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Using Microdrones and Problem-Based Learning with Engineering Students

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ABSTRACT
This work presents the results of an educational intervention applied in Calculus courses for engineering students, using microdrones to carry out application practices. Its objective was to motivate students' interest in their learning, and the development of technological competencies with those resources, in addition to the generic ones associated with the Problem-Based Learning approach used. The intervention was applied to six courses from four engineering programs with 70 first and second semester students. Various models of microdrones were used, most without a built-in camera. Results included students' improvement in at least 16 percentage points in similar classes for IC courses, while for DC course it was 19 percentage points. Students were enthusiastic (91%) about using new technologies for the majority, which represented a challenge and an opportunity for the development of generic and technological competencies.

***Keywords* –** Calculus courses, engineering students, microdrones, PBL approach

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I. INTRODUCTION

This paper presents results of experiences with the use of microdrones in first-year engineering students at a technological institute (TI) in Mexico. The foregoing, based on the high failure rates (33%-83% by 2015) in Differential Calculus courses included in the engineering curricula [1] and their attitudes towards study. The analysis of causes of failure in the first year of engineering students has been carried out in the TI, by using the entrance test results [2], and their relationship with the students' attitudes [3]. For this reason, various strategies have been carried out to provide opportunities of improvement in their academic performance.

Several studies indicate that the transition from high school to undergraduate students involves situations that place them at risk of dropping out and that must be addressed. Some of them adapt more easily than others to change, but all have different experiences with classmates, friends, teachers, cultural norms, and new content, which are sometimes full of shocks, ambiguity, and uncertainty [4].

Academic stress also affects student performance, but in a different way, or to a different degree of stress. Some studies agree that it is presented by excessive responsibilities inside and outside the school environment, methodological deficiencies of the teaching staff that includes evaluations, beliefs about performance, negative social climate, competitiveness, fear of failure, interventions in public, pressure from peers, parents, and changes in eating habits and sleep schedules [5].

Likewise, "the introduction of mathematical concepts is motivated by (grade appropriate) real-life applications which may include student action on objects leading to formal description of this action through the symbolism of mathematics" [6, p. 73]. In this case, the choice of the Problem-Based Learning approach combines action activities with challenges to solve problems. It is about motivating students to get involved with a technological challenge.

1.1 Problem-Based Learning Approach

The Problem Based Learning (PBL) approach spread through its use at the McMaster University School of Medicine in Canada [7] in the

1970s, but its description is based on Polya's proposal in 1940 on the solution of mathematical problems [8]. This learning approach has been sustained over decades in many educational institutions around the world and has evolved towards different models and practices such as the cases of learning based on teamwork, self-directed learning, and contextualized learning [9].

The stages established by Polya to solve a problem or a complex task are: 1) understand the problem, be clear about the objective or goal; 2) determine a plan to find the solution and achieve the objective, considering alternatives or varied techniques; 3) execute the established plan attending the needs of strategic decision-making, either in the techniques used or in the objective initially established; 4) assess the solution or achievement of the objectives, not only at the end but at each step or partial objective [10], [8].

Therefore, problem design must be done carefully, and essential components such as content, context, and relationships must be considered; but also, the process components such as research, reasoning, and reflection skills [11]. Students can face a problem when they are endowed with the basic knowledge and technical and strategic skills that they will eventually require [8]. A teacher must try the previous exercises that guarantee such a situation in his students, otherwise they will not be able to control and solve the problems presented, and the motivational aspects intended will be nullified, and unnecessary and negative stress could be generated.

PBL approach forces students to demonstrate sufficient generic and disciplinary competencies to develop and build high-level thinking skills, consistent with the demand of the problem [12]; and it could have "psychological or emotional effects on students' development of ownership, relatedness, and in turn, their engagement and motivation to solve the problem and study the learning materials" [11, p. 6].

Hung proposed a rigorous and detailed 9-Step PBL Problem Design Process "for students to be able to acquire and construct the intended knowledge on their own terms" [11, p. 3], but in this work we preferred a free form of inquiry for students with Polya stages proposal [10].

II. EDUCATIONAL INTERVENTION

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 microdrones that motivate interest in studying. We used microdrones because it was a novel but accessible technology, and TI professors had not used them for educational purposes. Hypothesis was the academic performance improvement of engineering students under the intervention versus the performance of the students without it. Research questions: Does the use of microdrones for teaching in mathematics courses motivate TI students to learn? Does the use of microdrones for teaching present complications for TI students? What generic competencies do TI students develop when they work with microdrones? Does PBL improve student performance?

We decided to carry out a qualitative study through action research to study the educational situation "with a view to improving the quality of action within it" (Elliot, 1991 cited in [13], p. 706); and, from the perspective of a technical-scientific vision, it was developed with sequential phases: planning, identification of facts, analysis, implementation, and evaluation (idem).

An educational intervention based on the PBL approach was designed, developed, and applied using microdrones in Calculus courses with first-year engineering students, to identify the benefits in their learning process, in particular their generic competences and their attitudes towards study, and thus impact by incorporating playful and challenging elements.

We worked in the school periods of January-June 2019 (SP1) with 31 students, and of August-December 2019 (SP2) with 39 students. Table 1 shows convenience samples: SP1 with two IC courses, one for Industrial Engineering (IE, 18 students, 3 microdrones), and one for Mechanical Engineering (ME, 13 students, 2 microdrones). Convenience samples for SP2: one IC course for Electrical Engineering (EE, 11 students, 2 microdrones), and two DC courses for Chemical Engineering (ChE, 28 students, 4 microdrones). IC-2 had more difficult than IC-1 by the repeating percentage.

Table 1 shows also control groups for each of the sample (IC-1C, IC-2C, DC-2C). The conditions included same teacher but without microdrone intervention. These control groups were not at the same time but a similar school period earlier.

Educational intervention limitations included the impossibility of having the same engineering programs both school periods, nor all the same math course, and not the same kind of microdrone.

Table 1. Comparative entrance indicators by Calculus course, scholar period and engineering program. Source: Own.

Course	Class	Students	Repeating	Programs
IC-1C	2018-1	25	0%	ME/IE
IC-1	SP1	31	0%	ME/IE
IC-2C	2018-2	14	64%	All
IC-2	SP2	11	38%	EE
DC-2C	2018-2	37	0%	EoE
DC-2	SP2	28	0%	ChE

Educational resources available from researcher: 4 microdrones for the IC-1 without a camera, two very small for ME students (Fig. 1 and Fig. 2) plus one provided by an IE team (Fig. 3); for DC-2, two built-in camera microdrones were added for ChE students (Fig. 4) and one of them also contributed by a ChE team. The two very small microdrones were assigned for EE teams with the hypothesis that they would have greater technological competences than IE teams.

Figure 1. Microdrone for ME and EE teams. Source: Own.

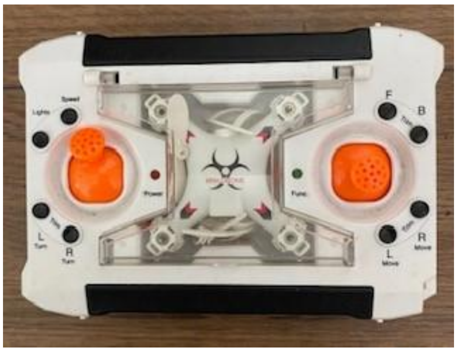

Figure 2. Microdrone for ME and EE teams. Source: Own.

Figure 3. Microdrone for IE and ChE teams, Source: Own.

Figure 4. Microdrone for ChE teams. Source: Own.

PBL approach was developed under the following strategy: i) apply the diagnostic test; ii) develop the first units of the program content in the same way as in the last three years; iii) use the PBL approach in Calculus applications, the last unit of the program content; iv) evaluate the PBL approach and propose adjustments for the following courses.

The activities for PBL approach: a) presentation and selection of the microdrone; b) commitment to teamwork with microdrone and use it to follow a previously defined objective, according to the course topics; c) implementation of the PBL and preparation of a teamwork record of the problems raised with photos and video; d) presentation of the experience to the class and on a video posted on YouTube.

According to the strategy, from SP1 to SP2 changes were made to the PBL approach. During SP1, they were not asked to make the microdrones video; for SP2, teams had to work on a video and use social media.

Some of the objectives of the teams were to define a trajectory from a mathematical function and follow it with the drone.

All the information was recovered from the students' team reports, the researcher's checklist and rubric for the follow-up and works' evaluation, and the researcher's observations. In addition to the intervention's qualitative analysis, we compared the results of the students' performance against their peers from a previous year, with two exceptions: ChE courses vs Electronic E (EoE) course, and EE course vs All programs' course -see Table 1. However, the characteristics of ChE students are like those of EoE according to previous studies [3].

III. RESULTS AND DISCUSSION

The most important qualitative findings are shown in Table 2. All microdrones were different, but there were no major complications in their use, teams looked for different resources to play them, with 91% of the teams motivated.

Table 2. Qualitative findings by engineering program and Calculus course. Source: Own.

IC-1 IE IC 18/3	18 students / 3 teams showed interest, emotion, teamwork, and great disposition. One of the teams donated a microdrone. The three teams prepared a good manual to use the equipment and made recommendations for better use based on their experience. They expressed their satisfaction since none of them had previously operated a microdrone; they found it very interesting because *we faced the challenge of operating the drone with a slightly high degree of complexity*, they said.
IC-1 ME IC 13/2	13 students / 2 teams showed interest, disposition, teamwork, commitment, and resourcefulness. One of the teams was assigned a very small microdrone that had a flaw, as the cable to recharge the battery had been misplaced. They investigated, they went to a TI laboratory to make some tests, changes, and adjustments, they even made a piece, but finally managed to get it to work well, and they did their practice very satisfied with their accomplished objective, which represented a double challenge.
IC-2 EE IC 11/2	11 students / 2 teams showed little motivation to work. They were assigned the oldest and smallest microdrones and one of the teams failed to make it work. This, even though they were the same devices that the SP1 ME students used successfully. It was observed that they did not work as a team or were committed or had initiative. They stopped attending the presentations. Several of them did not approve the course. The other team worked effectively.
DC-2 ChE DC 28/4	28 students / 4 teams showed interest, emotion, initiative, creativity, leadership, commitment, and teamwork. One team contributed with their own microdrone, and another chose a microdrone with an integrated camera. This last team lost the microdrone in the first practice, but they organized to buy another one and do the practice. All students enjoyed this challenge; they can be seen on videos which highlights the joy and fun.

Another public evidence for those funny Calculus practices with the microdrone can see on next links:
https://www.youtube.com/watch?v=R9PzrOLN_f8
https://www.youtube.com/watch?v=7DOU8ljxs7c

All teams met the mathematical objectives involved in the activity, with the exception of the EE team mentioned above.

Table 3 shows approval indicator with students' improvement in at least 16 percentage points in similar classes for IC courses, while for DC course it was 19 percentage points. Attrition rates also decreased for all cases. However, it should be clarified that between 2018-2 and SP2 classes the composition of the courses included repeating students from all the engineering programs, which implies a difference in the qualities and competences of the students' sample, as observed in Table 3 with average diagnostic test (ADT) and repeater students.

Table 3. Comparative indicators by Calculus course, and engineering program. Source: Own.

Course	Repeating	ADT	Approval	Dropout
IC-1C	0%	41%	72%	16%
IC-1	0%	40%	96%	4%
IC-2C	64%	38%	57%	36%
IC-2	38%	21%	73%	9%
DC-2C	0%	45%	73%	19%
DC-2	0%	35%	92%	11%

IV. CONCLUSIONS

The results are considered successful. We identified that the use of resources such as microdrones motivate students to study, since of the 11 teams where it was carried out, only one team showed apathy and disinterest. These technologies have not been available to most students, but they did not find them complicated; they took it as a challenge that prompted them to acquire other skills.

The generic competences developed: teamwork, search for information and its proper organization, leadership for the organization of tasks, oral and written communication of proposals and findings, and the recognition of the talents of each one to take advantage of them in the common work that involved the metacognition. In addition, the performance of the students improved in all cases, not only due to approval but also due to lower dropouts.

In addition, their joy of working with those devices, of playing with them, learning, and developing skills under this PBL approach was remarkable, which improves their self-esteem. The training of engineers was strengthened by these activities and challenges. We created "a more effective learning environment and also enhances the problem-solving capability of learners" [14, p. 223], and we managed to motivate most of the students to work on math activities without them being tedious or boring.

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