Educational Intervention using Virtual Reality Glasses and Problem-Based Learning Approach

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***Abstract*— This paper presents the results of a teaching intervention applied to Differential Calculus and Integral Calculus courses for engineering students, using Virtual Reality headsets to conduct practical applications. The objective is to motivate students' interest in their learning and the development of technological skills with these resources, in addition to the generic skills associated with the Problem-Based Learning Approach used. The intervention was applied to seven groups of students from five engineering programs, comprising 277 first- and second-semester students. Various models of Virtual Reality headsets were used, which involved the use of a smartphone. Some of the results show a reduction in the failure rate of at least 20 points, and the dropout rate also decreased compared to the previous year. For most, 95% of students were enthusiastic about using new technologies, which represented a challenge and an opportunity to develop generic and technological skills. Six percent of students remain involved with the projects they generated and have submitted proposals for their own projects.**

***Keywords*— Engineering students, Virtual Reality (VR) resources, Problem-Based Learning Approach, Calculus teaching**

I. INTRODUCTION

This work presents results of experiences with the use of Virtual Reality glasses in first-year engineering students at a technological institution. The above arose from the high failure rates in the calculus courses included in the engineering study plans, and from their attitudes towards studying.

The analysis of causes of failure in the first year of engineering has been carried out at the technological institute -TI- in a consistent manner through the results of the school entrance exam and its relationship with the students' attitudes [1]. Various strategies have been carried out to provide improvement opportunities to new students, either through differentiated entry and a comprehensive preparatory course [2], or to evaluate the informational and digital competencies of teachers [3].

However, academic stress affects student performance and for each one, the influencing factors are different, or cause them to a different degree. Some studies agree that the incidence occurs due to an excess of responsibilities inside and outside the school environment, methodological deficiencies of teachers that include evaluations, beliefs about performance, negative social climate, competitiveness, fear of failure, public interventions, parental pressure, and changes in eating habits and sleep schedules [4] [5].

An educational intervention was proposed that aimed to generate a playful learning environment in Calculus courses of a technological institute or TI. The subjects of Differential Calculus and Integral Calculus using resources such as Virtual Reality glasses -VR- that would motivate interest in the study of mathematical concepts, and that would allow the improvement of their academic performance during the first year of their studies.

VR technologies offer educators the opportunity to handle pastoral responsibilities within the learning context apart from traditionally allocating separate lessons to accomplish specific requirements [6]. It was also intended to open opportunities for collaboration in projects that invited creativity and innovation in responses to engineering problems.

II. ABOUT LEARNING APPROACH

A. Active Leaning Approach

Learning models, technological teaching resources and learning approaches intervene in the development of the student's critical thinking skills. All of this comes together in learning strategies that, under certain conditions, will produce active learning. If this process is done persistently, these critical thinking skills will improve in students. The relationships between these elements are shown in Fig. 1 [7].

In this work, Polya's approach was used to solve a problem or a complex task, with the following stages: 1) understand the problem; 2) determine a plan to find the solution and achieve the objective, considering alternatives; 3) execute the established plan, meeting the needs of strategic decision-making; 4) assess the solution or achievement of the objectives of the problem, not only until the end but at each step or partial objective [8], [9].

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B. Problem-Based Learning PBL

Polya's approach to problem solving is the origin of the approach to learning called Problem-Based Learning or PBL The requirement to make strategic decisions during the problem-solving process makes the difference with a simple exercise or practice. “Problems require the person to make decisions about the process that should be followed, about the techniques that should be used, about the type of solution that is appropriate, etc., while the exercises only require the implementation of techniques or skills, that can become routines through repetitive exercises” [9, p. 47].

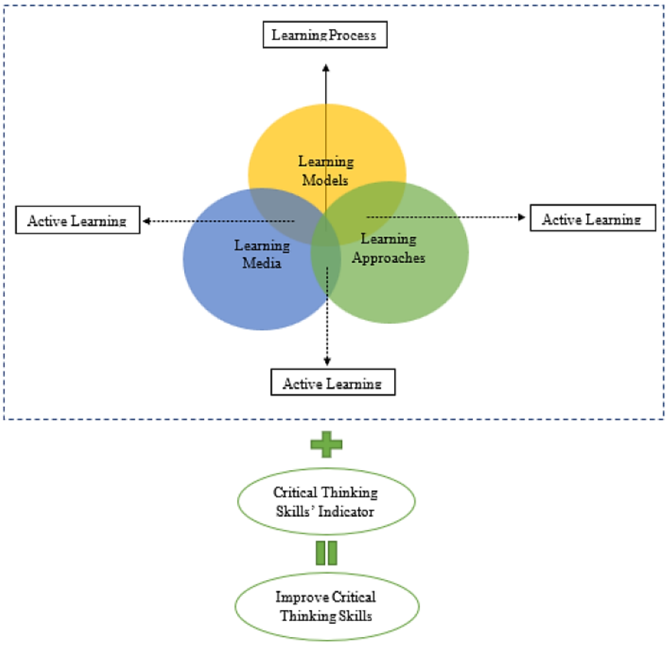

Fig. 1. Factors that improve critical thinking skills [7, p. 2]

However, the design of the problems must be done carefully, essential components such as content, context and the relationships between them must be considered; but also, the process components such as research, reasoning and reflection skills [8], generic competencies that are generally undervalued during the evaluation in engineering training.

It should be remembered that, when it comes to the PBL approach, the skills and attitude requirements of students are as important as prior knowledge. The need to work as a team implies attitudes and values such as responsibility, tolerance, and respect, but also intellectual, technical, and procedural skills to contribute to work planning, the organization of information for decision making, the analysis of data and results, critical thinking, and management of tools and equipment, for example, and even metacognition and self-esteem for independent learning.

The use of the PBL approach forces students to demonstrate sufficient generic and disciplinary competencies to develop and build high-level thinking skills, in line with the demand of the problem [11].

III. EDUCATIONAL INTERVENTION

TI had an enrolment of 6,710 and 7,617 students in each semester of 2019 with 10 engineering programs and 9 graduate programs. Table I shows the enrolment for engineering program in each semester of 2019 and the female/male ratio [14]. The very low female/male ratio stands out for programs traditionally associated with the male gender.

TABLE I. ENGINEERING PROGRAMS ENROLMENT IN 2019

Name	Engineering Program	SP1	SP2	F/M Ratio
IE	Industrial Engineering	1,162	1,454	0.7
ChE	Chemical Engineering	1,144	1,391	1.0
ME	Mechanical Engineering	826	932	0.1
BME	Business Management Engineering	686	821	2.2
GE	Geosciences Engineering	621	512	0.6
EE	Electrical Engineering	587	654	0.1
CSE	Computer Systems Engineering	448	540	0.2
EoE	Electronic Engineering	430	465	0.1
PE	Petroleum Engineering	412	455	0.3
EnE	Environmental Engineering	337	335	1.5
	Total	6,653	7,559	0.5

An educational intervention in the content of Differential Calculus -DC- and Integral Calculus -IC- courses was proposed with the premise of working in a playful learning environment using VR glasses that motivate interest in studying. We used them because it was a novel but accessible technology, and TI professors had not used them. Hypothesis was the academic performance improvement of students under the intervention versus the performance of them without it.

The research questions established for this work were: Does the use of teaching resources such as Virtual Reality glasses in mathematics courses motivate new TI students to learn? Do teaching resources that use Virtual Reality present complications for TI students? What generic skills do IT students develop when they work with teaching resources that use Virtual Reality?

A qualitative and cross-sectional study was carried out, it was developed with the practical design of action research proposed by Creswell (2005, cited by [10]) which involved: the study of students' practices, focused on their development and learning, the development of an action plan using the PBL methodology and under the leadership of the main researcher. This process is flexible and generally has a successive spiral sequence as Sandin calls it (cited by [10]), since after applying it and evaluating the results, feedback is given to reformulate it and initiate a “new spiral of reflection and action” (p. 708).

The work was done in the semesters of January-June 2019 -SP1- and August-December 2019 -SP2- with a convenience sample of four groups from the first semester and three groups from the second semester, from DC and IC, respectively. Table II shows convenience samples: SP1 with two courses for IE -40 students, 7 VR glasses- one for ME -19 students, 4 VR glasses- and one for PE -13 students, 2 VR glasses-. Convenience samples for SP2: one course for GE -21 students, 4 VR glasses- and two for ChE -49 students, 9 VR glasses-.

TABLE II. SAMPLE DESIGN

Courses	Class	Students Women/Men	VR glasses	Engineering Programs
IC-2 Control	2018-1	67 19/48	-	ME/ChE/CSE/IE/ GE/EnE/PE/BME
IC- 4	SP1	72 21/51	13	IE/ME/PE
DC-2	2018-2	68	-	EoE/GE
Control		12/56		
DC-3	SP2	70 37/33	13	ChE/GE

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Table 1 shows also control groups for each semester: IC-2C, and DC-2C. The conditions included same teacher but without VR glasses intervention. These control groups were not at the same time but a similar school period earlier. Teacher Action Plan

The action plan, incorporated into the didactic sequence of each Calculus courses, was developed under the following strategy:

1. Apply the diagnostic test in each of the groups.
2. Develop the first units of the program in the same way as has been done in the last three years.
3. Use the PBL methodology in unit 5 of the DC program and in unit 3 of the IC program, referring to the applications of Calculus.
4. Evaluate the results of the PBL methodology and propose adjustments to it for the next school year.

The teaching resources available for the PBL approach were VR glasses that require a smartphone to use, eight of them made of cardboard like those recommended for the Google Cardboard platform, and four of different brands and with different capacities and accessories. –see Figure 1- in addition to one that the students provided.

Fig. 1. Virtual Reality glasses used [16].

The activities included under the PBL approach for the Calculus application units were:

i. Present the VR glasses they had to each group.
ii. Discuss the usefulness of VR devices to solve engineering problems.
iii. Raise the need to operate as a team to look for VR applications that allow them to strengthen some knowledge, that is, remedy deficiencies that they detected in that semester.
iv. Make a record of teamwork to solve the problems raised, both written, and photographic.
v. Present the experience to the entire group in person.
vi. Submit a report with a minimum of content defined by a rubric, with a summary on the use of VR in the professional field of their career.

A. Limitations and Delimitations

It should be noted that from SP1 to SP2 changes were made to the aforementioned methodology. During SP1, VR applications were restricted to mathematics topics. After that experience, and to expand the richness of the contributions, the SP2 students were instructed to identify areas of opportunity to improve their learning in that school year, to look for an alternative to improve them using the resources of VR.

Educational intervention limitations included the impossibility of having the same engineering programs students both school periods but similar, nor the same kind of VR glasses.

All information was recovered from the teams' presentations to the entire group, and from the reports that were requested from them. The reports had to include the elements shown in Table III. In addition, a detailed observation was carried out on the soft skills developed during problem solving and the students' attitudes towards the challenges of the different stages.

TABLE III. CHECK LIST FOR REPORTS

Category	Characteristics
Identification	App name, URL, developer, license type
Content	Classification and scope
Usage guidelines	General procedure and recommendations
Notes on use	Comments and experiences of the App users
Conclusions	Perception on educational intervention using VR

At the end, a comparison was made between the averages of the approval rates of the intervened groups in each school period against those corresponding to the control groups of the previous year.

IV. RESULTS AND DISCUSSIONS

The most important findings of the educational intervention are shown in tables IV and V, where they were classified by semester, by engineering program and by course. It is worth remembering the difference between the methodology applied in SP1 and SP2, since in the latter they were allowed to choose the VR application related to their career.

In all cases the teams provided a very illustrative summary of the most important applications of VR devices.

A. Findings

Qualitative findings of the educational intervention are presented in Table IV corresponding to the 2019 first semester courses or SP1.

TABLE IV. FINDINGS IN FIRST HALF OF 2019

Qualitative Findings for Integral Calculus Students
Industrial Engineering, 40 Students, 7 Teams
They showed interest, willingness, commitment, and teamwork. One of the teams purchased their own VR glasses. The applications presented were: one for primary school children, three for secondary and high school students, and two for undergraduate students. A team showed the *Buckeye VR 3DPlot Viewer* application [10] aimed at students of physics, mathematics, and various areas of engineering. It requires a good level of English language and a certain programming background to operate. The application itself recommends using an Augmented Reality helmet. Another team preferred *Medieval Math* VR [17], a video game that primarily includes arithmetic and geometry content. The students found it fun and adaptive, using artificial intelligence to advance each user. Strengthens strategic thinking skills, but also mental calculation.
Mechanical Engineering, 19 Students, 4 Teams
They showed interest, willingness, and commitment. They worked as a team and proposed 3 applications related to basic arithmetic operations for basic education children. One of the teams tested the app with a 9-year-old girl. The fourth team presented an application aimed at teachers and students of Multivariable Calculus, *CalcVR Calculus in Virtual Reality* [11], and although they only knew some of the topics, they expressed their surprise that these glasses were used for more than just video games The students liked the "touch of fun" in learning mathematics.
Petroleum Engineering, 13 Students, 2 Teams
They showed interest, taste, creativity, great disposition, and teamwork. One team presented an application to learn mathematics, aimed at children from 6 to 13 years old. The other team chose the *VRMath* application [19] focused on the visualization of 3D objects for mathematics courses. Both teams prepared their user manual and added recommendations. One of the teams presented the results of their social project on their task. They tested the *VRMath* application on two children aged 8 and 9, a 36-year-old mother, and an older adult aged 62 and recovered their testimonies. These show the innovative perception of this way of learning, and adults say, "it would be very useful if this method were implemented in schools."

As can be read in the findings, the freedom to work with VR glasses under the sole condition of searching for applications that benefit learning in mathematics produced diverse initiatives. These involved everything from testing these technological resources with children, young people, and adults, to an application for advanced knowledge of physics and mathematics for engineering, but in English. The care they took to generate their report with the evidence of the process showed everyone's participation in the project, and the pleasure in sharing it.

Table V shows the qualitative findings from the 2019 second semester -SP2- of the intervention. Students were instructed to look for answers to the problems they had in any of the subjects they took not only for their learning problems in mathematics. This opened unimagined possibilities for the lead researcher who was her Calculus teacher.

TABLE V. FINDINGS IN SECOND HALF OF 2019

Qualitative Findings for Differential Calculus Students
Geosciences Engineering, 21 Students, 4 Teams
They showed interest, willingness, commitment, creativity, initiative, leadership, and teamwork. Two teams proposed a project to strengthen a laboratory in their career by generating VR content, even recording 360° videos as a test of what they could do. This initial proposal continues to be strengthened as it was presented at the Science Fair, and two projects have been structured and submitted to external financing. Furthermore, a creative contribution from this group was an interesting story for the generation of a video game.
Chemical Engineering, 49 Students, 9 Teams
They showed interest, willingness, initiative, leadership, and teamwork. The applications presented were 3 from Chemistry and one from Mathematics, which suggests a greater need for support for the science that underlies their career. it is interesting that most of the students decided to seek support for their Chemistry course. In particular, the application demonstrations were very attractive: *MEL Chemistry VR*, a basic English App whose creators are related to the Chemistry Olympics [12]; and *Learning Macromol VR*, an advanced Swedish App created by an educational start up on a molecular modeler [18]. Their presentations were a hit with all the students.

In this case, the students were in their first semester of engineering, very close because each group has the same subjects at the same time. A different situation with IC students who already have different class schedules and with some different subjects. This changes the dynamics of the group, since it is not easy for them to find coincidences in the times to work together.

In this SP2, the dynamics of working with the VR glasses changed to open the possibilities for any type of benefit that they considered important for their career, not just for their mathematics courses. The findings show GE students with great creativity and initiative, who see opportunities to contribute with the virtual laboratory. On the other hand, ChE students were very sensitive to the need to strengthen their learning in Chemistry, which was very successful among their peers.

B. Learning Evaluation

The academic performance of the students in the sample and the control groups is shown in Table VI, through the average of the passing rates in the courses per school period.

TABLE VI. ACADEMIC PERFORMANCE PER SCHOOL PERIOD

Courses/ Class	Approval Rate	Students Women/Men	VR glasses	Engineering Programs
IC-2C 2018-1	73%	67 19/48	-	ME/ChE/CSE/IE/ GE/EnE/PE/BME
IC- 4 SP1	96%	72 21/51	13	IE/ME/PE
DC-2C 2018-2	67%	68 12/56	-	EoE/GE
DC-3 SP2	87%	70 37/33	13	ChE/GE

Table VI shows the significant improvement in approval rates in the groups subject to the intervention, with respect to the control groups. In IC, it grew 23 percentage points, while in DC, it was 20 points. Greater integration was also observed among students, which allowed learning to be improved through collaborative work.

C. Discussions

During 2018, the population served by the researcher was 135 students, like the population served during the educational intervention of 142. However, the composition of the control groups in IC was eight majors offered by the IT, while which during the educational intervention was only three.

The results of the educational intervention are considered successful since it was identified that the use of resources such as VR glasses motivate students to study. These resources that use technologies that have not been available to most students

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were not identified as complicated, rather they took it as a challenge in the sense that it led them to improve their skills.

The generic competencies developed: teamwork, the search for information and its adequate organization, the essential leadership to organize tasks, the oral and written presentation of their proposals and findings, and of course, the recognition of the talents of each one to take advantage of them in common work.

It is very important to emphasize the remarkable joy of working with devices or equipment that they had never had at hand, of playing with them, learning, and developing skills under this PBL methodology. Situation from which proposals for projects after this one presented have been derived.

In addition to the above, the approval rates for the groups intervened during 2019 have been significantly higher -20 to 23 percentage points- than those presented in 2018.

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