Facilitating Science Learning through a Multidisciplinary Approach

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Abstract

The International surveys, such as TIMSS 2015 (Trends in International Mathematics and Science Study) show how does evolve the students performance in scientific subjects in some European countries, like Italy, are under the OECD average compared to other technologically advanced countries, mainly from Asia. Significant is the gap in the understanding between the more "real" geometry and the "abstract" algebra. The causes can be found in low incentives that students receive from the current teaching methods.

According to the current theories, student's motivation is directly proportional to their ability to understand the topic studied. The motivation activates even the self-assessment ability that promotes the performance improvement further in the learning process and increases student's interest in dealing also with difficult scientific concepts to be learnt.

However, due to the subjective student features, current teaching approaches are, sometimes, similar to the black box model, where are known the results, but unknown the processes implemented to reach them.

Therefore, teaching approaches should be more centered on student's needs and less being a systematic process focused only on the memorization of theorems enunciation and formulas to be applied. For example, in the case of mathematics study, the true knowledge occurs when it is possible to extract it from another context in which it is more visible, i.e. the mathematical concepts become vividly contextualized. This means that its learning is essentially facilitated when the concepts to be studied are learnt in relation with other subjects such as biology, art or philosophy, because this allow students to "visualize" and "concretize" better the mathematical abstractions.

In this context the paper intends to describe an innovative approach referred to the theory of variability, key aspect in the Singapore's method for mathematics study, by demonstrating, further, the added value of the interdisciplinarity and multidisciplinarity based on the absolute bonding existing between humanistic and scientific subjects where the same concepts are represented in different forms.

Keywords: *Mathematics education, learning by doing, problem solving, technology-enhancing learning.*

1. Introduction

An International survey dedicated to school learning monitoring in scientific subjects is TIMSS (Trends in International Mathematics and Science Study). Since 1995, it has reached the fourth edition in 2015 with the participation of 49 countries for fourth grade students and 47 countries for eighth grade. Analyzing the achieved results and trends, Italy shows a non optimistic situation.

From analysis TIMSS 2015 [1] for the fourth grade students, Italy shows a trend in mathematics that has not changed since 2003 and slightly higher the reference International OECD average. For the sciences instead the trend is negative with a marked decreasing from 2007 until returning to a level achieved in 2003.

According to the TIMSS benchmark, divided into 4 understanding level, Italian students have the ability to apply simple knowledge to simple problems in mathematics, while in the sciences they are unable to apply concepts to daily and abstract contexts.

In TIMSS Advanced for eight-grade students the Italian situation worsen both in mathematics and in physics, recording a trend below the OECD average and negative since 1995 for mathematics and since 2008 for physics. Both benchmarks for these subjects indicate the ability to apply basic concepts to simple problems.

Overall in terms of skill, according to the TIMSS benchmark, Italian students show a lack of ability in re-elaborating the concepts to apply them in different contexts from study. In this way the acquired knowledge remains limited to the notions without the possibility of intensifying the interdisciplinary factor.

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2. The differences with Asian student performances: the Singapore's method

If we compare these trends with those achieved in Asian countries, we note that the results are extremely negative. Actually, Singapore, Hong Kong SAR, Korea, Chinese Taipei and Japan continue to occupy the top positions in the education of science subjects from 20 years. This result difference derives, above all, from the application of a different approach. Contrary to the European ones, the Singapore method is based on problem solving solution and context variability concept that paradoxically derives from western studies like those of Jerome Bruner [2] [3], Richard Skemp [4] and Zoltan Dienes [5], inserted in a systematic process in which scientific subjects are only the means to facilitate reasoning.
In other words, the method favors a relational thought connected to a concrete arithmetic concept and to develop skills for the recognition of relationships among variables, to be able to work on them dynamically. This approach, mediated by teacher, can promote in the student a stronger recognition of the relationship between syntax and semantics of arithmetic writing. For example, the theory of the elements is defined on the base of their function in a situation. This is analogous to the method mostly used in mathematics, according to which an object is determined from the relationships established with the other objects [6].
Therefore, the mathematical reasoning results can be assimilated to a set of analysis and synthesis processes that evolve in the development of both abstraction and generalization phases through the so called "variations". In addition, the observation and recognition of invariant elements can give rise to generalizations through the search of algorithmic procedures unifying and contextualized in more fields [7].
In particular, the Singapore's method foresees the introduction of mathematical concepts through the three-phased process: concrete, pictorial and abstract. This means using a symbolic representation to ensure that the concrete mathematical experience allows students to reach an abstract representation [8]. Therefore, the learning process is supported by the necessity from the students to visualize and manipulate the objects before reaching the abstract representation of mathematical formula. In this context, the motivational stimuli to favour student learning are promoted, in particular in scientific subjects, where the difficulties are greater and directly proportional to their ability to learn.

3. Towards a reinforcement of student motivation

According to the motivational theories about learning, an extrinsic and an intrinsic characteristic can be identified [9] [10] [11]. The first one depends on obtaining a reward for having achieved a good result, for example, receiving a vote, as in the traditional procedure adopted in schools.
The second one is a more personal but is thought to be more effective as motivational boost, because students become the constructors of their own knowledge, according to the constructivist theories. In this case, the capacity to be the real character of own knowledge becomes the main key to activate and increase student's efforts towards a performance improvement in relation to the subject studied.
These processes, based on the development of the student self regulation, however, are not very easy to monitor as they provide a strong subjective student component.
In mathematics, these processes have behavior similar to the black box model [12], which is a system that can only be described by its external behaviour (output), because its inner functioning is not visible or unknown. So it is possible to study a black box system only by analyzing its results, produced starting from the incoming signals. To comprehend how it works it is enough to think that from an input signal, the output is examined to see how this has changed within the black box system, so that it is possible to understand how the algorithmic process had modified it.
In education, this process is associated to the tasks in which the teacher explains a concept, the student re-elaborates it and, through the written or oral examination, the teacher collects information on student's work to evaluate his/her elaboration.
This learning process favors the extrinsic motivation [13], in which the learning level corresponds to a vote. Thus, if the elaboration process is considered good, the vote will be good as well.
This means that the traditional teaching process' focus is always on trying to change the processes inside the black box (student), without modifying the teaching methodology itself, because students are usually expected not to understand and, consequently, there is something wrong in the black box.
However, trying to modify the input stimulus for the black box means to modify the teaching process itself which will have to be more flexible by guiding students towards learning process which will not have to be reduced to notional and mnemonic procedures.

4. Conclusion

Applying a more flexible teaching method to scientific subjects, it is possible to use the criterion of extrapolation to understand the concept after having extrapolated it from its natural environment to include it in another context in which it is most “visible”. In this way, between the different materials, bridges are created that can make the concepts more immediate and realistic, as the use of the arts in the scientific phenomena's study [14].

For example, the pictorial perspective is dominated by geometric concepts; the harmonics and its relationships used in music and studied by Pitagora; the use of relationships assimilates to the thought of Cusano; the coexistence of the opposites in the particle wave dualism, so dear to the oriental philosophy; the exponential laws on which biology is founded; the philosophies of the arches base of the periodic table of the elements; the mathematical concept of infinity that so much scared the Pythagoreans and that Leopardi turned into poetry with its famous “L’Infinito” etc.

These bridges exist because concepts such as logical thinking, hypothetical and critical reasoning, metacognitive skills, abstraction capacity belong indiscriminately to the human being as a whole, without distinction between scientific and humanistic predisposition. Therefore, multidisciplinarity [15] and interdisciplinarity are relevant factors for an effective teaching approach that aims to give a global vision of studied phenomena [16]. In this context, the Singapore’s method can be considered as a valid example.

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