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COMPREHENSIVE TRAINING FROM MATHEMATICS: CASE STUDY

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Abstract: The purpose of this research project was to describe and explain the effect on student performance by promoting a metacognitive process in parallel to the knowledge of the discipline in the classroom and seeking to contribute to the comprehensive training of the student. The methodology was action research, in order to obtain a good approximation to reality by considering the different perspectives of the participants involved in the study. An intervention was carried out using two instruments, a survey that gave a descriptive assessment of the metacognitive process applied before and after the intervention. The other instrument is a checklist implemented as a teaching tool in mathematical problem solving activities. The study was carried out with students of the first semester of the Higher School of Mechanical and Electrical Engineering, unit: Culhuacan, of the academic program: Communications and Electronics Engineering. The subject of differential and integral calculus was taken as the core axis for the construction of knowledge. Among the results found were: a better construction of mathematical knowledge by the student, the student's reflective self-assessment for continuous improvement and awareness of the need to grasp a metacognitive process. It can be concluded that, to contribute to the comprehensive training of the student from the discipline, it is necessary to implement teaching and learning strategies that articulate the cognitive, affective and metacognitive dimensions.

Keywords: Comprehensive training, Metacognition and mathematics, comprehensive training and mathematical problem solving

Nowadays, the training of professionals must raise scientific and technological levels and put them at the service of society, and the university is the social institution that must be responsible for the development of the human resources of any country towards the highest level., is what must prepare professionals to face the growing challenges in the scientific-technical and cultural spheres, with a solid ethical life project. Universities must promote the development of skills such as collaborative work, solving contextual problems with a global vision, learning to learn through knowledge management through the incorporation of a metacognitive process that promotes continuous improvement, with based on information technologies and integrating into the knowledge society (Tobón, González, Nambo et al., 2015a; Tobón, Guzmán, Hernández et al., 2015b; Hernández-Mosqueda, Tobón-Tobón &Vázquez-Antonio, 2015; Bortone, 2015; Rodríguez-Peralta, Nambo J. & Aniceto-Vargas, 2016a; López, Benedito & León, 2016). However, in the classroom, the teacher's eminently in-person methodology still predominates in master sessions, showing information that is not necessarily learned. In the particular case of mathematics, research has been done so that the student gives meaning to knowledge and so that they achieve better learning of university mathematics using mathematical modeling, problem-based learning, the management of different semiotic systems involved with the mathematical object (Romo-Vázquez, 2014; Vrancken & Engler, 2014; Yee & Bostic, 2014; Costa, Arlego & Otero, 2014); But these investigations do not consider the comprehensive training of the professional, only the professional one. Other research considers the importance of involving methodologies that incorporate a good scientific base where knowledge is integrated with knowing how to do and knowing how to be and live together, but from a mathematical perspective. One proposal is to consider the skills of mathematical thinking such as analytical, critical and reflective thinking that make up mathematics and at the same time promote collaborative work that helps develop solidarity, responsibility, ethics and honesty (Trejo, Camarena & Trejo, 2013;

This work addresses the following problem:

1. How to achieve the learning of differential and integral calculus, when it remains the guiding axis of learning for comprehensive training from the classroom?
2. Could the cognitive dimension of the discipline be articulated with the affective and metacognitive dimensions so that the student begins his comprehensive training?

COMPREHENSIVE TRAINING AND MATHEMATICS

Comprehensive training is based on the full development of the potential of the human being, assuming the person as a totality, an indivisible and complex being, in relationship with himself and others. Thus, an educational institution at the university level must train professionals in a comprehensive manner, all disciplines are the means to develop complex skills for life and work performance. In the area of engineering specifically, basic sciences are the basis from which the necessary disciplinary knowledge that constitutes the graduation profile of an engineer is built, and must be the starting point to form the skills of a citizen. that responds to the challenges of the context in a competent, efficient manner and with social commitment. This study considered training based on the development of comprehensive competencies since the development of these is a reflection of a high academic level, an adequate relationship between theory and practice, a degree of contextualization, reflection and critical analysis, and autonomy in learning with social commitment. The socio-formative approach was taken as a framework of reference, which is an educational perspective that is oriented towards the comprehensive training of students both in the work (professional) part and in the personal part within a knowledge society, it is taken as a basis. addressing contextual problems, considering that the context can be cultural, social, academic or work of the student, generally working in a collaborative framework, considering the ethical life project of each of the actors, the management and co-creation of knowledge and metacognition, establishing itself in information and communication technologies (Tobón et al, 2015a, Rodríguez-Peralta, Nambo J. and Aniceto-Vargas, 2016a; Paredes and Inciarte, 2013). From this perspective, comprehensive training requires that teaching practice and mediation focus on the development of competencies, relating them to the capacity for self-regulation and self-knowledge, elements that are part of a metacognitive process that allows for continuous improvement in the development of competencies and promotes autonomy in learning (Ortega-Carbajal, Hernández-Mosqueda, and Tobón-Tobón, 2015; Montes de Oca, and Machado, 2014).

Mathematics at the higher level. Mathematics in engineering must recognize the importance of building a good scientific base and contributing to the comprehensive training of the student. This can be achieved if knowledge and know-how are integrated with knowing how to be, which will be possible if combined with analytical thinking., critical and reflective, teamwork is encouraged that helps develop solidarity, responsibility, ethics and honesty.

This way, if it is supported by the socio-formative perspective, it contributes to training students with the attitudes, skills and values necessary to have engineers with opportunities for success in their academic training and in their professional life (García, 2013, Trejo et al, 2013). On the other hand, the teaching-learning process of mathematics aims at the development of mathematical skills such as abstraction, analysis, discovery attitudes, and mathematical visualization. Thus, the construction of mathematical knowledge with meaning and significance contributes to the development of metacognitive competencies, as important are the mathematical contents as the way in which the teaching-learning process is developed. Studies have been carried out that show the relationship between learning mathematics through problem solving and, in turn, with the development of metacognition. Because of the way they construct solutions to problems, mathematics supports the development of a "nutritious community" that is based on mutual understanding through dialogue achieved through the creation of a language with shared meanings. Mathematics allows, through the development of dialectical logical thinking, the development of metacognitive skills, a fundamental basis for the ability to learn to learn (Peñalva, 2010; García and Santarelli, 2004; Curotto, 2010).

Metacognition is assumed as a process in which one becomes aware of how one learns in order to regulate and control one's own learning (Monereo, 2001). In socio-training, metacognition is getting involved in the process that regulates and controls the learning of any competence, considering the cognitive and affective dimensions in being and doing with the intention of continually improving performance, it becomes an individual, social process. and ecological, focusing on the achievement of goals from the resolution of contextual problems (Tobón, 2013).

METHODOLOGY

This study was carried out using the action research methodology, considered as an active, systematic process that can account for reality, by involving the descriptions of situations, events, people, the perspective of the participants, their attitudes, their voices., their behaviors. This way, better evidence and understanding of the results of the study carried out are sought (Colmenares & Piñero, 2011; Erazo, 2011; Varela & Vives, 2016). Therefore, data collection was done in 4 aspects:

1) At the beginning, the implementation of a survey that allowed us to establish the general characteristics of the study sample, observe the time and ways that the student dedicates to learning a subject. The last part of the initial survey was the survey to establish the status of the metacognitive process with which each student manages her learning when solving mathematical problems. The last two parts of the survey were administered again at the end of the intervention.

2) The implementation of the use of a checklist that promoted the methodology for problem solving, collaborative work with social commitment (the participating students were co-responsible for the learning of their work group, the work was fed back with co-evaluation (between peers) and the heteroevaluation carried out by the (teacher) and the awareness of the metacognitive process associated with problem solving. The teacher induced constructive critical reflection at every opportunity that arose.

3) The students' productions (workshops, problems and exams carried out by the students) throughout the intervention. The workshops, problems and exams were worked on following the checklist.

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Activities such as workshops were mediated by the teacher, to induce reflection and awareness of the metacognitive process when solving problems.

4) Observation guide with student interviews carried out during in-person class sessions, during the intervention period.

PARTICIPANTS

We worked with a pilot group (GP) of 27 students from the Computer Engineering major, an experimental group of 27 students from the Communications and Electronics Engineering major, both from the first semester (the subject of differential and integral calculus is common to both academic programs) before the beginning of the study they were informed and asked for their consent to participate in the experience with their productions, their reflections, the analysis of their behavior when solving problems and the monitoring of the information collected, their Data was protected by the information transparency law. Once the study began, students dropped out of the course. The monitoring of the pilot group was carried out in the subject of Basic Chemistry, the atmosphere in relation to mathematics was more relaxed. In the experimental group (EG), in the end only 17 students remained in the mathematics course, so the information analysis was carried out with these participants. The experience was carried out around the subject of Differential and Integral Calculus.

Participants were informed that the information they provided would be used for the purposes of the study and their data would be safeguarded, in accordance with the Personal Data Protection Law in force in the Mexican Republic (Official Gazette of the Federation, 2010).

INSTRUMENTS

Assessment of the metacognitive process in problem solving (Rodríguez-Peralta, Nambo & Aniceto-Vargas, 2016b). This instrument was designed to assess the degree to which participants engage with a metacognitive process through a mathematical problem-solving methodology. The activities designed within the academic context are taken as a basis in congruence with Monereo (2001), who believes that metacognitive learning strategies or situations must be given and taught together with the different disciplines of the curriculum, without additional time and with the teacher's resources. (Jaramillo and Osses, 2012; Huertas, Vesga and Galindo, 2014; Monereo, 2001). This instrument has been validated for implementation in the classroom to be applied before and after the promotion of the mathematical problem solving methodology as a learning strategy.

Checklist for promoting mathematical problem solving (Rodríguez, Nambo, Aniceto & Viveros, 2015b; Rodríguez, Rodríguez & Hernández, 2016c). The instrument aimed to guide student learning through the methodology of mathematical problem solving according to Schonfeld (1987) and Polya (1965). The instrument is related to the metacognitive process in such a way that by solving a problem within the framework of the subject the participant becomes aware of a metacognitive process that guides him towards the apprehension of his own process. It is important to emphasize that teacher mediation within this context is important for achieving the proposed goal.

PROCEDURE

This was carried out in the following phases:

1. The intervention study began in the semester corresponding to August-December 2016. A first survey was applied at the beginning of the semester, after informing the student what it was about (to the pilot group and the experimental group). The survey was made up of three parts, the first to determine general characteristics of the study samples, the second part called: Supports for learning, the purpose of which was to determine the average time spent studying the subject per week, the resources used to the study, the commitment to follow all the activities and work sessions.

2. Once the course started, in each work session with the students, the use of the checklist was promoted, emphasizing each element of it. Individual and collective reflection was encouraged around each and every element of the checklist and the work carried out. The activities lasted a semester. The semester included continuous and summative evaluation in three midterms, each midterm closed with a group reflection on the expected learning and the learning achieved.

3. During the duration of the intervention, a field diary was kept where observations related to the active participation of the student, whether personal or collaborative, in monitoring the application of the checklist were noted. In this field diary, comments related to advances in knowledge and the methodology followed were also noted.

4. Student productions. Problems were made that the student had to hand in, he could ask questions that arose inside and outside the classroom. There were 6 workshops where they worked collaboratively, and 3 exams were carried out. All their products had to comply with the checklist.

5. In the last phase, the survey of supports for learning and the metacognitive process and problem solving were applied again.

RESULTS

1. In relation to the application of the first survey in the pilot group and the experiment group, the study population had the following initial characteristics:

In table 1 you can see the general characteristics, it must be noted that more than 25% of the students in the pilot group (GP) (39.29% and 28.57 5 in the experimental group GE) do not have the cognitive background of the area. disciplinary, around 30% did not choose ESIME as their first option, through a personal interview, there were 6 students who chose another option and were assigned ESIME, they hoped to achieve their change at the end of the semester. For this to happen, the Institution asks them to be regular, with an average greater than 8 and that there is a place in the school where they want to change. It is worth mentioning that 2 of the students obtained this change to the area of Biological Sciences. Thus, the student who really wants his change has the commitment to finish without failed subjects and with an average above 9.

The economic level considered is medium and the Institution offers them a maintenance scholarship, they only have to request it and complete the procedure in the specified time and manner. Despite this opportunity, not all students apply for a scholarship. the majority come from a public school and the high school GPA is greater than 7.

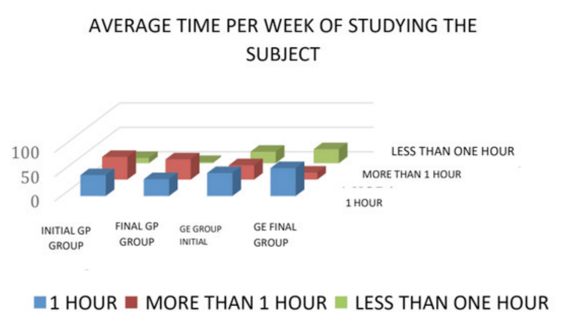
POPULATION CHARACTERISTICS	PILOT GROUP	EXPERIMENTAL GROUP
Average age in years	18.72	17
Gender:	4 women=16% 24 men=85.71%	9 women=32.14% 19 men=67.86%
They work	4=14.28%	2=7.14%
Disciplinary area of origin	-17=60.71% of the physical and mathematical sciences area -4=14.29% of the area of social and administrative sciences - 0 from the medical-biological area-6=21.43% other	- 20=71.43% of the physical and mathematical sciences area -4=14.29% of the area of the medical biological area -4=14.29% of the social and administrative sciences area
First choice school	19=67.86% chose ESIME as their first option	20=71.43% chose ESIME as their first option
Medium economic level	23=82.14% average economic level	27=96.43% average economic level
School of origin: public or private	24=85.71% public school	28=100& public school
General average	8.37	7.53 (13 did not answer the question)

Table 1: Population characteristics

Source: the own authors.

2. Supports for learning

In relation to learning supports, the results of the pilot and experimental group at the beginning and at the end of the event are presented in the following graphs.

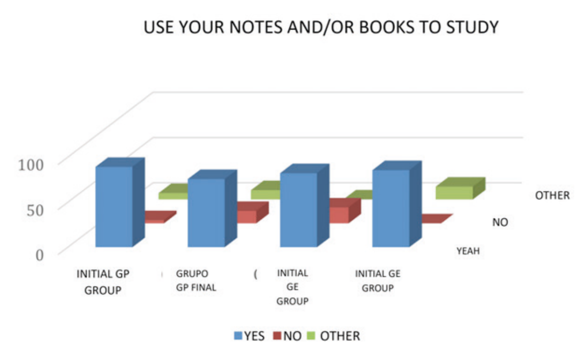


Graph 1. Graphic results of learning supports 1.

Source: the own authors.

The supports for learning, in graphs 1, it can be seen that for the pilot group the majority studies on average more than one hour a week, however, at the beginning of the survey they answered based on the activities they carried out in high school., when they studied mathematics, the survey was administered at the beginning of the semester. At the end of the intervention time in the GP, students who studied 1 hour or less increased their study time, showing that mathematics subjects require more dedication. In interviews with the students, the subject of differential and integral calculus seems complex and requires more time of dedication than the other subjects.

In the GE group, students who study one hour and less than 1 hour increased and those who study more than 1 hour decreased. In an interview with the students of the GE group, some argued that the subject was too complex for them (coinciding with the GP group), that they were not accustomed to the methodology used in the exploration and following the methodology required more time, time that they had. to remove from other subjects, so some students in the group "were" abandoning the subject.



Graph 2: Graphic results of learning supports 2.

Source: the own authors.

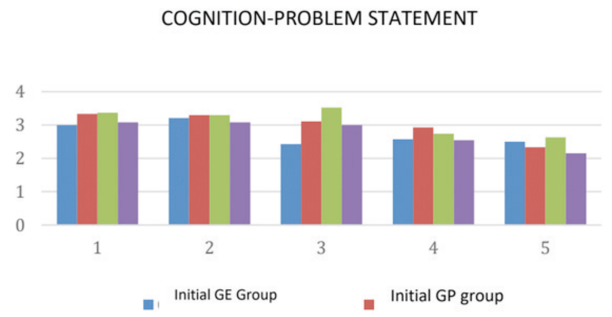
In graph 2, the majority say they use their own notes and/or books to study, however, in the class sessions of the GE group, they were allowed to use their notes when carrying out their activities either as a team or individually., but the situation that was evident is that the notes were not complete, that the notes were not well taken (I only had the literal copy of the blackboard) and that for extra-class activities they sought to rely on Internet pages, looking for problems " similar" to be able to solve them. When they "did not find something similar" they gave up and did not solve the problem, nor did they seek advice from the teacher or any other person who could help them.

3. Survey: METACOGNITIVE PROCESS AND PROBLEM RESOLUTION. The results of the survey are shown based on three categories: 1) cognitive process, 2) execution and implementation of the action and regulation plan and 3) learning control. Category 1 is related to cognition, this part is directly related to the identification of the problem, the requirements and the theory, and the knowledge that is put into play to formulate the problem, what is necessary to integrate the knowledge for the argumentation. and the justification. Table 2 shows the survey criteria involved and graph 3, the survey results in relation to this aspect.

4. I identify the information and data provided to resolve the problem.
5. I identify the information that is required or what the problem demands.
6. I identify the problem.
7. I link the information from the discipline and if necessary from other disciplines with the data and what is required.
8. Once I understand the problem and what is required, I represent the relevant information in schematic form (drawing, diagram, key steps) and then come up with a solution plan.

Table 2: Criteria 1 to 5 of the metacognitive process survey through the methodology of mathematical problem solving.

Source: the own authors.



Graph 3: Cognitive part of the metacognitive process. Category 1. The problem statement.

Source: the own authors.

Before the intervention, it is seen that the two groups, in general, do not formulate a good approach to the problem. In fact, in interviews with students, they argue that they do not state the problem because doing so takes up a lot of their time and they are not used to doing it, so they do not believe it is necessary. Some others comment that stating the problem is repeating the statement literally. What they showed in their activities is that they do not know how to pose a problem, nor how to integrate the information of the data and the requirements, much less make it correspond with the theory.

Regarding the execution of an action plan to solve problems (category 2), the student is required to develop the ability to become aware of the actions he is taking and developing, to ensure that these help him become aware of the way in which that you are learning by considering the comprehensive coherence of your development, the application of theory in practice, and the order and clarity of the communication of your ideas. Criteria 6 to 10 of the survey fall into this category (table 3):

6. I take care that each step is justified and briefly argued with the theory of the corresponding discipline involved.

7. I take care that my development has an order in such a way that if I follow up it is clear.

8. I take care that my development is in accordance with what is required in the problem.

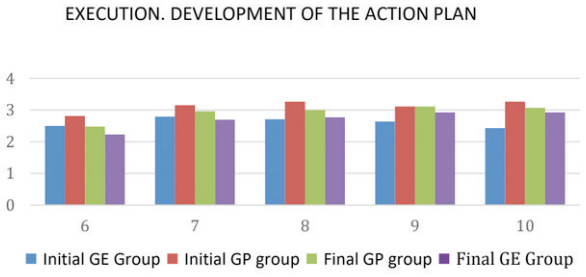
9. I take care that my arguments and justifications are consistent with the approach I made to the problem.

10. During the activity I become aware of the successes and failures I have in achieving the expected goal.

Table 3: Criteria 6 to 10 of the metacognitive process survey through the methodology of mathematical problem solving.

Source: the own authors.

Graph 4 shows the result of the survey in this regard. It is shown that the GP group initially carries out certain activities that at the end of the semester they leave them aside. On the other hand, in the GE group the method is permeating since the students' tendency is to reflect on the activities they carry out in problem solving, in some way they begin to get involved in a part of a metacognitive process, the increase The values of the graph show it.



Graph 4: Category 2. Development of the action plan within the metacognitive process.

Source: the own authors.

With respect to regulation in the metacognitive process, criteria 11 to 17 are shown in table 4:

12. If I work collaboratively, I look for feedback from other people.

13. I reflect on the way I "arrived" at the solution to the problem.

14. I self-evaluate my performance during problem resolution, identifying successes, errors, procedures.

15. I can clearly establish further achievements achieved throughout the problem solving process.

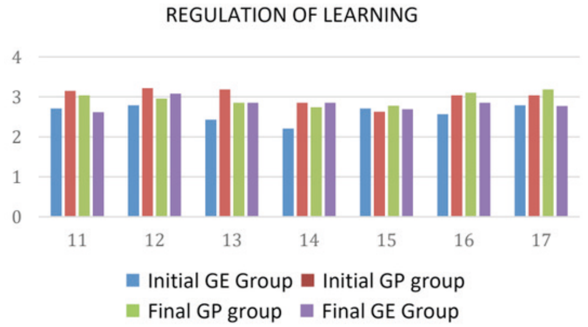
16. I can establish some aspects to improve my performance during a problem resolution process.

17. I promote the best possible situation, which allows me to concentrate and act assertively before, during and at the end of the problem to achieve the final goal efficiently and effectively.

Table 4: Criteria 6 to 10 of the metacognitive process survey using the methodology of mathematical problem solving.11. I check that the solution corresponds with the goals or objectives initially proposed.

Source: the own authors.

Graph 5 is constructed. This third category is associated with the control and regulation of knowledge within the metacognitive process. The teacher must be the guide and facilitator who encourages reflection on the related work and reflected in the criteria of the checklist., this part is very complex for the student because they must learn to be self-critical and critical of their partner's own activities so that they can build their own metacognitive process.



Graph 5: Category 3. Regulation and control of the metacognitive process.

Source: the own authors.

STUDENT*	CRITERIA			
	PERCENTAGE OF WORKSHOPS CARRIED OUT	PERCENTAGE OF TIMES THE CHECKLIST FOLLOWED (12 ACTIVITIES) **	CLASS ATTENDANCE PERCENTAGE (63 TOTAL SESSIONS)	DELIVERY OF PROBLEMS*** (3 IN TOTAL)
Luis	100.00	0.66	96.83	100.00
Gaby	0.66	0.33	84.13	100.00
Micky	0.33	0.00	71.43	100.00

* All three students passed the course.
** The formal activities for evaluation were: 6 workshops worked as a team, 3 problems to deliver and 3 exams.
*** Problem sets were accepted if they contained more than 80% of the problems solved..

Table 5: Students whose production was analyzed.

The production of the students. The action research methodology is rich in the way of validating results since it offers a way to have a greater description of reality by listening to the voices of those involved in the experimental situation. The experiences of the students are of utmost importance since they are the main actors in the phenomena that occur during the educational process of any training institution.

The comments made as student production: interviews and workshops were chosen from the activities of three students, one of them will be called Luis, another Gaby and the third Micky. All of them from the GE experimentation group, the following criteria were followed to select them:

IN CONCLUSION

From the work done by the students and the weakness shown in their knowledge and skills prior to the start of the course, the following is inferred:

1. The need for teachers to work in an articulated manner, to provide feedback on the formation of the same competencies in each subject, so that these are developed gradually, from the beginning of the academic program.
2. A good strategy is to promote mathematical knowledge through solving mathematical problems involving a metacognitive process in parallel to the discipline.
3. An instrument that contributes to the comprehensive training of the student is the checklist built from the socio-formative approach, since it allows integrating into the students' activities a way of self-evaluation and co-evaluation in the cognitive dimension and in the development of values and attitudes such as honesty, responsibility for collaborative work with social commitment.
4. It was evident that one semester is not enough time to promote and develop competencies; these must be nurtured gradually throughout the subjects of the curricular map.
5. These training processes must be promoted through the mediation of the teacher in a relevant, continuous and timely manner. And one way to do this is by articulating the cognitive dimension, the affective dimension and the metacognitive dimension.

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