

Teaching and learning high school mathematics through an interdisciplinary approach

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Abstract

The aim of this paper is to share the results of an implemented action-research project in teaching high schools mathematics through an interdisciplinary approach.

The starting point of the action research project was the high school students' lack of motivation in studying mathematics which had an impact on the students' learning outcomes. Few students learn math simply because they like it. Most students learn math if they understand why they have to learn it, if they have the possibility to apply mathematical concepts and algorithms in real life or within other subjects or various contexts.

The Romanian mathematics textbooks do not support teachers in motivating students' learning. In these textbooks they can find exercises like: "solve the equation" or "determine the derivative of the function ...".

The action research project answers the following questions:

- what are the effects of the interdisciplinary approach on the students' learning in mathematics?
- what are the effects of the interdisciplinary approach on reaching both the specific mathematical aims and mathematical literacy & competence in science and technology - as a key competence domain?

The action research project is documented with results of assessment and evaluation of the mathematical learning. Students' reflections on their interdisciplinary experience, on their learning mathematics through different subjects (physics, chemistry, music, etc.) are included in the paper.

The paper concludes that the interdisciplinary approach enhances both, the students' mathematical learning and their mathematics, science & technology competence.

Introduction

Students' motivation in learning mathematics is decreasing year by year. If students enjoy learning mathematics in the primary school – as during this stage it is more closely related to operations with natural numbers, their enjoyment in learning math is getting lower and lower as the level of abstraction is increasing. Most high-school students learn math only because they have to take the final examination at the end of the 12th grade. As a mathematics teacher, I have often heard the same question asked by different high-school students: "Why do we have to learn?" Lack of intrinsic motivation in learning mathematics has an impact on the students' learning outcomes. Even if the Romanian mathematics curriculum is quite generous, as it states that *the main aims of studying mathematics in high-school are to develop students' skills to reflect upon the world and provide them with knowledge to act upon the world; to formulate and solve problems by using knowledge across different domains*, mathematics textbooks do not support

teachers and learners in reaching these aims. Exercises and problems in the math textbooks have a high level of abstraction and they allow for the use of mathematical concepts and algorithms only in mathematical contexts.

The list of key competences for lifelong learning (European Commission, 2007) which *are particularly necessary for personal fulfillment and development, for social inclusion, active citizenship and employment*, includes mathematical competence and basic competences in sciences and technology. Mathematical competence is defined as *the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations, with the emphasis being placed on process, activity and knowledge*, while basic competences in sciences and technology refer to the use and application of knowledge and methodologies that explain the natural world. This key competence includes understanding of the changes caused by humans and each individual's responsibility as a citizen. Moreover, this key competence is one of the eight key competences which are all interdependent.

Mathematical thinking is not easy to define. Based on the Principles and Standards for School Mathematics published by the National Council of Teachers of Mathematics (NCTM), mathematical thinking is related to reasoning, problem solving, communicating and connections; it is a thinking process for building mathematical understanding.

Needless to say, developing students' ability to apply mathematical thinking to solve everyday life problems is a long process which is based on modeling the real world and developing problem solving skills. During the learning process, students have to learn how to apply mathematical thinking in different contexts.

In autumn 2010, I started teaching mathematics to a class of 31 ninth graders, who focus on studying sciences and English language (bilingual track). At the beginning of the school year, asked why they decided to take the sciences path, the students answered that:

- they wanted to study medicine (45%);
- they wanted to become chemistry researchers (10%);
- they wanted to study some mathematics during high-school, but not as much as those students whose curriculum focuses on mathematics and computer sciences and not as little as those students who focus on social sciences (45%).

I asked the students *what* they would like to learn in their high-school mathematics class; they answered that they would like to learn:

- things that would be useful in their personal and professional life (80%);
- concepts and algorithms that they needed to know to get a good score in the final exam (71%);
- how to reason (26%).

Being asked how they would like to learn mathematics, the students answered that they would like to learn mathematics:

- in as enjoyable a manner as possible;
- without being stressed;
- by interaction;
- with examples of practical/ everyday life problems which stimulate thinking/ reasoning;
- in English.

I carried out the initial/ diagnostic assessment in order to identify the level of the students' mathematical skills and their ability to use mathematical concepts and

algorithms they would have to use during the high-school math. The average score of the initial assessment test was 56.60 out of 100.

Considering all the above mentioned issues, I designed my action-research project in teaching high-school mathematics to this group of students through an interdisciplinary approach. I was, inspired by the results of the ScienceMath Project and the conceptual framework for cross-curricular teaching (Beckmann, 2009) about which I had learnt in the European Science Math teacher training, as well as by the philosophy of inquiry-based learning (Dewey, 1916).

Teaching high-school mathematics through an interdisciplinary approach

As I had to follow the national mathematics curriculum which limits my academic freedom, I integrated the interdisciplinary approach in teaching high-school mathematics in both my lessons and on the e-learning platform I developed for the ninth graders. The e-learning platform is a “moodle” which contains specific tasks for students. The forum on the platform as well as individual e-messaging and the feed-backing option when assessing students’ work allow individual support of learners. Currently, the e-platform contains each student’s e-portfolio.

During the first year of my action research project, the interdisciplinary approach took shape in the following learning activities:

Topic	Involved subject(s)	Students’ tasks	Specific methodology/ strategies used	Mathematic learning objectives
Real numbers	Music	- students compose and play a piano/ guitar piece to represent different rational and irrational numbers.	Music specific methodology	Students distinguish and explain differences between rational and irrational numbers
Number systems	Literature	- students read a passage from Ian Stewart’s book <i>Nature’s Numbers</i> using text coding. - students write an essay on Leopold Kronecker’s quote “The dear God has made the whole numbers, all the rest is man’s work.” - students watch Marcus du Sautoy’s videos <i>From Zero to Infinity</i> , <i>Safety in numbers</i> and the video <i>The Teaching Challenge – Simon Singh</i> (the videos were available on the teachers.tv website) and answer questions (conceptual clarification, probing reasons, perspectives, probing	Reading and writing strategies for understanding texts (reading with text coding, writing essays, Socratic questioning)	Students measure cardinality of number sets, explain the development of the number systems, explain the use of different numbers in everyday life situations and technology, appreciate contribution of different cultures to developments in mathematics.

Topic	Involved subject(s)	Students' tasks	Specific methodology/ strategies used	Mathematic learning objectives
		implications and consequences) which addresses different thinking levels.		
Numerical functions	Sciences (chemistry, biology)	<ul style="list-style-type: none"> - students collect water samples, measure dissolved oxygen, turbidity, temperature, pH; - students specify relationships among water quality indicators collected data; - students define and graph the numerical functions which described the established relationships. 	Inquiry and project based learning Chemistry experiments	Students use different ways of describing a numerical function, analyze practical situations and describe them by using numerical functions.
Quadratic functions	physics	<ul style="list-style-type: none"> - students watch the video of the freely falling ball experiment and use the freely falling ball graph (position depending on time); - by reading the graph, students identify the position of the ball at different moments, the interval of time between two different positions of the ball, the domain and codomain of the function, axes intercepts and their meaning related to the experiment, coordinates of the vertex point, monotonicity of the function, the image of the function; - students calculate the 2nd degree polynomial which defines the graphed function. 	Inquiry based learning	Students interpret functions from graphs, analyze quadratic functions to describe the motion of an object, identify applicability of quadratic functions.
Vectors	Physics, English language	Students explain in writing, in Romanian language, the solution of the two vectors problems (use of addition vectors tools to solve relative velocity); both problems and solutions are provided in	Reading and writing proofs for understanding math concepts and processes	Students use addition of vectors to solve problems in non-mathematical context, analyze and evaluate

Topic	Involved subject(s)	Students' tasks	Specific methodology/ strategies used	Mathematic learning objectives
		English language (the problems were available on Homework helper - Physics and Mathematics website www.jfinternational.com).		written proofs, read scientific text in English language, identify applicability of vectors.

Results of the action research project in teaching high-school mathematics through an interdisciplinary approach

I analyzed the results of the so far implemented action research project by answering my lead questions:

- What are the effects of the interdisciplinary approach on the students' learning in mathematics?
- What are the effects of the interdisciplinary approach on reaching both the specific mathematical aims and mathematical literacy & competence in science and technology – as key competence domain?

Interdisciplinary approach better addresses students' learning styles. For example, two students who are excellent guitar players were very proud about their performance when they represented real numbers through music. When they started the learning activity, they did not remember anything about rational and irrational numbers, even if they had learnt about them in the seventh grade. After six months, they still remembered the learning activity and they easily explained differences between rational and irrational numbers and gave examples of rational and irrational numbers. Learning was a process of "personal discovery of meaning" (Fatzer 1998, p.66) as these students understood real numbers very well; playing the guitar to demonstrate their learning was an important emotionally charged moment for them.

Twelve students (39%) who have predominant verbal/ linguistic intelligence were enthusiastically engaged in learning about the number systems by reading literature and writing essays, and they also obtained excellent results.

The interdisciplinary approach has improved students' motivation to learn mathematics. Their reflections on their interdisciplinary experience are relevant:

"My best work in the grading period is the essay on Leopold Kronecker's quote *The dear God has made the whole numbers, all the rest is man's work*. This is my best work because I took pleasure at writing it. Mathematics does not provide too many opportunities for free-writes. This assignment gave me the freedom to write my own thinking without being afraid that I'm wrong. I enjoyed working with mathematical concepts." (from the semestrial self-assessment report of Adela F., student)

"In the beginning, I didn't enjoy learning the Vectors unit. I thought this unit was useless; it was so different from what we'd learnt in geometry until then. Later on, I found that vectors are useful for solving some geometrical problems – and the proofs were short, and elegant, and that vectors are tools for physics in working with motion and forces. By studying the Vectors unit, I started using vectors to solve geometry problems (which I find difficult) and it has been really easy to solve mechanics problems in physics now I

understand the operations with vectors. These motivated me for learning.” (from the Learning Journal of Ana A., student)

“I don’t like mathematics very much – I’m good at physics, but I have to say that after understanding the vectors applicability in physics I started to think that learning math supports me in better understanding physics. Understanding the concept and the use of operation with vectors helped me to better understand velocities and forces.” (from the Learning Journal of Alex K., student)

“From my point of view the most important thing was that we learnt to work in a team and how to cooperate with our classmates. We had a lot of fun while collecting water samples and we wanted to act together to improve water quality. Defining the functions was a bit difficult but we managed to do it together.” (from the Feedback sheet – Water Monitoring Activity of Alina S., student)

During the implementation of the action research project 10 students (32%) improved their reasoning and logical thinking, 16 students (51%) used tools, physical models or technology appropriately, and all students were able to make at least one connection to topics outside mathematics.

The average score of the students’ assignments is 75.71 out of 100, which shows a relevant improvement in students’ learning outcomes (+19.11 as compared with the initial assessment).

Closing remarks

The theme of the South African Conference is *Turning Dreams into Reality: Transformations and Paradigm Shifts in Mathematics Education* has encouraged me “to share innovative and creative ideas for effecting reform and transformation in the area(s) of [...] classroom practices”. My ideas for transformation may be implemented with no or few adaptations to the learning environment and the specific group of students in mathematics. I do hope that my paper convinced you about the efficiency of the interdisciplinary approach in achieving improved mathematics learning. For me, this approach really is ‘*Turning Dreams into Reality*’ as my dream is to teach mathematics to students that are eager to learn it because they understand it.

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