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Artículos Científicos

Desarrollo de habilidades STEM en media superior como mecanismo para impulsar la continuidad en educación superior: Caso programa Bases de Ingeniería

Development of STEM Skills in High School as a Mechanism to Improve Continuity in Higher Education: Case Bases of Engineering Program

Desenvolvimento de habilidades STEM no ensino superior como um mecanismo para promover a continuidade do ensino superior: caso do programa Engineering Bases

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Resumen

La educación media superior (EMS) en México es ahora considerada parte de la educación obligatoria en el país. Ante esta obligatoriedad el desarrollar una educación que tenga un mayor impacto en el entorno tanto productivo como educativo cobra una mayor importancia. El aprendizaje basado en proyectos y casos prácticos ha demostrado ser una forma de generar un aprendizaje significativo, aunque desarrollarlo con los escasos recursos que se tienen en las instituciones públicas en el país representa un enorme reto. Por otra parte, está comprobado que las habilidades ligadas al enfoque de las ciencias integradas, a saber: ciencia, tecnología, ingeniería y matemática (STEM, por sus siglas en inglés), son muy importantes en la integración de un aprendizaje más activo y con mejor comprensión de los contenidos científicos. En la EMS en México existen el modelo tradicional de educación, la formación técnica y el modelo dual (ahora mediante el modelo mexicano de formación dual); sin embargo, a pesar de que son buenos esfuerzos, están más enfocados en la educación tradicional, en la capacitación técnica o en la resolución de problemas para adquirir experiencia que en desarrollar una habilidad de "ingenio" para la resolución de problemas prácticos pero no enfocados necesariamente al trabajo en una empresa en particular; habilidad que les permita tener facilidad para resolver problemas y enfrentarse mejor a compromisos como hacer frente al estudio de una ingeniería y posteriormente a diferentes tareas de investigación aplicada.

Así, pues, tomando como base el programa Project Lead The Way (PLTW), que se desarrolló en Estados Unidos, el Colegio de Estudios Científicos y Tecnológicos de Querétaro (Cecyteq) desarrolló un programa denominado *Bases de Ingeniería*, el cual busca desarrollar en los estudiantes de EMS habilidades que les permitan enfrentarse con mayor éxito ya sea tanto a los estudios universitarios de ingeniería como al desarrollo de actividades profesionales en su especialidad técnica en el campo laboral. Este artículo muestra el seguimiento a la eficiencia del programa y la satisfacción que este ha provocado en los estudiantes. Lo anterior con la finalidad de entender cómo aplicar programas especiales que permitan formar talento competitivo a pesar de no contar con un incremento de los recursos materiales disponibles, en un primer comparativo en los planteles Corregidora, Huimilpan, Menchaca, Montenegro, Pedro Escobedo, Querétaro y San Juan del Río.

Palabras clave: aprendizaje basado en proyectos, bases ingeniería, media superior, STEM.

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Abstract

High school in Mexico is now considered part of obligatory education in the country. Before this obligation to develop an education that has a greater impact on the productive and educational environment becomes more important. Learning based on projects and case studies has proven to be a way to generate meaningful learning, although the way to develop it with the scarce resources that are available in public institutions in the country represents an enormous challenge. In higher education in Mexico there is the traditional model of education, technical training and the dual model (now through the Mexican model of dual training); however, although they are good efforts, are more focused on traditional education, in technical training or problem solving to gain experience that in developing a skill of "ingenuity" to solve practical problems but not necessarily focused on work in a particular company; skill that allows them to have ease to solve problems and better deal with commitments such as dealing with the study of an engineering and subsequently with different tasks of applied research. Thus, based on the Project Lead The Way (PLTW), program that was developed in the United States, the Colegio de Estudios Científicos y Tecnológicos de Querétaro (Cecyteq) elaborated a program called *Bases de Ingeniería* to develop in the students of high school the skills that allow them to face with greater success the university studies of engineering as well as to the development of professional activities in their technical specialty in the labor field. This article shows the follow-up to the efficiency of the program and the satisfaction that it has caused in the students. This to understand how it has been possible to apply special programs that allow the formation of competitive talent even though it has not been possible to increase the available resources, in a first comparative in the campus of Corregidora, Huimilpan, Menchaca, Montenegro, Pedro Escobedo, Querétaro and San Juan del Río.

Keywords: project-based learning, engineering bases, high school, STEM.

Resumo

O ensino médio (SGA) no México agora é considerado parte do ensino obrigatório no país. Diante dessa obrigação, o desenvolvimento de uma educação com maior impacto no ambiente produtivo e educacional se torna mais importante. A aprendizagem baseada em projetos e os estudos de caso provaram ser uma maneira de gerar aprendizagem significativa, embora desenvolvê-la com os escassos recursos disponíveis em instituições públicas do país represente um enorme desafio. Por outro lado, está comprovado que as habilidades vinculadas à abordagem científica integrada, a

saber: ciência, tecnologia, engenharia e matemática (STEM), são muito importantes na integração de uma aprendizagem mais ativa com Melhor compreensão do conteúdo científico. No SGA do México, existe o modelo tradicional de educação, treinamento técnico e o modelo dual (agora através do modelo de treinamento duplo mexicano); no entanto, embora sejam bons esforços, eles se concentram mais no ensino tradicional, no treinamento técnico ou na solução de problemas para ganhar experiência do que desenvolver uma capacidade de "engenhosidade" para resolver problemas práticos, mas não focados necessariamente trabalhar em uma empresa específica; capacidade que lhes permita resolver facilmente problemas e lidar melhor com compromissos, como lidar com o estudo da engenharia e, posteriormente, com diferentes tarefas de pesquisa aplicada.

Assim, com base no programa Project Lead The Way (PLTW), desenvolvido nos Estados Unidos, a Faculdade de Estudos Científicos e Tecnológicos de Querétaro (Cecyteq) desenvolveu um programa chamado Bases de Engenharia, que busca desenvolver no Habilidades dos alunos do EMS que lhes permitem enfrentar com mais êxito os estudos universitários de engenharia e o desenvolvimento de atividades profissionais em sua especialidade técnica no campo do trabalho. Este artigo mostra o monitoramento da eficiência do programa e a satisfação que ele causou nos alunos. O exposto acima, com o objetivo de entender como aplicar programas especiais que permitam a formação de talentos competitivos, apesar de não haver um aumento nos recursos materiais disponíveis, em uma primeira comparação nas Corregidora, Huimilpan, Menchaca, Montenegro, Pedro Escobedo, Querétaro e San Juan del Río.

Palavras-chave: aprendizagem baseada em projetos, bases de engenharia, ensino médio, STEM.

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Introduction

According to figures from the National Institute of Statistics, Geography and Informatics [Inegi] (2017), Querétaro is the fifth state in Mexico with the highest growth, only followed by Aguascalientes, Baja California Sur, Quintana Roo and Yucatán. And following data from the Secretariat of Sustainable Development [Sedesu] (2015), there are 22 industrial or technological parks in the state, with strategic sectors such as food, beverages, automotive, appliances and aerospace. In a state with such a growing economy, the development of education, and in particular the higher average, becomes crucial. Particularly because a part of the graduates of that level is incorporated from that moment into working life, while the rest decide to continue studying to obtain a bachelor's degree or engineering and enter the labor market at the end of it.

Nationally, upper secondary education, according to the National Institute for the Evaluation of Education [INEE] (2014), had the largest increase with 1.7 million students, followed by higher education with almost 1.4 million. For example, in the state of Querétaro, the subsystem of the Colleges of Scientific and Technological Studies of the state of Querétaro (Cecyteq) in the last six years (2008-2015) has increased its student enrollment by more than 200%. Currently, Cecyteq is the first option of upper secondary education in the state through a bivalent technological baccalaureate model linked to the productive sector of the region, which should be strengthened with engineering-based education.

According to Peña and Bermúdez (2016), educational training is reinforced by the link between the company and the institutions, which allows learning to be more significant when there is the possibility of developing real projects with an innovative approach. In a study conducted by Cu Balán (2005) on the previous trajectories of engineering students in Campeche, the lack of orientation, motivation and low knowledge of the upper middle level were identified as the main causes of low performance, which shows the importance of this preliminary preparation. This is not an isolated case, since it has been analyzed by Mares et al. (2012), Sosa, Barrientos, Castro and García (2010) and Sosa, Tuyub and Aparicio (2014), among others. The ability of a country to access higher education and welfare studies depends on the school level of its population and its ability to solve problems and innovate.

González, González and Miles (2001) They mention that adapting the educational offer to the needs of the labor market has been a scarcely analyzed topic, and that when it has been analyzed, it has been very empirically. Bunk (1994), for his part, clarifies that a person who has

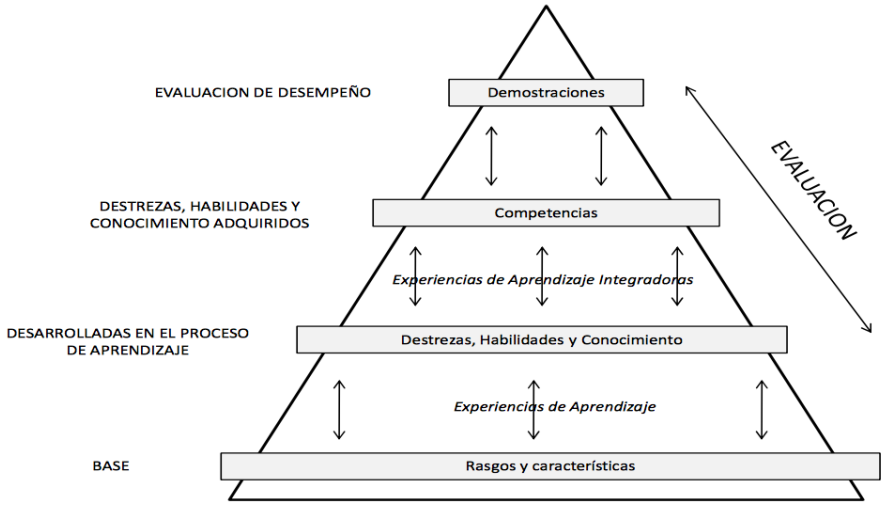
knowledge, skills and attitudes that allow him to solve problems autonomously and flexibly possesses professional competence. This is achieved in part with engineering-based programs. Studies show that the countries that have planned their future giving the highest priority to the coverage and quality of their education system, as well as the development of science, engineering and technology, have gained access to the knowledge society (Navarro, Iglesias y Torres 2006). The formation of the talent pool of these disciplines is a strategic task for the nation and demands visionary leadership that results, in the medium and long term, to reach higher levels of what is now called the knowledge economy.

However, for García, Reyes and Burgos (2017) it is important to consider the skills linked to science, technology, engineering and mathematics (STEM). Along the same lines, Becker and Park (2011) affirm that the integration of these subjects has a positive effect on students. However, according to this occasion with Vo, Zhu and Diep (2017), STEM disciplines must meet two requirements: 1) be from the fields of science, technology, engineering and mathematics and 2) classify within one of the four groups belonging to the hard sciences.

To better talk about the characteristics that are sought in engineering programs, it is important to mention that skills and abilities are sought based on the conception of competence. For Sebastián (2012), the basis of the competences are the traits and characteristics that help explain why people insert themselves into different experiences and acquire different levels of skills, abilities and knowledge, which are the second step, which only It is achieved through a series of learning experiences to become competencies. Thus, even in the terms of Sebastián (2012), a competition can be used in many ways, but it acquires utility in a context. In the above lies the greatest challenge: to determine what competencies can be added to achieve an optimal combination of skills, abilities and knowledge and create specific tasks.

This panorama is where the need to develop a program emerged from higher secondary education that allows, through the basis of features and characteristics of said educational level, to generate significant learning experiences to develop skills and abilities that subsequently integrate and generate is inserted skills related to the needs of the sector. In Figure 1 it can be seen that the base generates learning experiences that, added to the skills, abilities and knowledge that are transmitted, allow, through integrative learning experiences, the formation of skills, and that the best way to evaluate This is through demonstrations, where project-based learning plays a crucial role. This program will be discussed later.

Figura 1. Experiencias de aprendizaje significativo



Fuente: Elaboración propia con base en el Centro de Estudios para la Enseñanza y Política del Departamento de Educación de Estados Unidos

According to Morán (2012), the level of development of a country depends on the quantity and quality of the scientists and engineers it has, as they are essential for solving development problems, generating infrastructure and innovations in products and services, increase productivity, create well-paid jobs, increase national competitiveness and improve overall well-being. The level of performance of the collection of engineers that a country has depends on its quantity and, according to Tobón, Rial, Carretero and García (2006), also on the quality of the institutions of higher education in which they were formed.

Bottoms and Uhn (2007), as well as Blais and Adelson (1998), seeking to respond to a real problem in the region that has to do with the need to train more engineers and with better skills, analyzed the Project Lead the Way program (PLTW), which was born in 1997 in New York, United States, and that through a sequence of courses that prepare students in the necessary skills for engineering, fosters the development and interest in science through six strategic goals:

1) Increase the number of young people looking for a two to four year program in the areas of engineering.
2) Provide clear standards and expectations of success in the program.
3) Provide leadership and support based on continuous improvement in innovation.
4) Reduce dropout rates in engineering careers.
5) Contribute to the prosperity of the country.

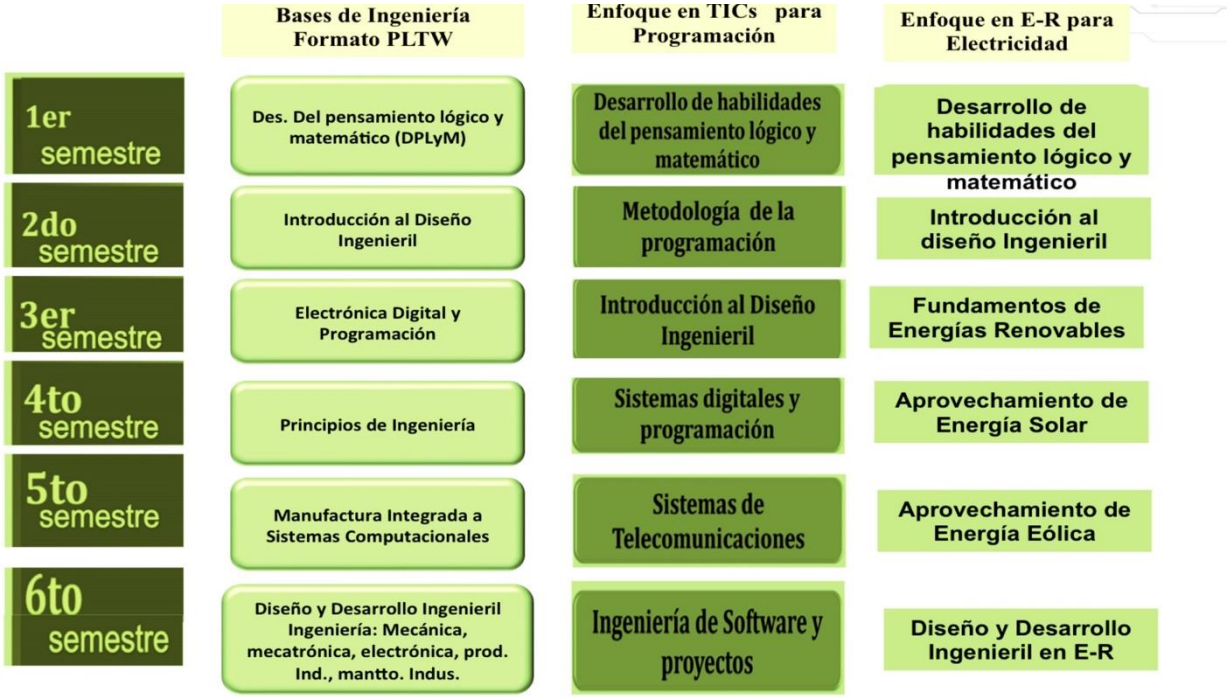
6) The approach is a theoretical third and two thirds of practice, taking as the main focus of the classes the resolution of project-based problems (Blais y Adelson, 1998).

The approach became very important mainly due to the worrying decline in recent years of young people's interest in the study of STEM, which, in line with what was said by Rocard, Csermely, Jorde, Walwerg-Henriksson and Hemmo (2007), It is translating into an insufficient number of technicians and scientists that allow the key development of science and technology systems to be maintained adequately, not only in Europe but also throughout the world. In addition to the above, Vázquez, de Talavera and Austin (2013) mention that the best valued features of school science are useful for future work, since increasing curiosity to know allows you to be interested in things that are not yet explained and improve career expectations; and on the negative side, the perceived difficulty in learning.

Methodology

With all of the above, the Cecyteq management sought to generate a program, with support from the Mexico-United States Science Foundation (Fumec), that was adapted to the reality of our country, which is very different from the realities of other countries from a primarily administrative point of view, since incorporating a curriculum such as the Project Lead The Way (PLTW) program implies a high administrative cost. Therefore, a project adapted to the reality of our country was implemented, as it was said, seeking only to impart it in an additional hour or two to the traditional groups, in order to maintain the primary objective of promoting interest in science and facilitate further study without compromising the financial stability of the institution.

Figura 2. Programa de materias del proyecto Bases de Ingeniería



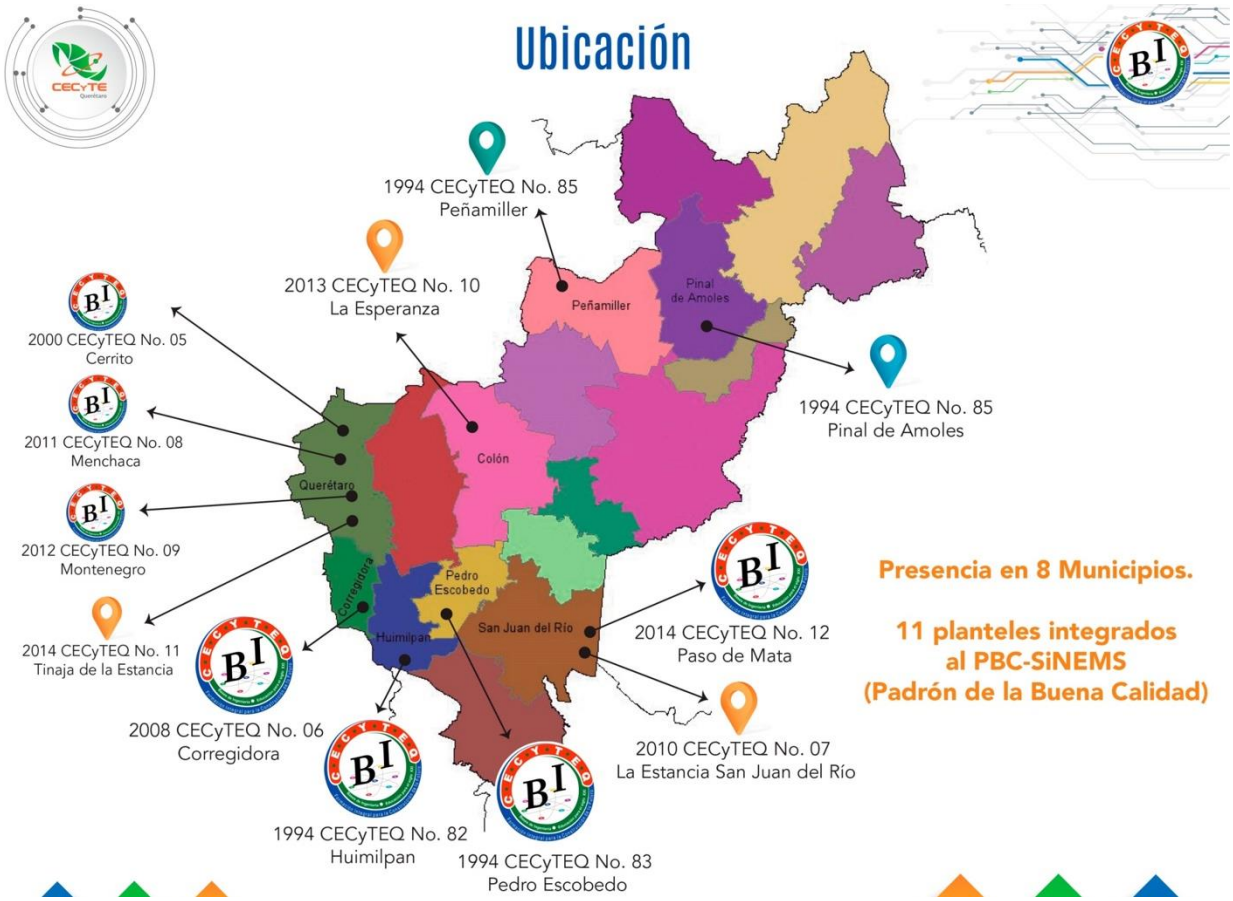
Fuente: Elaboración propia

To develop this study, it was contemplated to follow up the students who entered Engineering Bases, as the program was called, which is visualized in Figure 2, in a period from 2009 to 2014, contemplating with it the generations that graduated in the periods from 2012 to 2017. The students gradually entered initially only at the Querétaro and Corregidora campuses, which are those closest to the metropolitan part of the state of Querétaro; subsequently, already in 2011, students were added in San Juan del Río; in 2012, in Pedro Escobedo; 2013, in Huimilpan, and in 2015 in Menchaca and Montenegro until reaching a total of 1500 students in the program.

Several proposals of methodology were identified to evaluate satisfaction, such as that of Llarena and Páparo (2006) and that of Douglas, Douglas and Barnes (2006), among others, but we find the problem that in many cases they are in English or adapted to a different context, in addition to not measuring what we wanted to measure. Based on the above, we face the dilemma of using it directly or not, and reviewing Hernández, Fernández and Baptista (2010) we find that sometimes the instruments developed abroad and that have not been validated for our context mainly in Time and culture is not always the most appropriate. Translating the instrument does not mean validating it, even if it is translated by adapting it to the type of language, so it was decided to develop an instrument and do it in a small pilot population in order to validate it for the study in question.

Although the program can be implemented in different careers, since, as mentioned earlier, the Cecyteq model is a bivalent baccalaureate, that is, while the student studies high school, he obtains a technical career at the same time. Initially, the careers in which the model of the Engineering Bases program was managed were the following: Programming, Mechatronics, Informatics, Industrial Maintenance, Industrial and Electronic Production. Figure three illustrates below the geographic location of the Cecyteq campuses.

Figura 3. Ubicación de los planteles de Cecyteq y los programas Bases de Ingeniería



Fuente: Elaboración propia con base en Cecyteq

To select the students, a survey was applied where they expressed interest in participating in the program. Then the total number of students who entered the program according to each campus and the chosen career was recorded; they were followed up until the end of the program, and the number of students who successfully completed the study program was subtracted, as shown in table 1.

Table 1 shows only the income of students in the first semester and not those who entered later, since those whose income at later dates are very few and are usually replacements to those that were already inside. Those who graduated include the discount of those who changed to a traditional program and those students considered irregular, that is, who still had subjects still pending.

Tabla 1. Ingresos a Bases de Ingeniería 2009-2014

Generaciones de Bases de Ingeniería							
		2014-2017	2013-2016	2012-2015	2011-2014	2010-2013	2009-2012
Plantel	Carrera	Entraron en 1er. Semestre	Entraron en 1er. Semestre	Entraron en 1er. Semestre	Entraron en 1er. Semestre	Entraron en 1er. Semestre	Entraron en 1er. Semestre
Corregidora (06)	Programación	36	36	35	38		
Corregidora (06)	Mecatrónica	72	35	36	36	35	
Corregidora (06)	Informática					36	48
Huimilpan (82)	Mantenimiento Industrial	35	35				
Menchaca (08)	Producción Industrial	30					
Montenegro (09)	Mecatrónica	35					
Pedro Escobedo (83)	Electricidad	35	35	35			

Pedro Escobedo (83)	Programación	35	39				
Querétaro (05)	Informática					35	35
Querétaro(05)	Electrónica	36	35	36	35	35	31
Querétaro(05)	Mantenimiento	36	35	35	35	35	32
Querétaro(05)	Programación	36	35	36	34		
San Juan del Río (07)	Producción Industrial	32	34	35	16		
	Total	418	319	248	194	176	146

Fuente: Elaboración propia con base en datos de Control Escolar del Cecyteq

Results

Of the total revenue, the distribution was not uniform in part because the schools, as mentioned above, have been added over time and incorporating groups into the program in question, although terminal efficiency per generation goes up and down as shown in table 2. It is also important to analyze in detail whether this degree of dropout is due to campuses, generations, careers or simply general issues related to student retention mechanisms. Table 3 shows the breakdown of terminal efficiency by campus.

Tabla 2. Eficiencia terminal por generación

Generación	Eficiencia terminal
2009-2012	76 %
2010-2013	74 %
2011-2014	89 %
2012-2015	72 %
2013-2016	85 %
2014-2017	77 %

Fuente: Elaboración propia con base en Cecyteq

Tabla 3. Eficiencia terminal por plantel del programa Bases de Ingeniería

Plantel	Eficiencia terminal
Corregidora	83 %
Huimilpan	63 %
Menchaca	50 %
Montenegro	83 %
Pedro Escobedo	77 %
Querétaro	79 %
San Juan del Rio	80 %

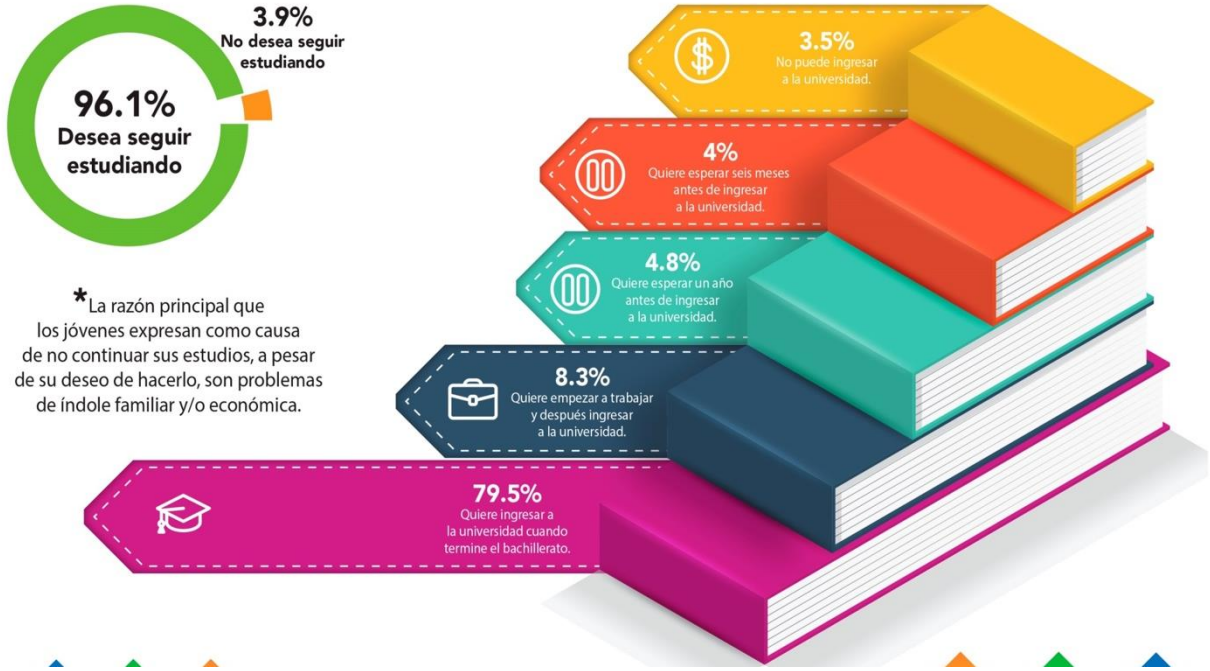
Fuente: Elaboración propia con base en Cecyteq

However, when reviewing the indicators by campus we can see that there are two campuses in which the terminal efficiency has been very low. The results generally allow us to see important information such as the following:

First of all, 66% of the respondents are men, while 34% are women, which implies that there is still a preference for the skills developed by STEM in men. Regarding the above, we can see that the results obtained in the work of the generations of the Engineering Bases program show us an increase in the interest of the students, where 96.1% of the students of the program want to continue studying a career, and these at least 62% look for it to be in an engineering; Only 3.9% do not plan to continue studying or plan to enter the labor market. Of these, the direct impact in the immediate semester is 79.5% that you want to enter immediately, 8.3% plan to work and then enter

the university and 8.8% plan to wait between six months and one year before entering (see figure 4. Plans to finish high school).

Figura 4. Planes al finalizar el bachillerato

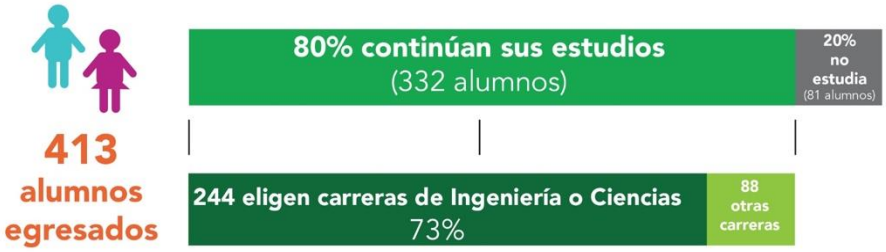


Fuente: Elaboración propia con base en Cecyteq

Other interesting facts are that, despite saying that the most difficult subjects are those related to mathematics, physics and English, more than 75% of students consider them to be their favorite subjects, which shows the impact of teaching subjects such as these through project-based learning, that is, it is feasible that although they do not find them simple they like them. Another fact that was quite relevant is that the students of the program have less impact on the socioeconomic level of the family with respect to the degree of drop-out, that is, they drop out less than the students of the traditional schemes despite coming from a low socioeconomic environment.

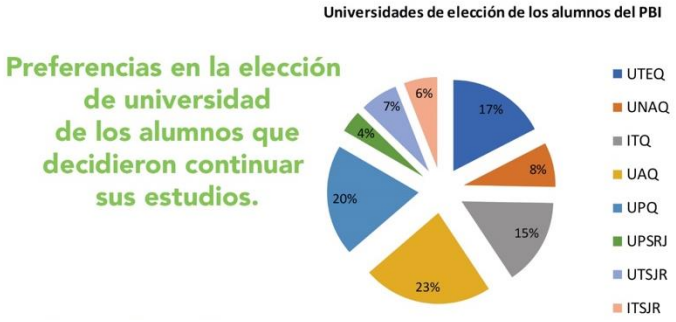
Once the program was finished, despite the difficulties to continue the follow-up of 413 graduates, it was obtained that 80% continued their studies. Of these, 73% chose careers in engineering or science and continued their studies in the main institutions of the state, the Technological Institute of Querétaro (ITQ) - now National Technological -, the Polytechnic University of Querétaro (UPQ), the Technological University of Querétaro (UTEQ) and the Autonomous University of Querétaro (UAQ), mainly (see figures 5 and 6).

Figura 5. Alumnos que continúan en ingeniería o ciencias



Fuente: Elaboración propia con base en Cecyteq

Figura 6. Preferencias en la elección de universidades



Fuente: Elaboración propia con base en Cecyteq

Discussion

At the beginning of the research, it was proposed how to promote thinking skills by promoting the development of STEM skills, and allow students to generate better conditions for them to continue from upper secondary education to higher education with adequate transit, and that not only the number of students who like engineering, technology or science careers increase, but also the number of students who continue studying — and this offers them a greater chance of success at the conclusion of their studies.

At the beginning, several authors and publications were reviewed that showed results on how the PLTW program in the United States worked in an important way; However, there was no similar adaptation for Mexico, one where one could analyze the impact of developing these programs, mainly in bivalent upper secondary education, which is the one that presents the possibilities of deepening generic skills as well as the disciplinary In sum, results very similar to

those expected when reviewing that the authors tell us about the importance of developing these skills as a way to boost knowledge and increase engineers in countries without generating very expensive programs that put the budget at risk .

In conclusion, the efforts linked to strengthening STEM-linked skills allow students to create a way of thinking that solves problems and increases their chances of continuing to study a career linked to engineering, technology or science, which are not only necessary in countries like Mexico, but an important part of the pillar of reducing technological dependence. This work also shows that while it is true that these “hard” areas are still not considered easy, seeing and learning from a project-based perspective allows them to look less arid and motivate students to perform projects even if they are complex. This article shows in general this monitoring for several years in different schools with different socioeconomic conditions throughout the state of Querétaro, but with a common result, which is the importance of the Engineering Bases program in promoting the development of young people and their possibilities to integrate in the areas of engineering, technology and science.

Conclusions

The Engineering Bases program presents an important alternative very suitable for the development of STEM-linked skills; It promotes an improvement in the resolution of problems and is shown as a low-cost alternative, tangible to replicate the efforts of initiatives such as the PLTW in the United States.

Although it is important to continue monitoring the generations of students, the data of the generations analyzed here show an interesting number of students who continue their preparation in higher education, as well as an increase in the possibilities of being admitted and continue their studies mainly in the areas of engineering and technology.

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