabilities in mathematics, in Interventation in School and Clinic, n. Issue 43(5), pp. 270-276, 2008.

[7] Brousseau G., "Theory of Didactical Situations in Mathematics – Didactique des Mathématiques 1970-1990", Kliuwer Academic Publishers, New York, 2002.

[8] Posamentier A., Lehmann I., “I (favolosi) numeri di Fibonacci”, Monte San Pietro, Muzzio, 2010.

[9] Gallo P., Vezzani C., “Mondi nel mondo. Fra gioco e matematica”, Mimesis, 2007.

[10] Tramonti L., Tramonti M., “Enhancing STEM skills through the Art”, "The Future of Education" Conference 2017 - Conference Proceedings to be published.

[11] Zheleva M., Tramonti M., “Use of the Virtual World for Educational Purposes”, in Electronic Journal for Computer Science and Communications, n. Issue 4(2), Burgas Free University, pp. 106-125, 2015.

[12] *Museum of Art 3D* produced with Unity 3D. Picture extracted from the video at link https://www.youtube.com/watch?v=Eg2be8gfGrU.