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The "Mathematical Ideas" course as an Innovation Project for Critical Mathematical Citizens

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Introduction

In the context of a pedagogical innovation project of the Universidad del Rosario, the specific needs of the School of Human Sciences were initially addressed to incorporate different spaces where the students of some programs of this School could learn mathematics and explain their use in each of the sub-disciplines. After these needs were collected, the course in question was designed and developed and is currently in an evaluation and sustainability phase.

Traditionally, mathematics has been one of the factors in dropping out of Colombian higher education. There is also the imaginary that mathematics turns out to be useless in diverse disciplines. As an institutional effort, we have proposed technology-mediated innovations that bring students closer to the applicability of what they have learned (from the mathematical context) to break down these beliefs that lead to obstacles in the learning of mathematics. The "mathematical ideas" course is aimed at students of programs that do not have a mathematical focus. In this regard, it seeks to enable an approach, an environment of reencountering, and in some cases "reconciliation", with mathematics. In class, basic concepts are addressed with important applications in everyday life, in order to have a more critical view of situations that involve using mathematics. That is, the use of mathematics as a tool to analyze and make decisions that positively impact their lives and society. In addition, there is a series of virtual support activities that have proved to be very useful as a complement to face-to-face classes and in accompanying the student's out-of-class work, that is, use of a blended-based learning methodology. There is constant discussion about the implications of knowing how to use mathematics and the responsibility that this entails, always focusing on, let's say, fair use. In this way we work on the forming of mathematically critical citizens, an idea that is closely related to what Paul Ernest (2002) denominates "critical mathematical citizenship". Also, students learn through projects, facilitated by the teacher, in which they can solve real tensions in society. With this, we seek to raise the levels of social sensitivity of our students in the mobilization of content and skills for the solution of real problems.

In this communication we will show the motivations that allowed the creation of the course. We will describe in detail the scope of the course, the use of different disruptive methodologies and virtual scenarios, and a reflection from a qualitative perspective (through a case study), which gives prominence to the voice of students who have taken the course.

There is evidence of the positive effect of this course in the face of the perceptions that students had about mathematics. Students who have taken this course have been empowered and have managed to mobilize the contents and skills learned for the solution of real problems that they have detected and modeled, and that they have solved with the use of mathematics. This is based on a project that works from the beginning of the course and that is nurtured as it progresses. Then, the results of their research are made public in the framework of *Pi Day*, an activity that seeks to give visibility to mathematics within the university, and that allows them to connect with their intrinsic motivations.

Objectives

General objectives

To encourage the education of critical and mathematically educated students for non-scientific academic programs.

Specific objectives

- To create a virtual classroom that supports blended learning processes.
- To create a space for reconciliation with mathematics.
- To provide students tools for the mobilization of mathematical content when solving real problems.
- To enable students to use mathematical knowledge to solve problems in their immediate environment that they themselves identify and towards which they feel empathy.

Theoretical framework

Withdrawal from university

According to the report on determinants of withdrawal of the System for Prevention and Analysis of Withdrawal from Higher Education Institutions, presented in 2014 by the Center for Economic Development Studies (CEDE) of the Universidad de los Andes, according to "the statistics released by the System for the Prevention of Withdrawal from Higher Education Institutions (SPADIES), 48.47% of the students who entered higher education in the first semester of 2000 did not reach the tenth semester, while 57.2% of those who entered the first semester of 2008 did not do so." (Centro de Estudios sobre Desarrollo Económico CEDE, 2014, p. 9) These figures are worrisome from an educational and social point of view, as this is saying that (by default) one in two people does not finish his or her university studies.

There are many variables that have been studied to account for what influences students not to stay in college until the end of their studies; withdrawal has been and "is *par excellence*, a problem of the educational system, intimately related to its surroundings, contours and content, such as the educational environments, family situations, and environmental and cultural demands that directly affect the dropout." (Páramo and Maya, 2012).

There is evidence that mathematics is precisely one of the areas in which students present greater difficulties and weaknesses: "[T]his is a problem that occurs in many higher education systems in the world. In the case of the United States, Herzog (2005) shows that one of the

factors that influence the probability of enrolling in the second year of studies is having passed a first year math course. Herzog indicates that mathematics is an indicator of withdrawal risk – students who come with greater academic disadvantages in the area of mathematics have a higher risk of dropping out." (Portales, Estay and Cabezas, 2015, p. 2)

In general terms, achieving the continued presence of students has been a latent concern at the Universidad del Rosario, as has been providing them with tools to make them feel comfortable with their work in mathematics. This has been a constant task of the university's department of mathematics and computer science. On more than one occasion we have asked ourselves about the factors that affect students to the point of being willing to give up on mathematics. Consequently, we have worked on different experiences and projects, seeking to contribute to a good relationship between students and mathematics.

Predisposition towards mathematics

We know, because we have lived inside the classroom, that some of our students arrive at their first math classes carrying a heavy baggage of prejudices and fears, thinking that mathematics is only for the smartest, that they are boring, that they do not have much relation to reality, and other imaginaries that prevent an attitude disposed towards a ... why not call it a "happy learning of mathematics"?

This is not a novelty. From the 80s the study of students' beliefs about mathematics and its impact on the learning of this science began to intensify. At the same time, greater interest was aroused by the study of concepts and recently by the study of perceptions and imaginaries. In such research it is recognized "that beliefs are as necessary as the psychological functions of cognition and metacognition to achieve effective learning" (Andrews, Mantecón and Op't Eynde, 2008, p. 326), and the role they play as regulatory system, indicator, inert force and prognostic character, in addition to mentioning that beliefs can greatly influence student learning and the way they use mathematics, so they can also be an impediment in their learning (Törner and Pehkonen, 1996). In the same line, Campos (2008) deals with affections (beliefs, attitudes and emotions) in mathematics education, and Da Ponte (1999) works on the topic of beliefs and conceptions as key studies in mathematical education as well.

A more recent field is the study of imaginaries in education: collective representations strongly related to experience, with intuition and feeling, which influence our ways of perceiving and acting (Suavita-Ramírez, 2017) in relation to, for example, math class.

These investigations have resulted in several general observations regarding how to get closer to achieving a better disposition in students in relation to mathematics. It is expected that with a better disposition they would be able to enjoy their classes and improve their attitude and their results, which at the same time would contribute to the students remaining in the university.

Critical citizens

One way to "hook" students with mathematics is by showing them that it is not devoid of social meaning, that is, it has powerful meaning and implications for social and political life, for their life and society. In this regard, critical mathematics education "argues that the values of openness, dialogicality, criticality towards received opinion, empowerment of the learner and social/political engagement and citizenship are necessary dimensions of the teaching and learning of mathematics, if it is to contribute towards democracy and social justice" (Ernest, P. 2001, p. 1).

Paul Ernest (2002) introduces the idea of critical mathematical citizenship, which aims at the formation of mathematically critical citizens, that is to say, citizens able to discern through critical judgment, and to make important political and social decisions. A mathematically critical citizen has the necessary mathematical tools to analyze a situation and understand it, before taking a definitive position with respect to it; you can, for example, make a critical reading of the mathematical instruments used in a newscast or in an election campaign and the way in which they are presented. A mathematically critical citizen can also make everyday decisions using mathematics, for example, in relation to personal economy (compare discounts, understand interest rates, make a comprehensive reading of the receipts of their public utilities). Therefore, a mathematically critical citizen is expected to contribute to the construction of a fairer and better society.

Blended learning

Electronic learning, or e-learning, accelerates the educational model and contributes to its effectiveness by promoting self-directed learning in a guided way (Rosenberg, 2003). The use of e-learning is in continuous growth, an expansion that is due to the fact that e-learning solves geographical, temporal and demand problems. However, this type of learning has drawbacks, such as that there is little or no interaction between teachers and students, the feedback of processes that are not automated (which can be slow and therefore untimely), greater complication in the rectification of errors in the material of both the teacher and the student, a possible decrease in the quality of the training, and that students may have feelings of loneliness, impersonality or isolation.

The Mathematical Ideas project is part of the lines of innovation of learning to learn, inclusion and equity, social impact, internationalization, use of ICT and integral training. The use of ICT is introduced under a blended methodology in which learning processes are supported by technology through work in virtual classroom activities.

Partial face-to-face learning or b-learning (blended learning) consists of the integration of face-to-face learning experiences with online learning experiences. These methodologies generate several benefits compared to e-learning:

- Encouraging appropriation by the student of the critical discourse obtained by listening to a teacher and discussing content in class
- Independent learning, self-reflective and self-taught
- The student can learn at the pace that best suits their knowledge
- Training of digital competencies (search, selection, collection of resources, elaboration, extraction of ideas, sharing of information, etc.)
- The content can be arranged in a more interactive way with the use of information technologies
- Encouraging the use of mobile devices as a guided learning tool by the university

Modes of inquiry

The Mathematical Ideas class arose as a project of technological mediation in the teaching of university mathematics as a result of a call for proposals for research support at the Universidad del Rosario. This proposal was an important challenge that obliged us to redesign and rethink strategies and content in such a way that we could identify and delimit the extent to which face-to-face teaching was taking place so that there would be a learning process that would also integrate the technological resources available, and that would work.

A consolidated pentagonal scheme was used in the phases of (1) sensitization, (2) ideation, (3) construction, (4) implementation; and (5) evaluation, as shown in Figure 1.

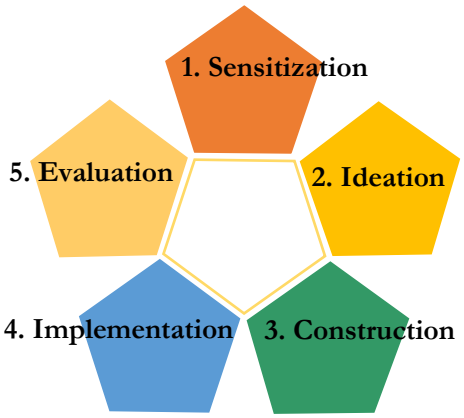

Figure 1. Pentagonal creation scheme

Phase 1: Sensitization

- Dialogue with directors and students: Throughout a semester, meetings were held with the directors of the School of Human Sciences, to recognize opportunities for improvement in the mathematical academic offer of this School. Given that a course on fundamentals of mathematics was offered and its impact on student learning was presenting major obstacles, it was decided to approach the students (the target population for action) to explore what problems they were experiencing with this course. Having held some focus groups with students, it was concluded that the fundamentals of mathematics course was designed in such a way that the students could not motivate themselves or connect positively with the content and competencies linked to the course. It was also concluded that much of the content offered was not relatively relevant for this particular type of student. This formative dialogue that was held with both directors and students allowed the emergence of a seed of research that would end up delivering an interesting course, mediated by technology, where the students really connect with the content and competencies, and achieve, in addition, mobilizing them for the solution of real problems that interest them.

Phase 2: Ideation

- Why e-learning and projects? The courses were not designed properly, not thinking of the students but only of the sweep through the discipline that was made to correspond with what the teachers thought was best. It was not inclusive. It was necessary to think about offering students an innovative alternative for their reconciliation with mathematics. Taking into account that this generation of students is one of digital natives, we decided that technological mediation would be an efficient tool to guarantee their academic success, achieving, among other things, their commitment to the course knowing that they would have to perform relevant academic work at home via virtual classrooms. We also decided to make (tangential) use of project-based learning, guaranteeing the mobilization of contents and competencies for the solution of social problems of interest to students.
- Levels of social sensitivity: This course also sought to raise the levels of social sensitivity of our students. This means that during the exercise of solving problems

students should be the protagonists in the collection of data and design of models that represent real problems that they find painful.

Phase 3: Construction

- Instructional design: The Mathematical Ideas course was structured in four fundamental thematic blocks. A first block explicitly addresses the art of posing and solving problems; in this regard, factors to be taken into account when addressing a situation, such as making a good reading of the problem understanding what the meaning of the problem is, what information is available and what information is sought, are explored. Problems are solved by inductive reasoning and solution strategies are developed. Variational thinking constitutes the second thematic block. In this part of the course we mainly work towards understanding the concept of proportionality (ratio, proportion and variation, and percentages) and its implications in daily life, seeking that students become a little more aware of the uses of this important idea.

  The third block provides an introduction to counting and probability; specifically, counting techniques, permutations and combinations, and counting problems that include "no" and "o" are addressed. Finally, the course closes (in a fourth block) with an introduction to statistics. In both cases always using problems in which such concepts are applied.

- The final project: A fifth block was also proposed with the title of "projects" and refers to an assignment that students carry out from the beginning and throughout the course, until its final delivery and defense to conclude the course. The aim of this project is that the students address one or more of the contents of the four major themes through the study of a real situation in which the student shows what he or she learned in the course and presents a solution to a problematic situation.

These student projects are presented in poster format, within the framework of the Universidad del Rosario's Pi Day (see Figure 2). This activity aims to give visibility to mathematics and empower students, allowing them to publicly display their mathematical findings in the different mathematics courses.

Figure 2. Pi Day at the Universidad del Rosario

- Virtual objects: In this phase of ideation, it was decided to create simple, but empathetic, virtual learning objects that would be embedded in virtual institutional classrooms (Moodle). Some views of these objects are shown in Figures 3, 4 and 5.

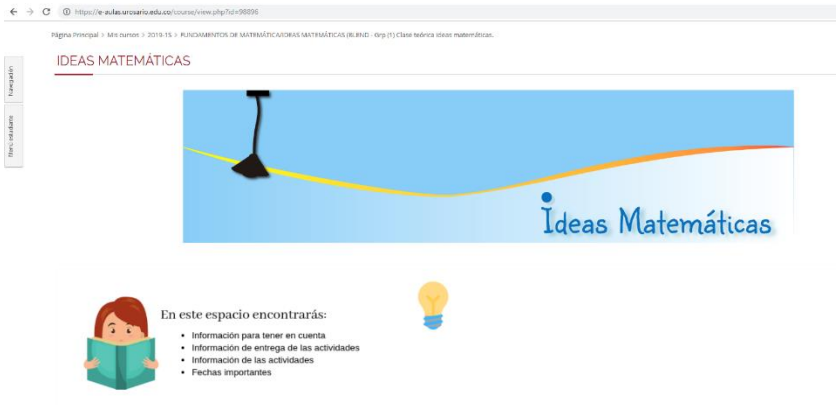

Figure 3. Main page of the virtual classroom of Mathematical Ideas

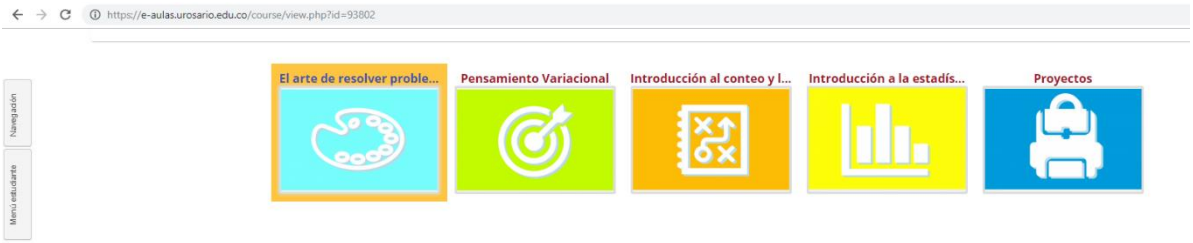

Figure 4. Panel for access to the activities according to the thematic blocks

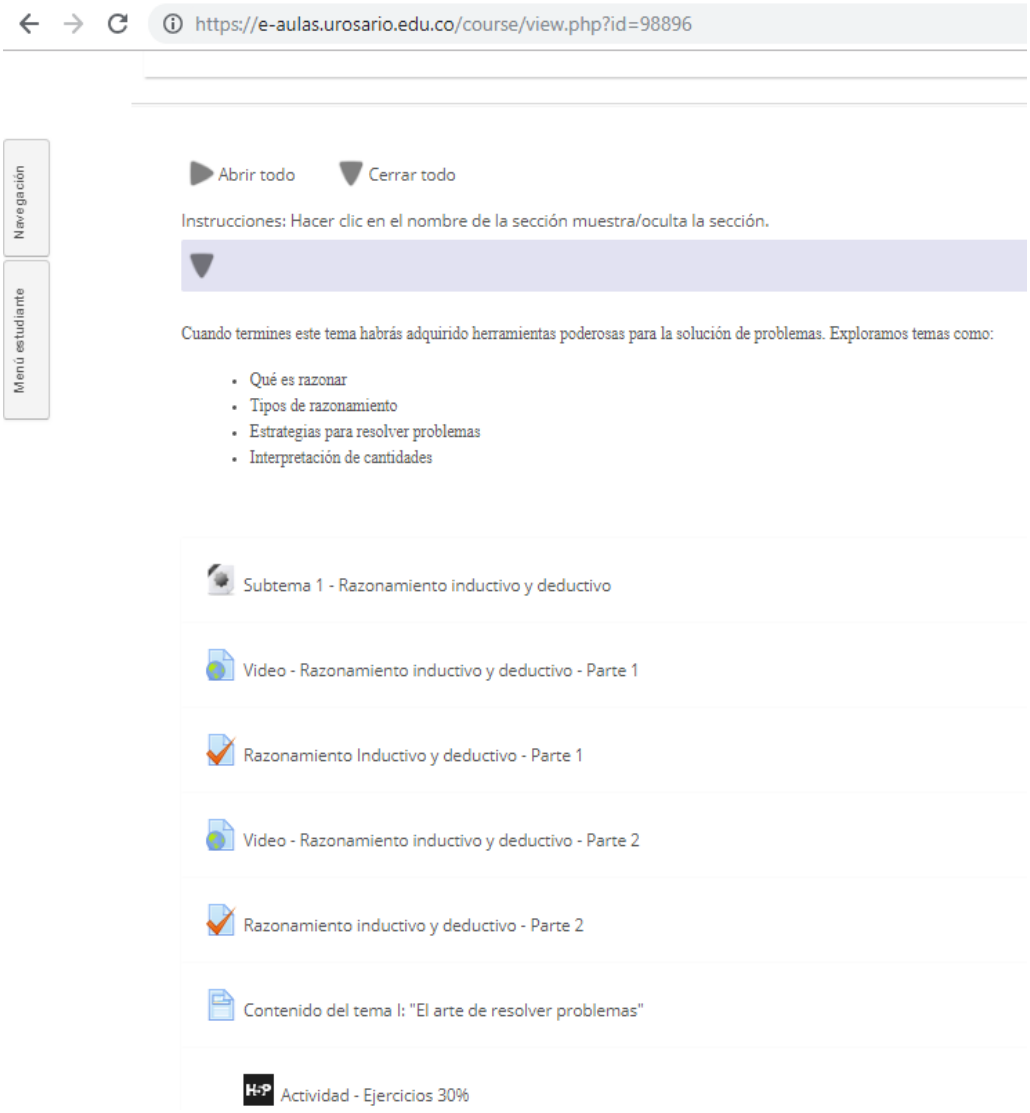

Figure 5. Thematic block 1: The art of solving problems

Phase 4: Implementation

Once the virtual classroom was constructed the course was offered for the students of the School of Human Sciences in the second semester of 2017, and there was a group of 15 students belonging to the philosophy, anthropology and sociology programs. For the first and second semester of 2018, the groups were of 11 and 15 students, respectively. Currently, there is a group of 16 students.

The classes were carried out according to plan and the students, in general, responded positively by attending the classes with responsibility and working in the virtual classroom activities. While this was happening, a report was prepared during each semester on aspects that were identified as susceptible of improvement, especially in relation to the virtual objects. At the end of the semester the classroom was nourished considering these observations and making the appropriate adjustments to the activities.

In relation to the teacher in charge of the course, it is important to highlight that he/she has the constant support of the university's e-learning center and its guidance for any questions regarding both the blended learning methodology and the operation of the virtual classroom.

In this way, we attempt to ensure good execution of the Mathematical Ideas class independent of changes of professor.

Phase 5: Self-evaluation

To evaluate the Mathematical Ideas project, two focus groups were established with the students who had studied the course in two different terms (the first and second semesters of 2018). In this way, we were able to get closer to what the students had experienced and thought about the Ideas course and mathematics.

An instrument was created as an orienting guide for the holding of the focal groups, in which aspects such as the image of the Mathematical Ideas course constructed by the students and the methodology they associated with how the class was executed, their idea regarding mathematics and whether this idea had changed after their class, and the use given or that should be given to mathematics according to their constructions in class were considered,.

Letting different voices speak – Results

Below are some student comments from the focus groups that were conducted with them in the self-evaluation phase of the course.

- When we asked our students about how they defined the Mathematical Ideas class, they used words such as "tool", "usefulness" and "novelty", and phrases such as "foundations for the inexperienced" or "a different approach". This made it possible to show that they were perceiving what we wanted to transmit, and it was even more interesting when comparing it with other opinions in which they related the class to "analysis", "demonstration" and "rigor", among others.
- With regard to the perception of what the class of Mathematical Ideas is like, we will let our students speak:

GD1_P1: *It was interesting for the simple tools that any professional should know even for everyday life. A novel proposal in the curriculum.*

GD1_P3: *The class covers the objectives set; it does not represent an impenetrable area of knowledge, although it is not without rigor.*

GD1_P6: *It is interesting and dynamic.*

GD2_P4: *It cultivates practice and the love of mathematics.*

GD2_P2: *I loved the experience I had with mathematics. Despite studying for a career in human sciences, mathematics has always caught my attention. This class, besides reminding me of some basic and fundamental things that I will need for my life, allowed me to approach again this incredible world of mathematics.*

- Some students agree that what they thought about mathematics changed after passing through the course. One of them said, "I usually thought that mathematics was only theorems and demonstrations. Of course it has that, but it was interesting to apply mathematical ideas to my areas of knowledge." [G2D_P3]
- With regard to the project of the course, during the discussion one of the participants mentioned: "As I said before, mathematics from the beginning have always attracted my attention, and I enjoyed them with this course. Especially the final project, in which I had to relate mathematical elements with social aspects. It is a very interesting work of analysis and one can not only learn but also be surprised, since in fact mathematics is everywhere. On the other hand, I think it is important to break the division that has

existed since centuries ago between the exact sciences and the human sciences, because they are closely related. In addition, both coexist within the same field. It could be said that sometimes one depends on the other, and vice versa." [GD_P5]

Figure 6 shows a couple of examples of posters for the final project of the course.

Figure 6. Posters presented by two of the students of the course to defend their final project: *Mathematics in the kitchen* and *Twilight of the principle of progressivity*.

- In general, participants agree that mathematics should be used to solve everyday problems, "from understanding a banking transaction to understanding politics or economics," and they also agree that mathematics serves to interpret reality critically. However, some of the participants are still not very convinced that mathematics can help make better decisions.

Discussion and conclusions

The contrast of opinions as regards considering the Mathematical Ideas course innovative, with a different approach, and at the same time rigorous, was a revealing. We wagered on a kind of reencounter with mathematics, but besides that we found that the class contributes, in a natural way, to the destigmatization of topics such as that an innovative methodology, of mathematical creation, lacks rigor. In the same way, we bring the students to experience more human mathematics, and from their work in the projects, for which they themselves identified real

problems to solve, they discovered the power of mathematics to impact their environment, giving them social meaning.

Why is "Mathematical Ideas" so significant for our students?

We consider, based on the evidence, that the strategic design of this subject, responding to the specific needs of this student population and including non-traditional learning methodologies, has allowed, for example, the average approval rating of this subject to reach 98%, greatly surpassing the approval that the fundamental mathematics courses offered by this School had in the past.

Also, there is evidence of the change in the way the students who experienced the course think about mathematics, especially in terms of the tools that this science provides for understanding the world and the way in which it contributes to its construction as critical citizens.

Lastly, a group of students empowered with knowledge and satisfied with their learning outcomes is being formed. The inclusion of the projects in the curriculum of the course has allowed imprint both intrinsic and extrinsic motivations in the teaching and learning processes of our students.

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