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A first year design experience based on SAE Aero Design contest to support ABET learning outcomes and engineering vocation in freshmen students

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A first-year design experience based on SAE Aero Design contest to support ABET learning outcomes and engineering vocation in freshmen student

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Abstract - **The a-k outcomes established by Accreditation Board for Engineering and Technology (ABET) for Engineering students in their self-assessment framework, should be reflected in the different subjects that taught to the students of the first two years of the various engineering programs. On the other hand, in those first semesters, the vocation of the students about the different Engineering is not very well defined. This experiment shows a proposal that links the results of ABET with an international student competition such as Society of Automotive Engineers (SAE) Aero Design, to reinforce and guide the new students in their future choice of specialization in the School of Engineering. We also show the relationship between the challenges and problems in the SAE Aero Design competition for new students and ABET's a-k outcomes. We show the results obtained with nineteen students over three years. It is important to mention that none of the students involved in this experiment comes from Aeronautical Engineering (or similar to it).**

Index Terms – ABET outcomes, Engineering vocation, Learning problem based, SAE Aero Design contest, Self-learning based on real problems.

INTRODUCTION

A paper written by Johnson and Sheppard showed that over 30% of first-year engineering students do not finish with a degree and only 8% of all students enrolling in a four-year college chose an engineering program in the USA. This problem is very similar in Mexico, is critical to focus on first-year engineering education and to enhance the students' commitment to graduate with an engineering degree [1]-[3].

The Universidad Panamericana is a young private university with 50 years of creation. It has three campuses in the main cities of Mexico: Guadalajara, Aguascalientes and Mexico City. The School of Engineering at Mexico City has 36 years of creation and offers the following Engineering programs: Industrial, Mechanical, Innovation and Design, Mechatronics, Information Technology and Digital Animation.

The undergraduate programs, mentioned above, have a duration of 4 years divided into semesters. These semi-annual periods run from August to December and January to June. Approximately 900 students enrolled in these engineering programs.

All Engineering programs have shared Mathematics and Basic Sciences subjects such as: Differential Calculus, Integral Calculus, Algebra, Vector Calculus, Differential Equations, Electricity and Magnetism, Physics, Chemistry and other courses of academic areas of humanities and businesses.

The programs of School of Engineering has accredited since 2000 by the Council for Accreditation of Teaching Engineering (CACEI, by its initials in Spanish). Since 2009, our programs are accredited by Engineering Accreditation Commission (EAC) of ABET.

ABET LEARNING OUTCOMES

ABET accreditation gives assurance that a college or university program meets the standards of the profession for which program prepares graduates. Four accreditation commissions develop the ABET accreditation process; each committee sets accreditations standards for specifics program areas and degree levels. Each program that requires a certification will be assigned to a particular commission or various commissions, take into account the name of the program.

EAC commission accredits all of our programs. Programs accredited by EAC review must include, in the program name, the word engineering. EAC accredits programs a bachelor degree and master degree. A program must formulate the program educational objectives (PEO) that address program and institutional mission statements, to comply with the EAC engineering criteria.

Various program stakeholders express in meetings, interviews or surveys, their interests about the students and then the program will write PEOs to satisfy these. Then, the program must formulate a set of program student outcomes (PSO) (knowledge, skills, attitudes) that directly address the educational objectives and have specific outcomes. These PSO must be the ultimate goal acquired by the students when they complete the bachelor program. Table I show the PSO in EAC commission [4].

It is important to highlight that PSO "e" that addresses effective communication, which for our programs in Engineering School, is not only the effective communication in Spanish (which is our mother tongue) but also the effective communication of our graduates in English.

With PSO shown in Table I, the next step is to identify a set of courses in the curriculum to address the knowledge, skills, and attitudes specified in the outcomes. To know how

TABLE I

EAC PROGRAM STUDENTS OUTCOMES

PSO	Description
a	An ability to apply knowledge of mathematics, science, and engineering.
b	An ability to design and conduct experiments, as well as to analyze and interpret data.
c	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
d	An ability to function on multidisciplinary teams.
e	An ability to identify, formulate, and solve engineering problems.
f	An understanding of professional and ethical responsibility.
g	An ability to communicate effectively.
h	The broad education is necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
i	A recognition of the need for, and an ability to engage in life-long learning.
j	A knowledge of contemporary issues.
k	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

and where program outcomes are covered in the curriculum, a course assessment matrix might be constructed [5].

The first column is assigned for each PSO (one by row) and other columns with each program´s courses related with this PSO. In each cell, we wrote 1, 2 or 3. These numbers inserted in each cell of the matrix indicate respectively that a course addresses an outcome: slightly, moderately or substantively. Table II shows our matrix. We show only cells that are common for our five engineering programs in a first year.

As we can see in Table II, all these subjects have a high rate of failure in engineering students. Since difficulty or failure in mathematics and science is one reason, students leave engineering during their first year, if program leads to improve student performance in these topics, is expected to have a positive effect on freshman engineering retention. [6]-[7].

It is well known that the initial phases strongly influence the outcome of any process. This previous sentence is also true in the development of engineers.

The first year of any engineering program is crucial for building an educational foundation that will serve to transform the student into an engineer. In much the same way, a first-year engineering program is also essential for the successful transition of the student from first-year into the second year and so on [8].

WORKSPACE TO SUPPORT LEARNING OF MATH AND SCIENCE BASED ON SAE AERO DESIGN

During four years in the School of Engineering of the Universidad Panamericana, we conducted an experiment to support the learning of Mathematics and Sciences.

The purpose we want to achieve is not only to reduce the students' failure rate in these courses but also to improve other skills that are required by EAC PEOs.

TABLE II

COURSE ASSESSMENT MATRIX

PSO	Algebra	Differential Calculus	Integral Calculus	Vector Calculus	Differential Equations	Chemistry	Physics	Electricity and Magnetism
a	3	3	3	3	3	3	3	3
b						3	2	3
c						3	1	2
d							1	1
e	3	3	3	3	3	3	2	3
f							1	
g							1	1
h							1	
i							1	
j							1	
k						3	2	2

Among these skills we can mention for example:

- Conduction of experiments.
- Elaboration of mathematical models to simulate a problem.
- Use specialized software for simulation.
- Develop schemes and designs for the following construction of a scale model.

With previous antecedents, we call the students of new entrance to participate in the team of the School that will compete in SAE Aero Design [9]-[10].

These students who are invited to take part in these competitions are not required to have any previous prerequisites for their performance in high school, nor are they given financial support for participating in this contest. It is important to highlight that all of them come from engineering programs that are not related to Aeronautical Engineering, for this reason, the knowledge they need for participating in the competition is taught throughout the first year of their studies.

The Aero Design competition is held annually. Competition is in the USA and has two places: one in East and other in the West region. Each of this contest takes place in March or April. The past four years competition located in Los Angeles, California, Fort Worth, Texas and Lakeland, Florida.

The Aero Design competition need the student teams: to conceive, design, manufacture, test and fly a radio controlled aircraft (the pilot must be certified by Academic of Model Aeronautic in the USA). We prefer a professional pilot because this way the students focus their efforts on other goals of the contest. Moreover, is very hard learn to fly a model with a high-level expertise in this short period.

The competition has three categories: micro, regular and advanced class. The distinguishing differences between classes are: size and weight of the airplane, propulsion by an electric engine or internal combustion engine, rules about takeoff and landing, and the most notably is about the missions that the model need to complete [11].

The competition has three stages: Technical Written Report on the design and construction of the model, Oral Presentation, and Flight Tests. The written report contributes 45 points and the oral presentation 50 points.

The requirements of the advanced class are the following:

- All equipment uses one or more two-stroke engines whose sum of displacement does not exceed .46 cubic inches. The model can not have any other propulsion system such: balloons, rockets, compressed gas impellers and other.
- The full size of the runway can be used to take off and land.
- The airplane has to transmit video in real time from the model to the station on land.
- The model must load as much static payload as possible. The team can drop one or more loads of 2 pounds from a minimum height of 100 feet (humanitarian charges).
- The model must have a data acquisition system (for example based on GPS) and transmit at all times the height.
- The pilot flies the plane visually, and another member of the team drop the humanitarian charges.
- In each flight round the team has 180 seconds to start the engine, to verify that the GPS and video data are transmitted correctly and take off. After that time the flight is considered to be unsuccessful.

The flight test score is given by (1):

$$\text{Final Flight Score} = 4\left(\frac{1}{N}\sum_0^N FS\right) - \sum T \qquad (1)$$

N is the total of rounds of flights. Flights are carried out for two days after the oral presentation and technical inspection of the airplane.

If during the technical review the judges detect some discrepancy between the measurements written in the technical report and the aircraft that presents the equipment, points are subtracted to each flight. *T* represent these deducted points for each flight.

FS represents the team score in each of the flight attempts considered valid by the judges and is calculated with (2):

$$Flight\ Score = S_p + \left(S_p \sum Z_m\right) \qquad (2)$$

TABLE III
VALUES FOR MULTIPLICATION FACTOR Z_M

Zone	Minimum distance to Target	Maximum distance to Target	Factor value
1	0 ft	15 ft	1.00
2	15 ft	30 ft	0.75
3	30 ft	45 ft	0.50
4	45 ft	60 ft	0.25
5	more than 60 ft		0.00

S_p is the total static payload lifted by the airplane in pounds and Z_m is called zone multiplier, and it is related to the humanitarian loads that hit the ground target as we can see in Table III.

For each of the humanitarian charges *m* that impact the target, the values listed in Table III are taken and summed. For example, if two humanitarian loads hit Zone 1 and one hits Zone 4, the multiplication factor will equal 2.25.

As we can see in the design of the aircraft students must select the best configuration between the amount of static payload and how many humanitarian charges will be dropped in each flight round. This problem example was raised to students with a simulation model to find the best configuration.

To comply with all the requirements of the competition and have a plane ready to fly, we begin to work with students from July to March or April (depending on when SAE schedules each two competencies: East region and the West region).

The month of July is Mexico is a vacation period for students, but those engaged in this contest begin work during this holiday period.

Mainly this first month is used to carry out the following tasks:

- To teach students basic knowledge of aerodynamics.
- To train students in the management of software for engineering design like SolidWorks.
- To teach students stability and aerodynamic control
- Instruct students the basic techniques for building models.

The fall period begins in the first week of August and runs through the first week of December when the winter break begins. The Spring period starts in January and runs through the end of May.

When the class period begins, the project students join the same activities as the rest of the students and spend several hours in which they do not have academic or extracurricular activities scheduled to work on the SAE Aero Design project.

In every year the team members have dedicated many weekends during the class period to work on this project. For example, the team that participated in the 2017 edition worked 1400 hours on average in the SAE project and spent about 300 hours per student self-study the new subjects required by the contest.

TABLE IV
ACADEMIC RESULTS OF SAE AERO DESIGN TEAM

Academic Program	Students	Program progress	Average Grade	Math & Science fail	Total courses fail
IND	2	41	A	0	0
MEC	9	40	B	4	5
ITD	4	70	B	4	7
INN	3	48	B	1	2

RESULTS AFTER THREE YEARS

The Table IV show grouped students by similar curricula in their academics programs, taking into account only Math and Science courses, with the next distribution:

- Industrial Engineering Program (IND).
- Mechanical Engineering Program and Mechatronics Engineering Program (MEC).
- Information Technology Engineering Program and Digital Animation Engineering Program (ITD).
- Innovation and Design Engineering Program (INN).

In Table IV the column entitled "Program progress" is the percentage of courses approved in relation to the total of subjects that the student should complete to obtain his bachelor's degree studies.

We also show the overall average. It is necessary to clarify that the grades in the Universities of Mexico are done on a scale of 10 points, and if the grade is inferior to 6.0, the course is considered failed. For clarity, we have converted Mexican grades to the usual system of Universities in the USA [12]-[13].

As can be seen in Table IV of the total of subjects failed by students, 64% correspond to topics in the area of Mathematics or Basic Sciences.

About the total number of students participating in the experiment, 36% did not pass the first time they took a Mathematics or Basic Science course, achieving a passing grade on the second attempt. It is also crucial to note that none of the students who failed courses have dropped out of engineering studies, and 36% of them have completed more than 85% of their engineering program, and 16% of them have completed more than 60%.

Differential Calculus, which is taught in the first semester of the curriculum, was the most failed subject with 33% of the cases, followed by Physics and Algebra with 22% each.

Figure 1 shows the percentages of failures of the students in the school, compared to the students who are on the SAE team.

We can see in Figure 1 that the team students have the same difficulties as the rest of the students of the school. As we can see in Figure 1, percentages of failure are high on

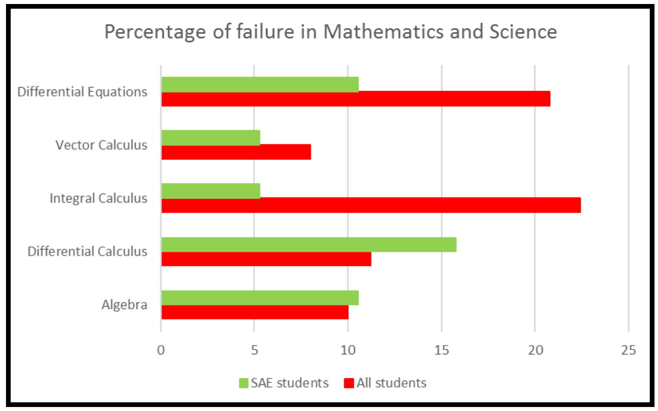

FIGURE 1
COMPARISON OF FAILED RESULTS OF THE STUDENTS OF THE SAE TEAM AND ALL THE STUDENTS OF THE SCHOOL.

these subjects of the program of study as compared with others areas like as: humanities, applied engineering, the science of engineering, etc.

These problems with first-year students are consistent with the results about the quality of High School programs. The standardized tests applied by some agencies (like The Organisation for Economic Cooperation and Development, OECD) to measure students' academic achievement show not very favorable results, such as the International Program for the Evaluation of the Individual (PISA by initials in Spanish). According to the PISA in 2012, the results of mathematics, science and reading development showed that:

- 55% of students did not reach the level of basic competences (level 2) in mathematics (23% OECD average)
- 41% of Mexican students did not reach the basic competency level in reading (18% is the average in the OECD)
- 47% of the students did not reach the level of core competences in science (the average in the OECD is 18%).

The biggest concern with first-year students is that if they engage in extracurricular activities (sports, cultural activities or student competitions) they neglect their commitment to academic activities and reject subjects that make them drop out of engineering studies.

The results of the students show that the vocation for the engineering is also increased, the students learn to manage better their study time and to use their time efficiently.

It is noteworthy that of the participating students, 26% have averages above 9/10 points (A+ in USA grades) and 47% averages above 8/10 points (B+ in USA grades). The remaining 27% is at its average close to 8/10 points (B in USA grades).

Table V shows the results of the students in the subjects of oral and written expression in Spanish language. We also show the results of the SAE team students on the TOEFL test (Test of English as a Foreign Language).

TABLE V
GRADES OBTAINED IN SPANISH AND ENGLISH

Academic Program	Students	Spanish	English
IND	2	A	75
MEC	9	A	97
ITD	4	B	91
INN	3	A	83

TOEFL is a standardized test to measure the English language ability of non-native speakers wishing to enroll in English-speaking universities, and it is accepted by many English-speaking academic and professional institutions.

Table V shows the results of the students in the subjects of oral and written expression in Spanish language. We also show the results of the SAE team students on the TOEFL test (Test of English as a Foreign Language). It is a standardized test to measure the English language ability of non-native speakers wishing to enroll in English-speaking universities, and it is accepted by many English-speaking academic and professional institutions.

More than 10,000 institutions in over 130 countries accept TOEFL scores. Normally 79 or more point is the minimum grade required to said that one student has an ability to communicate in English. As you can see in Table V, 90% of SAE students achieved this minimum grade. In School of Engineering, all students need to pass TOEFL test when they arrive at the four years of theirs engineering program.

The outcome "g" is "an ability to communicate effectively", in this sense it is important to note that 74% of students already have passed the TOEFL IBT test with an average score of 86/120 points.

It is important to know that all communication in the SAE contest is conducted in English, which is an excellent way to practice their communication skills in a non-maternal language. Also, their average in matters related to writing and oral expression in Spanish is 8.7/10 points, which is higher than average grade.

Figure 2 shows the percentages of Completion Rates of the different Engineering programs. The average Completion Rate in Engineering School in the last five years is 54%.

Of the total number of students who fail to complete their degree program, 86% are related to the failure in Mathematics and Science subjects in the first year [14]-[16].

Fifty percent of the students who have participated in the SAE competition have already passed at least 65% of the subjects of their undergraduate study program, indicating a high probability of completing their entire Engineering program.

UPabove is the name of our team. In 2015, we achieved the place 15, in 2016 position 10 and the last edition of 2017 to position 6. Usually, participate in this advanced class, between 20 and 25 teams from different universities, it is mostly from the USA but also from countries like Japan, Poland, Germany, Canada, France, Puerto Rico, Egypt, India, United Kingdom and other. Our Campus was the first university in Mexico to enter the advanced category of this contest.

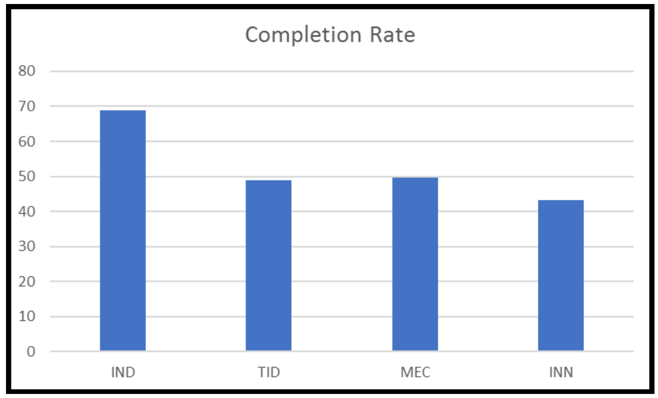

FIGURE 2
COMPLETION RATES PER ENGINEERING PROGRAM

We will continue conducting this experiment and will allocate more human and material resources to get more students engaged.

We may also research for other international competitions that help us motivate first-year students, so they do not abandon their studies of engineering when they have a failure in some of the subjects of the first year.

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