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Artículos de Investigación

Reducing School Dropout Risk in a Mexican Private University*

Reducción del riesgo de deserción escolar en una Universidad Privada Mexicana

Luis Cuautle Gutierrez [a]
Universidad Popular Autónoma del Estado de Puebla, México
ORCID: https://orcid.org/0000-0003-2424-2381

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Abstract:

Objective: This work shows how the Define-Measure-Analysis-Improve-Control (DMAIC) cycle reduces the school dropout risk in a Mexican private university.
Materials and method: The materials used to develop this research were data collected from an academic enterprise resource planning software called UNISOFT, property of the Mexican Private University and the statistical software Minitab, which was used to perform all the numerical analyses. The methodology used to reduce the school dropout risk in the freshman year of engineering studies was Six Sigma.
Results and discussion: Three six-sigma metrics were developed and measured to understand the process and reduce risk management. Each phase contributed to identifying the root cause and formulating possible solutions.
Conclusions: The DMAIC methodology was implemented in a period of four semesters; it involved both management and academic personnel. The results show an improvement in the dropout indices, and a new approach is being considered by the faculty to sustain the effort.
Keywords: School Dropout, Six Sigma, Risk Management, DMAIC.

Resumen:

Objetivo: Este trabajo muestra como el ciclo Definir-Medir-Analizar-Mejorar-Controlar reduce el riesgo de deserción escolar en una Universidad privada mexicana.
Materiales y métodos: Los materiales empleados consistieron en información proveniente de un software de control académico llamado UNISOFT, propiedad de UPAEP así como del software estadístico Minitab para el análisis numérico. Para identificar las causas que originan esta problemática, se empleó la metodología Seis Sigma.
Resultados y discusión: Se plantearon y evaluaron tres métricas para entender el proceso y reducir el riesgo latente. Cada fase contribuyó en la identificación de la causa raíz y la generación de posibles soluciones.
Conclusiones: La metodología planteada se desarrolló en un período de cuatro semestres e involucró tanto a personal académico como administrativo. Los hallazgos encontrados muestran una mejora en los índices de deserción y un nuevo enfoque está siendo considerado por la Facultad del programa para mantener los esfuerzos.
Palabras clave: Deserción Escolar, Seis Sigma, Administración de riego, DMAIC.

Introduction

In Mexico, school dropout is present at all educational levels. For example, the performance averages for undergraduate studies are as follows: 50% reprobation, 20% dropout, 40% attrition, and 30% certification [1]. A large number of dropout students come from engineering majors, which is largely due to students' lack of mathematical competencies [2]. At Universidad Popular Autonoma del Estado de Puebla (UPAEP), a private university in Mexico, more than 45% of automotive design engineering students drop out of their major studies in their freshman year. Several researchers have studied the causes of dropout, such as enrollment in other careers or institutions, entering the job market [3], teaching modality [4], lack of career planning [5], and students', instructors', and academic leaders' roles [6] and their impact on school trajectories [7]. This study aims to identify new reasons for dropping out that have not been explored, such

Author notes

[a] Correspondence author: luis.cuautle@upaep.mx

as early class hours, the number of advisory hours in the area of mathematics and the place of origin of first-year students pursuing the Engineering in Automotive Design field at a private Mexican university. On the other hand, the Six Sigma (SS) methodology eliminates defective goods in production lines by decreasing process variation. This quality approach employs the Define-Measure-Analyze-Improve-Control (DMAIC) method. The literature reveals that this perspective has been implemented in the education sector in admission processes [8], enhancing educational quality in organizations [9], and identifying the success factors of applying Six Sigma in an academic library [10], among others. Meanwhile, at higher education institutions in Mexico, it has only been used in the implementation of ISO9001 quality management systems [11] and examining the causes of reprobation from academic and administrators' perspectives [12].

Risk is the occurrence uncertainty that affects target goal achievement at the organization or personnel level. Thus, risk management in firms, and including universities, consists of the control of activities of the operations process, avoidance assumptions, and the elimination of unacceptable risks to adjust the risk level in the proper management of future events [13].

The International Standardization Organization (ISO) developed a risk management standard named ISO31000:2018. This norm applies to any public or private organization. It deals with institutional activities, including strategy, operations, processes, functions, products and services. A study of secondary schools in Thailand provides a useful risk framework that can be applied; it considers four main elements: input, process, outputs and outcomes, and feedback [14]. In addition, this norm increases the likelihood of achieving objectives, improving the identification of opportunities and threats, and effectively allocating and using resources for risk treatment.

In addition, there is a desire to decrease the current dropout rates, and to accomplish this goal, the Six Sigma methodology and the risk management approach will be used.

Materials and methods

Materials

The materials used to develop this research were data collected from an academic enterprise resource planning software called UNISOFT, property of UPAEP, and the statistical software Minitab, which was used to perform all the numerical analyses. An improvement team also supported the project; no economic funding was necessary to implement the improvement initiatives.

Methods

The methodology to identify causes that can be addressed and contribute to a reduction in dropout rates in the first year of studies of engineering students was the Define-Measure-Analyze-Improve-Control cycle. In the defining stage, the university engineering degree with the highest dropout rates is identified using statistical tools in the grade records of the enrolled students. Subsequently, the latent risks of the student must be identified from their applicant category as a freshman. Therefore, metrics are established that reflect the problems studied. A baseline is established, and a process capability study is performed for each metric at the measurement stage. Next, in the analysis stage, the possible causes are discovered and validated through inferential statistical methods. To improve the previously established metrics, interventions are established that cover aspects such as effectiveness, ease of implementation, cost, and security. Finally, the control measures that ensure the repeatability and reproducibility of the results achieved are documented and implemented.

Define Stage

The Industrial and Automotive Engineering Faculty at UPAEP has three majors: industrial, manufacturing and automotive design engineering. The main purpose of the university is to create critical thinking by using current theories and developing leaders that transform society. To accomplish this goal, a joint venture was created with an original equipment manufacturer (OEM) located in Puebla, México to create an engineering major dedicated to the automotive design field. In this case, the OEM contributed the personnel and know-how to support academics to address this matter. Therefore, a new major was developed. This new educational program consists of 60 courses in nine academic periods with three elective areas: electrical harnesses, engines, and vehicle interiors. The first two student classes lacked a sufficient science background and did not have the appropriate attitude to effectively engage in their professional studies.

At the beginning of the study, there was an average of two failed courses of four courses in which first year students enrolled in the automotive design major; see Figure 1. The objective of this research is to reduce the number of failed courses among freshman students of automotive design engineering.

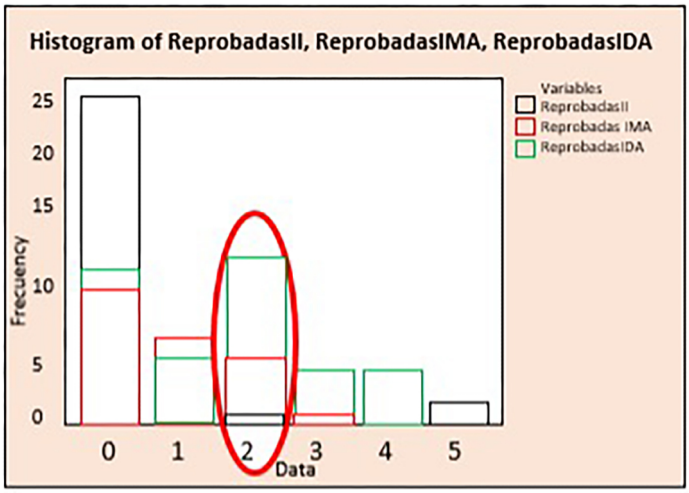

FIGURE 1.
Failed course comparison
Source: Author's own creation.

To understand the process, an IPO chart was developed. Meanwhile, in Figure 2, the desired function in terms of the academic situation that freshmen present was established in a How-How diagram. It is necessary to point out that the CENEVAL test is a mandatory admission requirement and that the academic director chooses the courses for the students due to the lack of academic knowledge regarding the curricula and their management processes.

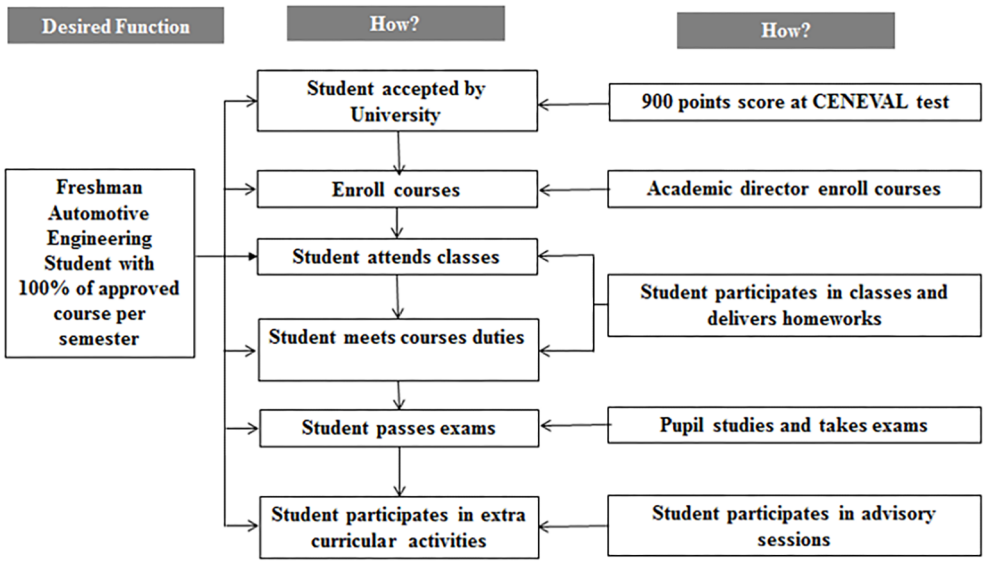

FIGURE 2.
Academic freshman How-How diagram
Source: Author's own creation.

In addition, an institutional risk matrix, Figure 3, shows the five main risks that new students confront. Two phases of risks were considered: candidate status risks and freshman status risks. Before the student's enrollment at UPAEP, the risks consist of an unmotivated and/or poor attitude and insufficient funds to complete the entire major. After their enrollment, the principal dangers are an excessive number of academic courses and skipping classes. This matrix also confirmed that the lack of control in some steps of the enrollment process generates the most crucial school dropout risk effects.

UPAEP

Institutional Risk Matrix

Code: ENG-F-001
Page: 1 of 1
Created by: Luis Cuautle

Process: Engineering Freshman Student School Drop Out

No.	Risk	Risk Cause	Risk Efect	Controls?		Control Description	Severity	Class	Frecuency	Class	Detección	Class	Risk Priority Number	Recomended Actions
				Yes	No									
1	Bad candidate admission	Low CENEVAL score test requirement	Early student school dropout	X		Admission department certifies score	High	10	Ocassional	5	High	1	50	Statistical Analysis for each class to set a fair admission CENEVAL score
2	No desired Psychological Background	There is no admission interview	Early student school dropout		X	NA	Medium	5	Ocassional	5	Low	10	250	Department Head must do a candidatess interview
3	Lack of economic funds	There is no economic requirement	Early student school dropout		X	NA	High	10	Ocassional	5	Low	10	500	Financial department must create economic requirement
4	Excesive number of academic courses	Enrolment done by the student	Low semester average		X	NA	High	10	Ocassional	5	Low	10	500	Academic advisory from the Automotive Engineering Faculty members
5	Skip classes	Starting classes at 7 hrs	Low semester average		X	NA	High	10	Ocassional	5	Low	10	500	Academic advisory from the Automotive Engineering Faculty members

FIGURE 3.
Institutional Risk Matrix
Source: Author's own creation.

As a result, the author decided to take into consideration three metrics to reduce the number of failed courses by the students. Those metrics, their current values and the academic requirements are shown in Table 1.

TABLE 1.
Six sigma metrics

Six Sigma Metric	Description	Current performance	Academic Requirement
Yp_1	% Attendance per student	86.27%	$\geq 75\%$
Yp_2	Semester average per student	6.11	≥ 7
Yp_3	CENEVAL test score	1,018	≥ 900

Source: Author's own creation.

Measure Stage

In this stage, UPAEP uses UNISOFT as enterprise resource planning software, and academic performance data are collected. This information allowed the baseline establishment and the construction of control charts for each metric considered.

In terms of the percentage of attendance, Figure 4 illustrates that in four cases (points outside the upper control limit and the lower control limit), the students received a score of less than 50%. Therefore, the percentage of attendance is out of statistical process control. In addition, the calculated capability index, C_{pk}, had a value of 0.30, which means that students perform poorly in this metric (see Figure 5).

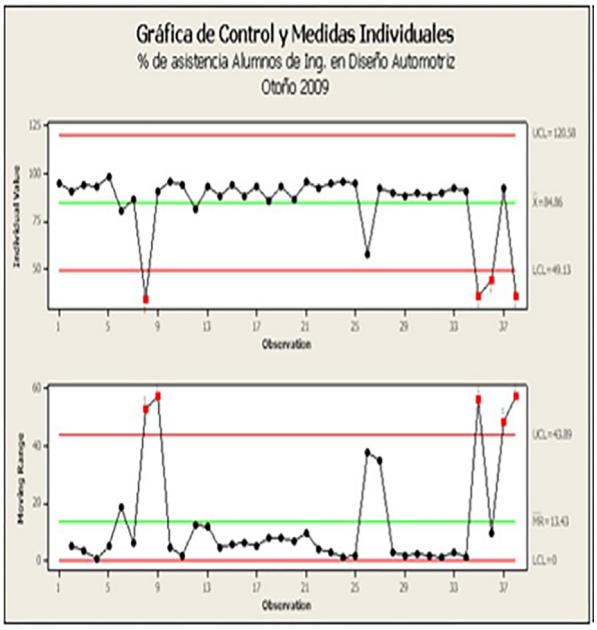

FIGURE 4.
Attendance % quality control charts
Source: Author's own creation.

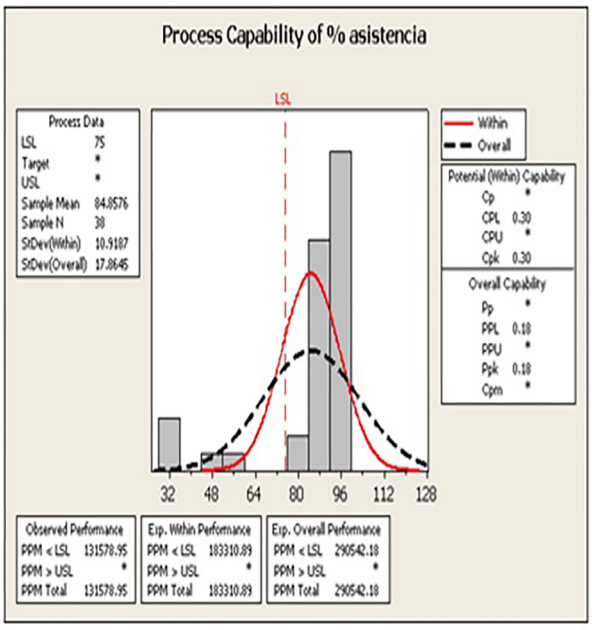

FIGURE 5.
Attendance % capability analysis
Source: Author's own creation.

Statistical studies were performed for the semester average and CENEVAL test score metrics, and the results are summarized in Table 2.

TABLE 2.
Initial statistical process control and capability index results

Six Sigma Metric	SPC	Capability Index	Findings
Semester average per student	In control	-0.11	Average below the minimum requirement, including excessive variation
CENEVAL test score	In control	0.52	Excessive variation

Source: Author's own creation.

Analysis Stage

In this phase, an academic team was assembled to identify the possible root causes that are generating the three six sigma metrics. The members of the team were full-time professors and the Industrial and Automotive Engineering Faculty Head, Mathematics Head, Physics Head, and Director of Admissions.

After a brainstorming session, the team delivered three Ishikawa charts to identify causes that can be addressed. Figure 6 establishes the detected cause for the class absence problem. This demonstrates that early morning course scheduling affects the decision to drop a class. In fact, several students live by themselves, and the lack of parental authority enabled them to skip morning classes without any consequences or family members encouraging them.

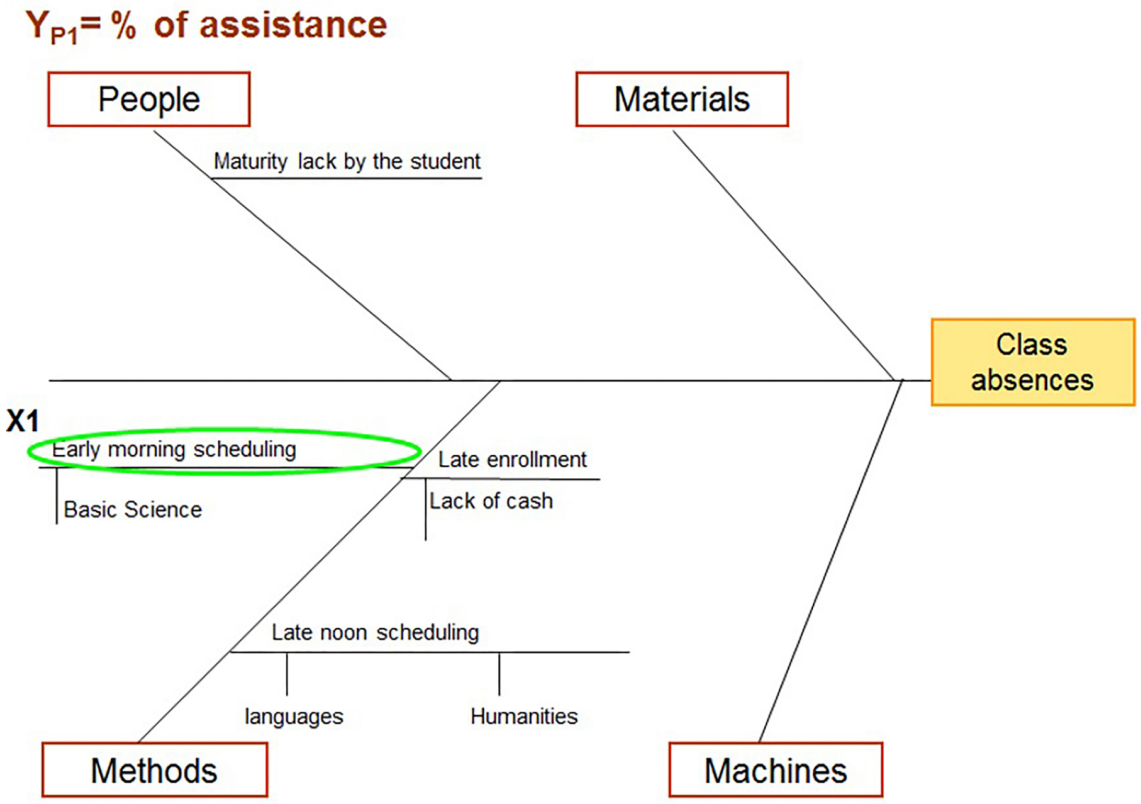

FIGURE 6.
Ishikawa chart for attendance percentage
Source: Author's own creation.

In the other two six-sigma metrics, the same analysis tool was used, and the results are shown in Table 3. Professors of mathematics and physics affirm that there is a relationship between the final score in a science course and the number of advisory hours, so this fact must be considered. On the other hand, the number of courses enrolled in by the students could be an explanation for bad academic performance. Finally, the team identified that most of the freshman engineering students came from the southern part of México, and it is well known that this area had disruptions in education due to continuous industrial action in universities.

TABLE 3.
Potential cause identification

Six Sigma Metric	Root Cause	Potential Cause (X's)
Semester average per student	Number of advisory hours	X_2
	Number of courses taken	X_3
CENEVAL test score	Origin zone	X_4

Source: Author's own creation.

With this in mind, several statistical studies confirmed the potential causes. The following summary in Table 4 highlights the findings.

TABLE 4.
Potential causes validation

Yp	Xs	Ho	Ha	Data validation	Data Type	Validation Method	Result	Cause Verification
Y_{p1}	X_1	$\mu_A = \mu_B = \mu_C$	At least one differing	Collect 10 samples with classes in the morning	Variable	One way ANOVA	P < 0.005	Yes
Y_{p2}	X_2	$\mu_A = 5$	$\mu_A \neq 5$	Collect 30 samples of enrolled students	Variable	1 sample T Test	P = 0.000	Yes
Y_{p2}	X_3	$\mu_A = 6$	$\mu_A \neq 6$	Collect 10 samples	Variable	1 sample T Test	P = 0.000	Yes
Y_{p3}	X_4	$\mu_A = \mu_B = \mu_C = \mu_D$	At least one differed	Collect 10 samples of students from A (Puebla), B (Veracruz), C(Oaxaca) y D(Chiapas)	Variable	One way ANOVA	P < 0.005	Yes

Source: Author own creation.

Improvement Stage

For each verified cause, an intervention is proposed. The team, following the risk management principles, established the following actions considering four criteria: effectiveness, easy implementation, cost, and safety, which are shown in Table 5.

TABLE 5.
Possible counteractions

Yp	Cause	Possible counteraction	Effectiveness	Easy implementation	Cost	Safety
Y_{P1}	Early morning scheduling	Schedule classes starting at 8:00	High	Easy	Low	High
		Create 15-minute grace period in the first class	Medium	Easy	Low	Medium
Y_{P2}	# Mathematics tutoring hours	Establish # of mathematics tutoring hours and create registers	High	Not easy	Low	High
Y_{P3}	Origin zone	Increase admission score	High	Easy	Low	High
		Create waiting list and interview each candidate	Medium	Easy	Medium	Medium

Source: Author's own creation.

To validate each intervention, measurements of the six sigma metrics were taken to demonstrate improvement. In the attendance percentage (Y_{p1}), the students increased their participation; however, the performance of one student fell outside of the new control limits, as presented in Figure 7. Figure 8 shows an improvement of 1.26 in the capability index (Cpk). This means that only five absences occurred in one million opportunities.

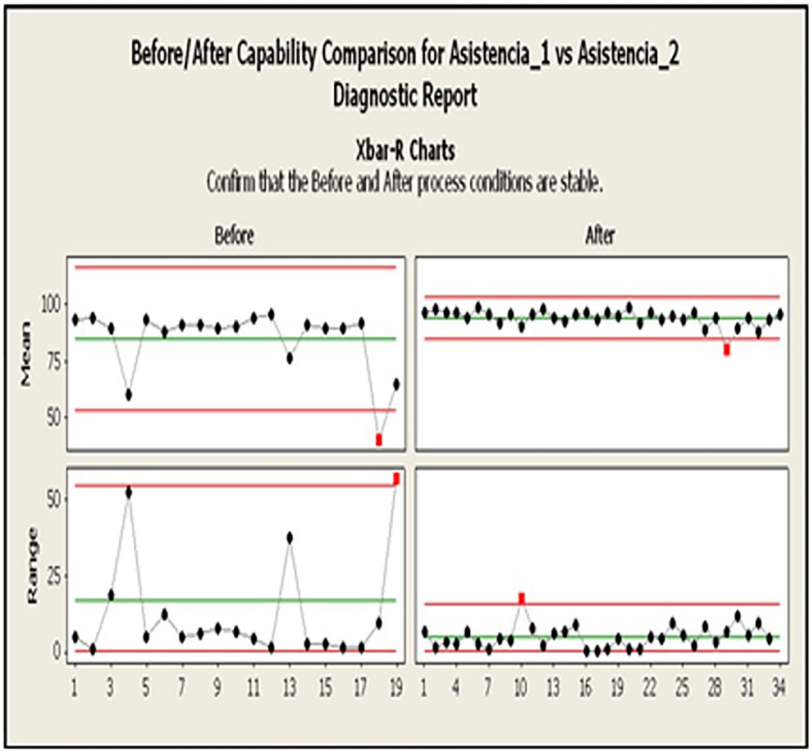

FIGURE 7.
Percentage of attendance comparison
Source: Author's own creation.

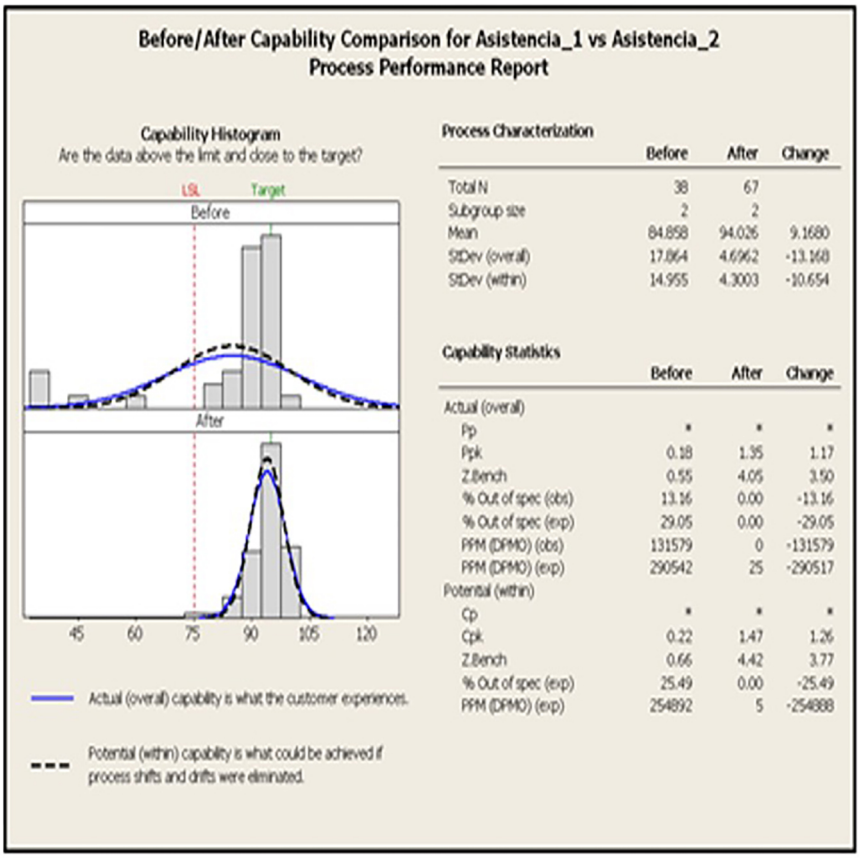

FIGURE 8.
Capability comparison for the percentage of attendance
Source: Author own creation.

The semester average (Y_{p2}) increased from a value of 6.11 to a new average of 8.24. In addition, the standard deviation decreased by 50% from the original data. The CENEVAL score increased by 50.55 points in the new class of students and ended with a capability index of 0.54.

Control Stage

Finally, the improvement team created a control plan, see Figure 9, that documented all the steps to sustain all the improvement gained with the project.

Control Plan

Six Sigma Project

Area:	**Facultad de Ingeniería Industrial y Automotriz**	**Project:**	**Eliminar el número de materias reprobadas por los alumnos de nuevo ingreso.**
Process:	**Ingreso y desempeño de alumnos de IDA**		**de nuevo ingreso.**
Process owner:	**Dr. Luis Cuautle**		**Produced by:** **01/04/20XX**
Created by:	**Dr. Luis Cuautle**		**Reviewed by:** **04/05/20XX**
Date:	**09/05/20XX**		

Process Step	Process Change Date	Defect (X)	Counteractions		Where the results are documented?	Corrective Action	Validation Method
			Method	Document			
Semester Scheduling	Spring	X1: Early morning scheduling	Schedule classes starting at 8:00	UNISOFT	UNISOFT	Hire hour-class professor	
Semester Enrolment	Spring	X3: Number of courses taken	Five courses maximum policy	UNISOFT	UNISOFT	Increase/decrease number of courses parents validation	Enrolled courses control chart
Semester Enrolment	Spring	X4: Origin zone	Pre-science test to freshman students application		UNISOFT	Algebra course installation	
Regular classes during semester	Spring	X2: Number of advisory hours	Establish # of mathematics advisory hours and create mandatory registers	Operative Programme		Contact Academic Advisor to fix situation	Advisory number of hours control chart

FIGURE 9.
Control plan proposal
Source: Author's creation.

Results

Four interventions were implemented after the spring semester, and their impact is shown in Figure 10. The upper part of the figure shows the name and major of the student, as well as the student's schedule during the semester period, and in the lower part, the final score of the periods demonstrates the reached achievement.

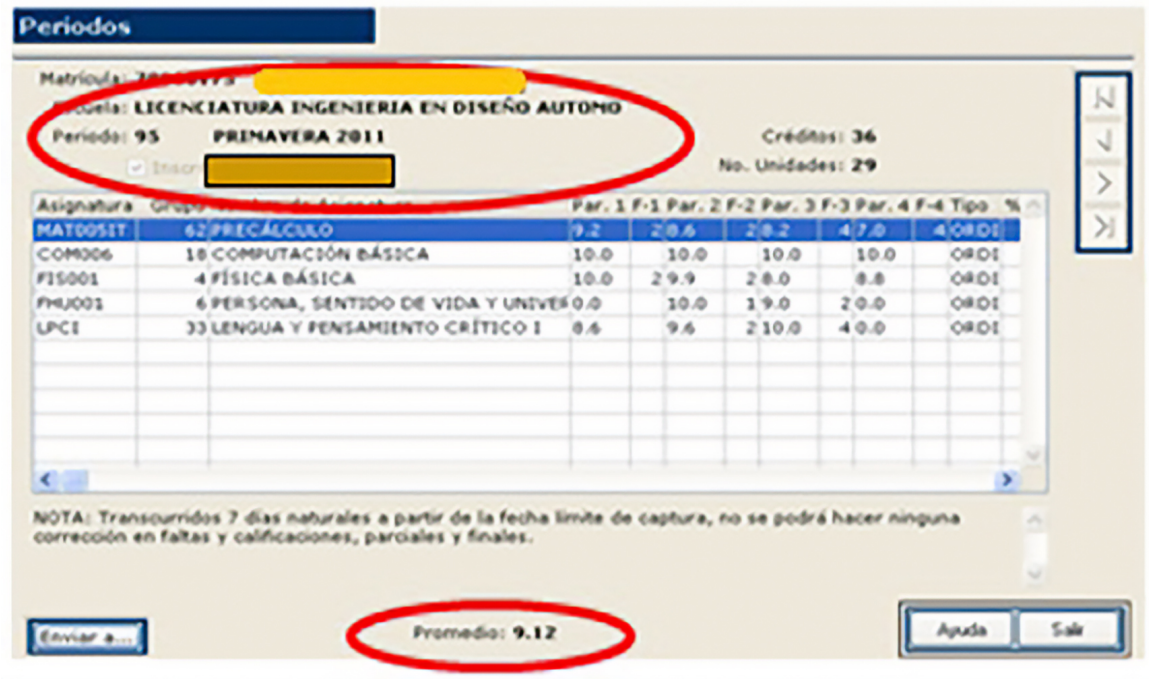

FIGURE 10.
Achievement evidence
Source: Author's own creation.

The DMAIC methodology was implemented in a period of four semesters; it involved management and academic personnel. The three six sigma metrics showed at least 5% improvement in each one (see Table 6).

TABLE 6.
Six sigma metrics after improvements

Yp	Description	Before Six Sigma Project	Objective	After Six Sigma Project	% Improvement
Y_1	Attendance % per student	Average: 86.27 Cpk: 0.22	Average: 95 Cpk: 1.33	Average: 94.03 Cpk: 1.47	8.99%
Y_2	Semester average per student	Average: 6.11 Cpk: -0.11	Average: 7 Cpk: 1.33	Average: 8.24 Cpk: 0.44	34.86%
Y_3	CENEVAL test score	Average: 1,018 Cpk: 0.07	Average: 1,050 Cpk: 1.33	Average: 1,068.90 Cpk: 0.52	5%

Source: Author's own creation.

Conclusions

In terms of the interventions established, scheduling classes starting at 8:00 am and creating a 15-minute grace period in the first class of the day represented parental interest from the Faculty Academy to promote confidence and motivation among freshman students. Therefore, attendance and counseling programs should be implemented by innovation centers [15]. This represents a different outlook from the one that posits that adult learners are initially highly motivated and self-directed [16].

Another finding of the research was the positive relationship between the attendance percentage and the final course scores. The results support the conclusion that class attendance is the best predictor of college grades compared to any other known predictor of academic performance [17].

In terms of CENEVAL admission test scores, the research concludes that an increase in the admission requirement only results in a 5% improvement in reducing school dropout risk. There is evidence that high school grades and scores on standardized admission tests are not correlated with study skills [18], so there is no guarantee of academic success during college studies.

The author realizes that the research performed has certain limitations such as the study having a scope of only one engineering major and the results being based on a private Mexican university. Additionally, he recommends investigating cognitive deficit profiles among individuals with mathematics difficulties and assessing them in engineering program candidates [19] to reach better results in the DMAIC process.

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Notes

* Research article

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