TECHNOLOGY AND ART TO IMPROVE MATHEMATICS LEARNING

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Abstract

The technology is rapidly changing our world, especially the labor market. Consequently, education has to deal with other challenges provoking a re-conceptualization of teaching processes in order to enhance and amplify the learning achievements. On the other hand, the performance results in mathematics achieved by an essential part of European students in the international surveys, such as Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) are below the Organisation for Economic Co-operation and Development (OECD) average, against the best performances achieved by some Asian countries. This also has been demonstrated by the decreasing interest and motivation of young students in professional and research careers based on science and technology.

One of the major cause of the current situation is the resistance of some teachers towards innovative changing and their persistence in the managing of their classes with traditional teaching and learning methods. In fact, the traditional teaching approaches introduce “mathematics” as too abstract subject for students avoiding to emphasise the strict connections that are between scientific topics and reality. Therefore, students can’t see the immediate application of science to their everyday life.

This situation is intensified, firstly, by the fact that some teachers are lacking digital skills jeopardizing a real and effective integration of technology in their everyday lessons. But where teachers have a good digital literacy, they need more support on how to exploit all the learning potentialities in the use of new technological tools.

In this context, a different interdisciplinary and multidisciplinary approach is required to improve and develop science and mathematics skills and to stimulate actively students' interest in the scientific study and for their future careers. An innovative combination between the technology and arts is proposed in this research work ensuring the interconnection of different languages, such as visual, sensory, verbal and non-verbal in the mathematics study.

Although the official school curricula are not oriented to underline the existing relations between science and art, the use of painting, dance, theatre, poetry in the mathematics teaching makes science more interesting and attractive and facilitates the development of creative and complex ideas in students.

This article discusses the introduction of the technological tools and art-works on the base of the three phases, as defined in Singapore’s method applied to mathematics study, that can guide students to the discovery of the challenging connections between math and reality.

In particular, the pathway consists in the following basic steps: the objects manipulation (concrete - the first phase), the visual representation (pictorial - the second phase) and the abstract representation of the mathematical concept or formula (abstract - the third phase). In addition, the introduction and integration of technology and art-works in the whole process will allow students to reinforce their conventional, conceptual and procedural understanding based on the theory of variability.

Keywords: mathematics education, learning by doing, problem solving, inquiry-based learning, arts, technology-enhanced learning.

1 INTRODUCTION

The technology is rapidly changing our world, especially the labor market. Consequently, education has to deal with other challenges provoking a re-conceptualization of teaching processes in order to enhance and amplify the learning achievements. In this direction, European Commission has undertaken several actions to promote people’s digital skills, mainly in youth [1]. One of the example is represented by the e-skills for Jobs campaign aiming to increase ICT professionalism and to improve the e-competences framework for ICT professionals.

According to the Grand Coalition for Digital Jobs [2] the European Commission has fixed three relevant goals. The first is the training and matching for digital jobs in order to increase the offer of training co-designed with the ICT industry so that people get skills business that real need. The second is awareness raising to attract more young people to ICT foreseeing rewarding careers for them. The third goal is the coding to improve coding skills.

Another initiative of European Commission in ICT field is the Digital Single Market strategy, where other three important points can be identified. First of all the demand for employees with digital skills is growing of only 4% per year. The situation could be getting worst by 2020 if decisive actions are not taken. The second point is that European countries need to increase the digital skill levels among employees in all economic sectors in order to improve the employability. Therefore, it is shown that the education and training systems should be adapt to the changes of the digital revolution, because digital skills should be central of this strategy [1].

Moreover, the international surveys, such as Program for International Student Assessment (PISA) [3] and Trends in International Mathematics and Science Study (TIMSS) [4], show performance results, mainly, in mathematics achieved by an essential part of European students, below the Organisation for Economic Co-operation and Development (OECD) average, against the best performances achieved by some Asian countries.

Actually, looking over the last TIMSS survey of 2015, the mean scores achieved in mathematics are below the OECD average where, for example, Italian student performance performance has reached the average (494) in math, ranking at the 19° in the final classification. The situation is very different if we consider the scores achieved in Asian countries, like Singapore, Korea, Chinese Taipei, where their students are placed at the best positions of the final ranking as Figure 1:

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

Figure 1. IEA's TIMSS 2015 - Distribution of Mathematics Achievement (Grade 8)

This context is easily demonstrated by the fact of the gradually decreasing interest and motivation of students in professional and research careers based on science and technology.

One of the major cause of the current situation is the resistance of some teachers towards innovative changing and their persistence in the managing of their classes with traditional teaching and learning methods. In fact, the teaching-learning traditional process is focused more on contents mastery than on the abilities development and enhancement of research aptitude. Mainstream education system is oriented towards the teachers: teacher gives and students receive. Since the education system is often focused on school performance and results, the student "learning to learn" capability for lifelong doesn't develop.

Therefore, the learning to be effective should be more meaningful where learners construct their own knowledge in "meaningful" contexts. This means that they should deal with authentic tasks strictly connected to the real world, where they meet their "real problems" [5]. However, students consider mathematics like something abstract, far from the reality by not seeing its immediate application to their everyday life. This determines their disengagement for the science studies.

The situation gets even more problematic if we consider that some teachers are lacking digital skills jeopardizing a real and effective integration of technology in their everyday lessons. Nevertheless, where teachers have a good digital literacy, they need more support on how to exploit all the learning potentialities in the use of new technological tools.

2 METHODOLOGY

In this context, a different interdisciplinary and multidisciplinary approach is required to improve and develop science and mathematics skills and to stimulate actively students' interest in the scientific study and for their future careers. An innovative combination between the technology and arts is proposed in this research work ensuring the interconnection of different languages, such as visual, sensory, verbal and non-verbal in the mathematics study [6].

As defined in Singapore’s method applied to mathematics study, the pathway proposed takes up its three basic phases as follows: the objects manipulation (concrete - the first phase), the visual representation (pictorial - the second phase) and the abstract representation of the mathematical concept or formula (abstract - the third phase). The introduction of these steps will lead students towards a better discovery of the challenging connections between math and reality.

In this model, the students are provided with learning experiences and meaningful context from using concrete manipulatives and pictorial representations in order to support them learn abstract mathematics concepts. This approach stimulates students to draw a pictorial model to represent mathematics concepts (known and unknown) and to catch their relationships (part-whole and comparison) emerged in a specific problem, and to help them visualize and solve the problem itself. This favours students to make their connections and draw generalizations about the concepts learnt by leaving out the simply memorization of disconnected and isolated facts [7] [8].

The Singapore’s method is based on specific mathematics framework, as shown in the Figure 2, that underlines the principles of an effective mathematics programme applicable to all levels: from primary to more advanced levels. It fixes the lines of the teaching, learning and assessment in mathematics [9].

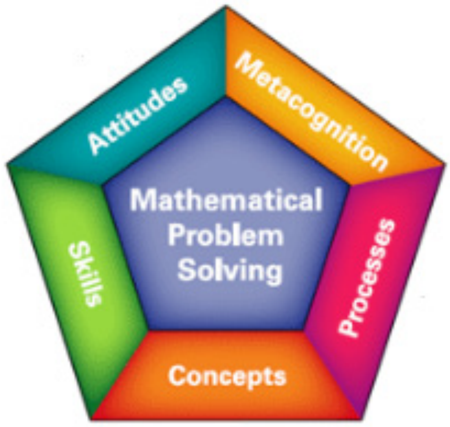

Figure 2. The Mathematics Framework from the Singapore Ministry of Education.

The graphic representation of Singapore’s method is a pentagonal figure where mathematics problem solving skills are at the center and five sides are represented by: 1. Attitudes (such as beliefs, interest, appreciation, confidence and perseverance); 2. Metacognition (monitoring of one’s own thinking and self-regulation of learning); 3. Processes (reasoning, communication and connections, thinking skills and heuristics, applications and modeling); 4 Concepts (numerical, algebraic, geometrical, statistical, probabilistic, analytical); 5 Skills (numerical calculation, algebraic manipulation, spatial visualization, data analysis, measurement, use of mathematical tools, estimation). It shows visually how the development of mathematical problem solving ability is dependent on these five inter-related elements (Concepts, Skills, Process, Attitudes and Metacognition).

In addition, the application of this method foresees the acquisition and the application of mathematics concepts and skills in a different and numerous situations, comprehending non-routine, open-ended and real-world problems [9].

2.1 Technology and Art-works as reinforcement student understanding

In this framework the Singapore’s method allows students for the whole learning process to reinforce their conventional, conceptual (or relational) and procedural (or instrumental) understanding that, in its turn, is well supported by the conceptual understanding. The understanding process, as meant in the

Singapore’s method, is based on the theory of both perceptual and conceptual (or mathematical) variability, which means that the mathematics formula or concept can remain the same even if the context in which is studied can change.

Therefore, the introduction of the art-works and technology in the whole learning process, can even more reinforce these components both from the understanding and variability point view.

The art-works [10] 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. These provide effective tools that can guarantee an active involvement and a creative inclusion of learners in order to let them experience the interconnection of different languages, such as visual, sensory, verbal and not verbal.

One of well-known example is represented by Fibonacci series [11] where each number after the second is the sum of the two preceding numbers in the sequence. The Fibonacci sequence is found in music, for example in J.S. Bach in “Das Wohltemperierte Clavier I” – BWV 846, as well as in nature (Figure 3) and in architecture (Figure 4).

Figure 3. Fibonacci Sequence in nature.

Figure 4. Fibonacci sequence in architecture – Face of a Church in Pisa (Italy).

Another example is related closely to the science education and particularly Algorithms topic understanding.

Students have difficulties to formalize an algorithm (in maths and science) through natural and formal language, to distinguish the simple steps of the algorithm, the moment/s of adjudicating and the repetitive sequences (cycles) of steps, and totally to trace and describe algorithmic structures. However, understanding algorithms is essential for the math understanding and computer science (viz. Programming through procedural languages), studied at school. More general, algorithms understanding is fundamental for real life and algorithms are used for organizing the daily tasks in a certain (often) predefined way.

Paneva-Marinova [12] proposes an educational solution based on the Understanding by Design (UbD) approach, aiming to improve the knowledge understanding of the Algorithms topic. UbD provides a common language for educators who are interested in promoting student understanding rather than formulaic knowledge or recall learning. The approach also gives a framework and a toolkit of research-based best practices that have been proven effective in helping educators to promote understanding-based results for learning, expand the range of assessment tools and processes they use to monitor student achievement, and enhance their design of instructional activities to promote high levels of student achievement.

The use of technology [13] combining with art in the research model proposed based on the Singapore's method can provide students with digital tools which emphasize the interactivity of learning process, the active testing and construct of new knowledge by stimulating the creativity and understanding better complex relations between mathematics and reality. It is enough to think the use of the modeling program, Geogebra, which allow students to explore and understand mathematics concepts through the help of visualization and virtual object manipulation. In fact, it help students reinforce their visualization skills, modeling the real world problems and making connections between the real world and mathematics (Figure 5).

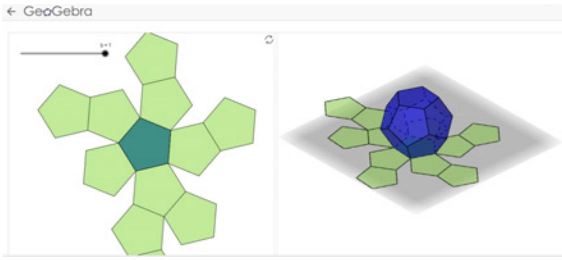

Figure 5. Visual Modelling Programming in 3D – Geogebra

3 CONCLUSIONS

Currently, the research project is in the phase of the designing of educational tools which will be tested in the next experimental phase with secondary school students. The selection of appropriate digital art repositories, virtual museum and libraries and analysis of their content [14] are also inseparable part of the project.

The aim is to demonstrate that the introduction of the digital and technological tools and art-works in the development of a learning process based on the base of the three phases (concrete – pictorial - abstract), as defined in Singapore's method applied to mathematics study, can favor the creation and the development of a more effective and attractive learning environment for students. This will allow them to discover the challenging connections between math and reality and to show them that mathematics is not something abstract and difficult but something belonging to their everyday life. Moreover, the use of painting, dance, theatre, poetry in the mathematics teaching makes science more interesting and facilitates the development of creative and complex ideas in students though the official school curricula are not still oriented to underline the existing relations between science and art.

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