PMI-PSI - AN INNOVATIVE STRATEGY TO GENERATE MEANINGFUL MATHEMATICS AND SCIENCE LEARNING AMONG STUDENTS

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ABSTRACT

Society demands that students have mastery of scientific-technological knowledge and skills that will allow them to grow to be productive citizens and to make great contributions to society in the fields of math and science. Student achievement in mathematics and science is a high educational priority worldwide. In a many countries, governments have made improved student achievement in these subjects a national objective. In Argentina, as in the United States, the educational system is not meeting its objectives in these subjects; our students have low achievement scores in math and science, they don't enjoy learning in these fields, which is reflected in the small percentage of students undertaking university studies in mathematics and natural sciences, especially physics and chemistry. The problem is endemic, leading to the conclusion that it is structural in nature.

This paper describes the implementation of a teaching and learning program in a secondary school in San Luis province whose result is student mastery of science and math concepts.

Key words: Teaching methodology; mastery, science and mathematics

Introduction

Society demands that students have mastery of scientific-technological knowledge and skills that will allow them to grow to be productive citizens and to make great contributions to society in the fields of math and science. Student achievement in mathematics and science is a high educational priority worldwide. In a many countries, governments have made improved student achievement in these subjects a national objective. In Argentina, as in the United States, the educational

system is not meeting its objectives in these subjects; our students have low achievement scores in math and science, they don't enjoy learning in these fields, which is reflected in the small percentage of students undertaking university studies in mathematics and natural sciences, especially physics and chemistry. The problem is endemic, leading to the conclusion that it is structural in nature (Goodman, 2006).

The majority of students do not enjoy learning science and math within the traditional educational system, which is based on wrote memorization and recall (Moreira, 2005). For this reason it is necessary to make a change in teaching methods in order to generates better results, raise the level of student achievement. motivate students to learn science and math, improve the climate in the classroom and elminate the stresses on students and parents that currently accompany learning.

Today, type of learning most teachers expect to create through their teaching is "significant learning" defined by Moreira as learning characterized by retention, comprehension and the ability to transfer knowledge (Moreira, 2011).

This document describes a learning experience that resulted in significant learning of math and science concepts among students whose teachers implemented a new teaching methodology. It analyzes data obtained from the work of of a group of teachers that participated in the Progressive Math Initiative® (PMI®) and the Progressive Science Initiative® (PSI®) in 2010. Their training was sponsored by the Universidad de la Punta (ULP) located in the city La Punta, in San Luis province, Argentina.

PSI and PMI were developed in New Jersey, in the United States, by Dr. Robert Goodman, who is the Executive Director of the New Jersey Center for Teaching and Learning. This orgnization is a center for teaching and learning that employs

more than a 1000 teachers who provide support and teaching materials designed with embedded differentiation and integrated with formative assessment questions.

PMI-PSI has demonstrated effectiviness in 55 schools in the US since 2003. Since 2011 PMI-PSI has been implemented in San Luis in 4 public secondary schools. In addition, some units of instruction have been implemented in three of the six digital schools there. Initially the methods were implemented with much uncertainty about the results that would be obtained; however, in San Luis as in the US the methods have been seen to effectively improve student learning and motivation in math and science. The implementation continues today.

This article describes the experience and implementation of PSI-PMI methods in secondary schools in San Luis particularly, and analyzes the quantitative results of student learning as well as qualitative aspects relating to student and teacher motivation and the classroom learning environment. The experience of teachers who have implemented the methods in other schools is mentioned as well. It outlines questions that still remain about improvement and future decisions that will be made.

PSI-PMI Program

PMI and PSI are instructional programs that integrate curriculum and methods of teaching based on Vigostky's theory of social constructivism, new technology and training of teachers with the objective of achieving significant student learning in science and math. This progressive teaching initiative respresents a new paradign for educational practice that naturally combines new technology and new methodology creating something fundamentally different than traditional methods of teaching.

Each program is composed of the same basic philosophy, pedagogy, and testing and technology strategies. The foundation of these programs are:

1) Free and open source digital materials that replace traditional textbooks and are continuously updated

2) Teaching methods based on social constructivism

- Short segments of direct instruction
- Collaborative learning groups
- Formative assessment continuously interwoven in the teaching process

3) Summative Evaluation

- Retakes allowed on all assessments
- Grades are based solely on what students know and can do: short quizzes, laboratories, unit tests, and midterm and final exams.

Both PMI and PSI have their own freely-accessible digital matierials to support the teaching of more than 20 courses in math and science. These materials are available for free on the website www.njctl.org, including presentations, homework and student assessments. These materials replace textbooks and can be used on interactive whiteboards, student netbooks, or can be printed. Online instructional materials works better than using textbooks, which can become outdated or can require teachers to eliminate unnecessary parts. The digital content is updated frequently, can be easily edited by the teacher, and is designed to take into account how to make a subject easy to learn. The instructional sequence takes into account the students' prior learning when presenting new content. Organization follows the principles of progressive differentiation, comprehension and retention.

PSI-PMI methods are based on established theories, for example, Social Constructivism, which is the idea that people construct knowledge as a result of group interaction. In the classroom this translates into students working in groups together with a common purpose, to learn. Group interaction accelerates individual learning.

Traditional classrooms are teacher-centered in that the teacher uses narrative presentation as the basis of instruction. In this model a teacher lectures and students listen. In contrast, in a classroom where PMI or PSI is impelmented, direct instruction lasts only 5-10 minutes. Once the direct instruction is over, students work in groups to solve problems. During this part of the class, the teacher becomes part of the social group, facilitating discussion and encouraging to students to work together.

The teacher walks around the room, from group to group, guiding the conversation and gauging how the students are trying to learn. This additional informal formative assessment provides information allowing the teacher to make immediate decisions about how to shape their teaching.

In the presentations after each topic there are a series of quesions that students respond to through a real-time voting device allowing the teacher to quickly decide whether to reteach or move on to the next topic.

Grades are based soley on what the students know and can do as demonstrated on assessments and labs. Class participation and homework are still required, but are not graded because they are a part of the learning process. If a student does not perform well, he or she can retake an assessment to obtain a higher grade. The retake grade can replace the old grade. The student is given the highest grade. This is because the grade should reflect what the student knows and can do. It is more important *that* the student learns, than *when* the student learns. Students can learn from their mistakes, which results in better understanding.

Why was this program implemented in San Luis?

In the majority of schools in San Luis, science and mathematics are taught traditionally, which is to say the teacher presents the content and gives the explanation while the students are required to listen, pay attention, and do the exercises the teacher assigns. The assumption is that the teachers assign these question and as a result the students learn. This method of teaching and learning, based on memorization and reproductiong content first by the teacher and later by the student, has proven ineffecient. Students memorize questions in hopes of passing the tests and after a short time forget everything that they learned because they didn't learn it in a significant, profound way. This method is boring for students, does not result in deep and significant learning, and rapidly deteriorates the classroom environment. A change in the classroom that permits students to learn in an agreeable environment and provides a rich conceptual understanding of science and math is needed.

Because the teachers that began PSI-PMI training in 2010 at the Universidad de La Punta understood that the proposed alternative to traditional science and math teaching could prove to be more effective they chose to try this method, which had already obtained great results in New Jersey, in the classrooms of San Luis.

Implementing PSI-PMI Methodology in a Different Context

The primary question is whether or not this method functions in a different context, especially since public schools do not have the technology necessary to implement PSI-PMI as designed. In these schools teachers do not have interactive whiteboards or projectors and the students do not have netbooks or student response devices.

In the beginning the methods were brought to the classroom using a projector that the school loaned and a short time later ULP provided projectors so PSI-PMI could

be implemented in the classroom. As of 2011, 4 secondary schools have begun to implement this method of teaching.

The four aformentioned schools are secondary level and located in Villa Mercedes and San Luis, cities in San Luis province. These institutaions serve students between ages 12 and 17.

The implementation began and continues in these four schools. This paper describes the implementation of the PSI program in one school, Remedios Escalada de San Martin, located in Villa Mercedes, San Luis province. This school, located in the central zone of the city, has 300 students distributed in 13 courses between first and fifth year and shares the building with the primary school.

The PSI program was implemented in two second-year courses (divisions B and C) and two third-year courses (divisions B and C) within the domain of Natural Sciences, and for 90 students total.

They implemented that basic PSI-PMI defining tenents but did not use an interactive whiteboard or electronic student response system. However, the need for formative assessment was resolved with an alternative voting system.

The resources used in implementing the project were the SMART Notebook software, a projector, a computer and daily matierials including assessments accessible for free on the NJCTL website.

Evaluation Plan

The evaluation plan was performed useing a two parameter analysis, first student motiviation to learn and second, grades that students obtained on unit and final exams.

A. Motiviation: making a comparison between previous years, teachers found that the students were much more motivated to learn. Early analysis suggests the causes of increased student motivation to learn may be:

1. The students were less tired because they had not spent a lot of time and energy coping notes or long exercises.
2. The idea of collaborative learning in groups promoted solidarity between the students and improved classroom environment. The students who had difficulty solving problems learned from their classmates and slowly developed the skills necessary to solve problems on their own while the more advanced students also benefited from explaining the knowledge they possessed.
3. The ability to retake assessments and the fact that they knew they could keep the highest grade earned motivated the students to keep studying for retakes. One low grade did not constitue an irreversible failure.

B. Grades: Table 1 shows students grades for the PSI physics units implemented.

Table 1. Percentage of passing students after the implementation of PSI Physics Units

PERCENTAGE OF STUDENTS PASSING KINEMATICS AND DYNAMICS UNITS BASED ON PSI INSTRUCTION COMPARED TO PRE-PSI INSTRUCTION YEARS

Courses	2008	2009	2010	2011 PSI
Second B	81.48	48.00	60.00	77.27
Second C	37.50	45.45	43.47	60.00
Third B	36.84	77.77	100.00	84.21
Third C	46.60	87.50	31.250	90.00

As demonstrated in the table above, this quantitative data indicates that the implementation of this program at N° 29 Remedios Escalada de San Martín is highly satisfactory. In the majority of the courses student performance increased considerably. In only one course did the grade indicate a slight decline in the number of students passing.

In regard to qualitative aspects of implementation it is notable that student motiviation to learn increased as did student self-esteem. The classroom dynamic changed considerably. The teacher had less work, was less tired, and the students were not tired from writing resulting in an improved classroom environment.

Discussion

The PSI and PMI teaching and learning programs were implmeneted and then evaluated by San Luis teachers. Similar results were obtained in New Jersey by Professor Robert Goodman, including a higher level of student learning, more effective teachers, and an incease in student, teacher, and administrator satisfaction (Goodman, 2011).

The method of teaching integrates the use of technology like interactive whiteboards and student response systems, promotes the use of formative assessment, helps the teacher make teaching decisions, allows the role of the teacher to change, and facilitates collaborative student group learning. In San Luis the program had to be implemented with some adjustments because the appropriate technology was not available and neither was a permanent classroom for each teacher. However, despite these adjustments, the program, according to initial results, is proving to be effective. Some aspects of this approach that are worth highlighting are:

- Applying this methodology means the teacher does not have quiet classrooms with students who do not want or are afraid to ask questions or talk, but on the contrary has active classrooms in which the students are discussing, debating, and teaching each other;

- The use of PMI-PSI presentations means the teacher writes much less on the board and does not spend too much time with his or her back turned to the classroom. The students do not spend too much time in class writing, but can focus on solving problems in collaborative learning groups and on individual assessments;

- The use of this methodology helps the teacher stratigically change his or her role. The instructor provides short, concise periods of direct instruction but the primary role is to be a companion, director and debate moderator, promoting significant learning.

As a result, the teacher is doing less and the students are doing more. This coincides with what Marco Antonio Moreir expresses in his Teoría del Aprendizaje Significativo Crítico (TASC), including the ideas of not using the chalkboard, promoting active student participation, using diverse teaching strategies and abandoning the idea of the teacher narrative: permitting the students to talk. (Moreira, 2011). The two principles mentioned are powerful metaphors in the sense that they do not mean the teacher cannot use the board or that he or she should stand mute in class. Rather, the author uses these ideas to indicate that teachers should talk less in order to permit the students to talk with each other more for the purpose of learning. This type of instruction focuses on the students and how they learn. It takes into account how the human brain learns. The teacher's role inside the classroom is to facilitate student discussion and significant learning.

Conclusions

We know the best, most innovative strategy can be implemented in a different context and not have the desired success. This was one of the initial concerns: the change of context. Antonio Viñao Frago references this in his article “Sistemas educativos, culturas escolares y reformas: Continuidades y cambios” when he says that “innovation has to be viewed in a cultural context, ignoring context would be a mistake ... the implementation of an innovation in a context different from that in which it originated, always involves interpretation and adaptation. This is one of the few "laws" that can be obtained from historical analysis of innovation processes: all innovations require modifications for adaptation” (Viñao Frago, 2002).

In Argentina, the teachers did not have the same technological resources available in New Jersey schools. The education system in Argentina possesses certain characteristics that are different from the educational system where this method originated, for example, the lack of consistent hours for teachers, lack of planning time and preporatory space for teachers, and lack of collaboration time with colleagues to review their teaching methods and exchange best practices. Argentinian teachers do not have their own classrooms and generally teach in multiple schools.

However, despite these differences, from the moment teachers applied these methods the results were highly satisfactory. These schools are the first step in the implementation with a small cohort of students. The step was a pilot. Like all innovative strategies, it requires time and the right conditions for development.

Today, negotiations are underway so that PSI and PMI programs can be implemented in primary, secondary, and alternative public and digital schols in San Luis province with the aim of measuring broader implementation results both qualitatively and quantitatively. The goal is to apply the methodology integrated with the corresponding technology coherently, from primary through secondary schools across all grade levels. This will be carried out as a joint project between

the Universidad de la Punta and the New Jersey Center for Teaching and Learning with participation of teachers from both organizations.

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