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IMPACT OF THE APPLICATION OF SIX SIGMA IN PROJECTS DEVELOPED FOR MICROENTERPRISES

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Abstract: Six Sigma is a comprehensive methodology that employs statistical and management tools to optimize performance and maintain a competitive position in the market. Its main goal is to improve processes by identifying and solving problems, applicable to both operational and transactional processes within a company. The Six Sigma methodology is structured through the DMAIC cycle, which comprises five phases: Define, Measure, Analyze, Improve, and Control. This systematic approach is essential for achieving continuous and sustainable improvements in any type of organization (Harry & Schroeder, 2000; Pyzdek, 2003). Although Six Sigma is often associated with large corporations due to its focus on defect reduction and quality improvement, its application in small businesses and microenterprises can be equally beneficial. Projects carried out within the Six Sigma framework have demonstrated that small companies can achieve significant improvements in their operational processes by implementing the DMAIC cycle. These improvements not only optimize efficiency and reduce costs but also contribute to greater customer satisfaction and better positioning in the local market (Antony, 2006). Practical experience with DMAIC in real projects provides students with a deep understanding of how to apply theoretical concepts to real-world situations. This not only strengthens their technical and analytical skills but also teaches them teamwork, project management, and effective communication of their findings. Additionally, collaborating with small businesses allows students to contribute directly to the improvement of these organizations, providing valuable and practical solutions that can have a positive and tangible impact (Antony, 2006; Harry & Schroeder, 2000).
Keywords: Six Sigma, Projects, Impact.

INTRODUCTION

Integrating the DMAIC methodology of Six Sigma into the training of Industrial Engineering students is crucial for their professional development and the growth of small businesses. DMAIC, representing the phases of Define, Measure, Analyze, Improve, and Control, offers a structured approach to process improvement that can provide significant benefits to both students and the small businesses where they apply this knowledge.

For Industrial Engineering students, applying the DMAIC methodology to real projects represents an invaluable opportunity for practical learning. The Define phase teaches them to clearly identify the problem and establish measurable objectives, while the Measure phase allows them to collect relevant data to assess the current state of the process. The Analyze phase provides the necessary tools to investigate the root causes of problems, and in the Improve phase, students develop and test innovative solutions. Finally, the Control phase ensures that improvements are sustained over the long term, integrating a continuous process management approach (Marr, 2009).

Small businesses, often limited by resources and quality management experience, can greatly benefit from implementing DMAIC. The methodology helps these businesses improve operational efficiency, reduce waste, and increase customer satisfaction by optimizing key processes. By collaborating with students, small businesses can access modern approaches and advanced techniques without incurring high costs, enabling them to implement significant improvements that might otherwise be beyond their reach (Harry & Schroeder, 2000).

Applying DMAIC in small businesses also enriches the educational environment for students. It allows future Industrial Engineers to tackle real problems and develop effective solutions in a controlled setting. This type of practical experience not only enhances their understanding of Six Sigma concepts but also increases their ability to work in multidisciplinary teams, communicate findings, and manage projects—skills that are highly valued in the job market (Marr, 2009).

Using DMAIC fosters a culture of continuous improvement in both students and small businesses. For students, the experience of applying DMAIC to real projects teaches them the importance of innovation and adaptability in problem-solving. For small businesses, the methodology provides a framework for continuously evaluating and improving their processes, leading to a competitive advantage and sustained growth (Antony, 2006; Harry & Schroeder, 2000).

In summary, applying the DMAIC methodology of Six Sigma to small business projects offers significant benefits for Industrial Engineering students and the businesses themselves. It facilitates the development of practical skills in students, provides valuable solutions to small businesses, and fosters a culture of continuous improvement and innovation. This practical and structured approach is fundamental for preparing future industrial engineers for real-world challenges and supporting growth and efficiency in the business sector.

SIX SIGMA

Six Sigma is a quality management methodology aimed at improving process efficiency and reducing variability through the use of statistical and management techniques. Originated by Motorola in the 1980s, the term “Six Sigma” refers to a quality level in which the variability of a process is reduced to a level that produces fewer than 3.4 defects per million opportunities (Pyzdek, 2003). The methodology is based on two key components: Define, Measure, Analyze, Improve, Control (DMAIC) and Define, Measure, Analyze, Design, Verify (DMADV), used respectively for improving existing processes and designing new processes or products (Harry & Schroeder, 2000).

The primary objective of Six Sigma is to achieve a high level of quality and consistency by identifying and eliminating defects in processes. This approach relies on the rigorous application of statistical tools for data analysis and evidence-based decision-making. The concept is based on the premise that variability in production or service processes can be minimized through continuous improvement, resulting in increased customer satisfaction and reduced costs (Antony, 2006).

A crucial aspect of Six Sigma is its focus on organizational culture. For it to be effective, Six Sigma requires the commitment of top management and integration into corporate strategy. The methodology promotes a culture of accountability and continuous improvement, encouraging active participation from all levels of the organization (Marr, 2009). Additionally, Six Sigma training, which includes certification at levels such as Green Belt and Black Belt, is essential for equipping employees with the tools and techniques for improvement.

In summary, Six Sigma is a comprehensive methodology that combines statistical techniques with a management philosophy to enhance the quality and efficiency of processes. Its success depends on organizational commitment and proper training, focusing on reducing defects and variability to achieve high-quality standards (Pyzdek, 2003; Harry & Schroeder, 2000; Antony, 2006; Marr, 2009).

DMAIC

DMAIC is a fundamental methodological approach within the Six Sigma philosophy, designed for the continuous improvement of existing processes. The acronym DMAIC stands for Define, Measure, Analyze, Improve, and Control, and is used to identify and eliminate defects, reduce variability, and improve quality (Harry & Schroeder, 2000). This approach provides a systematic structure that allows organizations to make data-driven and evidence-based improvements.

The first phase, Define, establishes the scope of the improvement project by identifying the specific problem to be addressed and setting clear, measurable objectives (Pyzdek, 2003). During this phase, the project is defined in terms of its benefits, the team involved, and customer expectations. It is crucial to align the project with business needs and ensure that all stakeholders understand the project's goal and direction.

In the Measure phase, relevant information about the current process is collected and analyzed to understand its performance and establish a baseline reference. This includes identifying key performance indicators (KPIs) and collecting data necessary to evaluate the impact of proposed improvements (Antony, 2006). Accurate measurement is essential for correctly diagnosing problems and assessing the success of implemented solutions.

The Analyze phase involves examining the collected data to identify the root causes of problems and defects. Statistical and analytical tools are used to understand relationships between variables and determine factors affecting process performance (Marr, 2009). This analysis allows for prioritizing areas for improvement and formulating effective strategies to address identified issues.

In the Improve phase, solutions are developed and implemented based on the findings from the analysis. Interventions are designed

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and tested to optimize the process, and their effects on performance are evaluated (Pyzdek, 2003). This phase requires creativity and collaboration to develop innovative and practical solutions that align with project objectives.

Finally, the Control phase ensures that improvements are sustained over the long term. Controls and procedures are established to monitor the process and ensure that improvements remain effective. This phase includes training personnel and implementing tools for continuous performance monitoring (Harry & Schroeder, 2000).

In summary, DMAIC is a systematic approach that guides organizations in the continuous improvement of processes through a structured cycle of definition, measurement, analysis, improvement, and control. Its proper implementation can lead to significant improvements in process quality and efficiency (Antony, 2006; Harry & Schroeder, 2000; Marr, 2009; Pyzdek, 2003).

CASE STUDY

Considering that Six Sigma methodology is practical and must be applied to be learned, microenterprises in the region were sought where Industrial Engineering students could apply DMAIC, in order to complement what they had learned throughout their career with a real problem that presented a challenge regarding the application of the tools they had been trained in.

As a requirement for crediting the Six Sigma course, projects were to be developed that allowed for analyzing and applying the DMAIC phase by phase. A study group of 36 eighth-semester Industrial Engineering students was selected. Random teams were formed, and each team chose a microenterprise. Seven businesses from the Córdoba-Orizaba region in the state of Veracruz, Mexico, were involved. For confidentiality, their names are omitted and will be referred to by their type:

- Car Wash
- Rotisserie
- Pharmacy
- Coffee Shop
- Poultry Shop
- Water Purification
- Paint Store
- Construction Company
- Grocery Store

The initial challenge for the students is their integration with the assigned team, which helps them develop soft skills alongside the technical skills relevant to the subject.

At the end of the course, which was delivered theoretically and through advisories for applying DMAIC in the businesses, results were evaluated in several areas to measure the degree of impact of the project development on future Industrial Engineers. A measurement instrument in the form of a survey was applied, with different questions aimed at measuring the degree of application of what was learned in their career, the level of knowledge at the beginning and end of the course, the industrial engineering tools they applied in the project, as well as the impact on the microenterprises from the obtained results.

Once the projects were completed and closed after concluding the five phases of DMAIC, students were asked to respond to the survey.

RESULTS

Regarding the extent to which they applied what they learned in class to the project: Out of 36 students, 25 believe that the degree of application of what they learned in class while developing their project was High. That is, 70% of students had a High degree of application of the theory in the project, as shown in Figure 1.

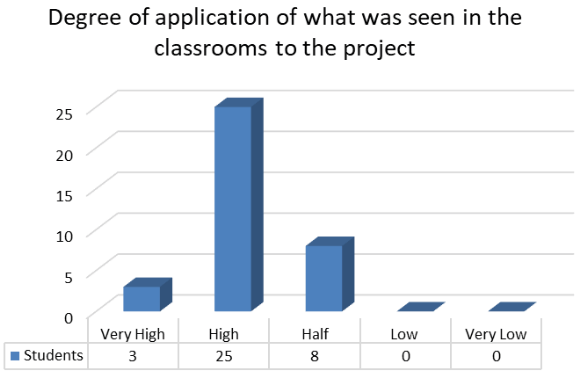

Figure 1. Degree of application of what was seen in the classrooms to the project. Authors' elaboration

On the other hand, as shown in Figure 2, regarding each student's participation in project development: 24 students had Active participation in the project development. That is, 67% of students were active, 30% had a neutral stance, and only 3%, represented by one student, had passive participation.

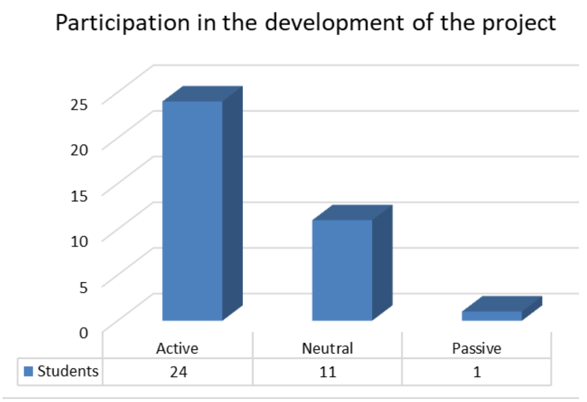

Figure 2. Participation in the development of the project. Authors' elaboration

When observing personal behavior, the predominant characteristic in each student was being Analysts, as 15 out of 36 students held that role. There were 7 leaders, 7 negotiators, 3 followers, 2 conciliators, and 2 animators. It is expected that the predominant characteristic would be Analyst given the engineering field and the methodology employed, which can be seen in Figure 3.

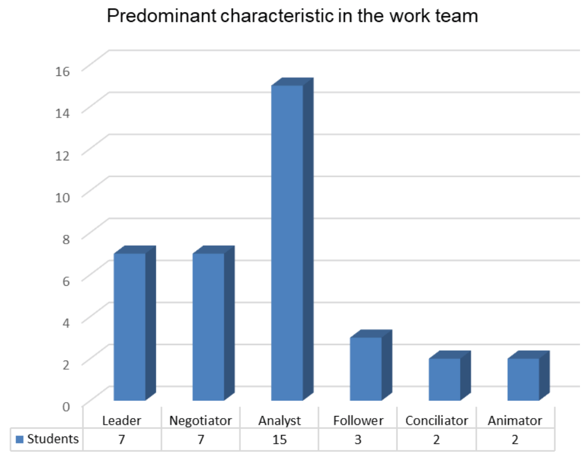

Figure 3. Predominant characteristic in the work team. Authors' elaboration

Regarding the industrial engineering tools they applied in the project and have encountered throughout their training, it was found that they were as varied as the problems they solved, and according to Figure 4, the most commonly used were the cause-and-effect diagram, check sheets, SIPOC diagram, Gantt chart, and the 5 whys, among others.

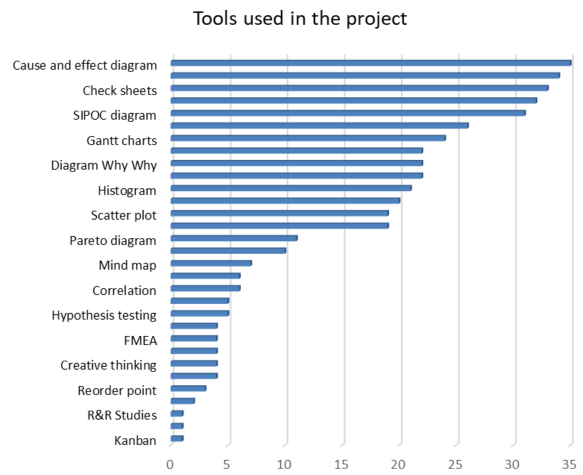

Figure 4. Tools used in the project. Authors' elaboration

Regarding the rating assigned to their knowledge of the Six Sigma methodology at the beginning of the course, using a scale of 1 to 10, where 1 is the lowest score and 10 the highest, the average of the 36 students was a score of 3.8, reflecting that their knowledge at the beginning of the course was very basic, and they had only heard about the methodology but did not know exactly what it entailed or how to apply it.

On the other hand, the score assigned to their knowledge of the Six Sigma methodology at the end of the course, using the same scale, was 8.7.

According to comments from the study group, they believe that the development of the project allowed them to learn not only theoretically but also to apply DMAIC to a real case.

Based on personal experience, the score assigned to each soft skill depending on its importance in successfully completing such a project was shown in Figure 5, where it is observed that there is no significant difference in the different soft skills that they must possess as future professionals.

Figure 5. Required soft skills. Authors' elaboration

Regarding the degree of application of the knowledge acquired throughout their career, students consider this to be High, as shown in Figure 6.

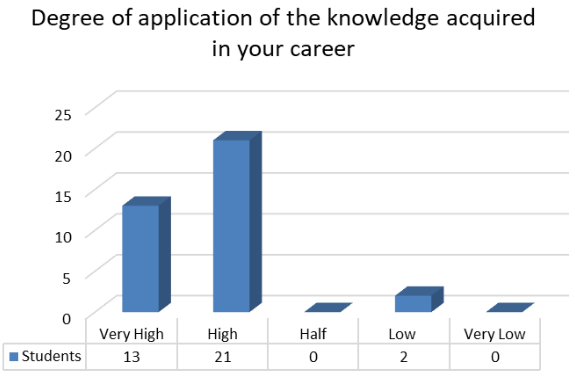

Figure 6. Degree of application of the knowledge acquired in your career. Authors' elaboration

Additionally, students believe that the importance of carrying out an application project as part of the activities in the Six Sigma course is Very High, as shown in Figure 7.

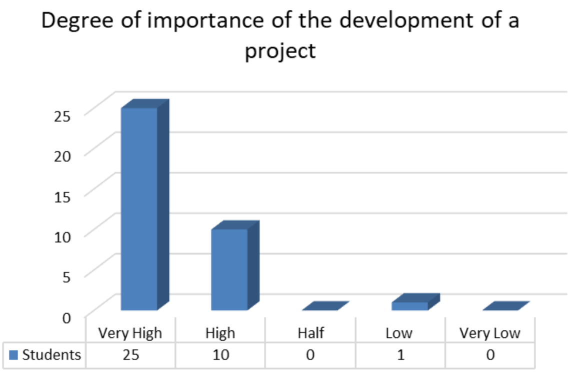

Figure 7. Degree of importance of the development of a project. Authors' elaboration

69% of students consider this to be the case, as it allowed them to practice not only the knowledge acquired in the classroom but also the skills and competencies they have developed.

Regarding the projects, Figure 8 shows the types of businesses, as well as initial and final performance. It can be observed that the realization of the projects had a significant impact on the businesses, as very favorable results were obtained.

Business Sector	6S Project	Initial Performance	Final Performance
Car Wash	Reduction of car washing time	Small: 19.9 min	Small: 11.8 min
		Medium: 18.9 min	Medium: 14.3 min
		Large: 18.8 min	Large: 13.7 min
Rotisserie	Increase in sales by 20%	197 chickens sold per week	238 chickens sold per week
Pharmacy	20% reduction in cash variability at cash register closings	6 times did not balance	3 times did not balance
Coffee shop	Reduction in delivery time for home orders	25 – 37 minutes	24 minutes
Chicken Shop	Reduction in the amount of leftover chicken	30 kilos per week	9.5 kilos per week
Water Purification	Reduction in the production process time for water jugs	153 seconds	91 seconds
Paint Store	Increase by 15% in the number of people aware of the store	38 people out of 100 know it	55 people out of 100 know it
Construction Company	Reduction in time for payroll preparation and approval	289 minutes, 4.9 hours	125 minutes, 2.1 hours
Grocery Store	Reduction in customer service time by properly locating products	28 times location was unknown	3 times location was unknown

Figure 8. Comparison of results and performance. Authors' elaboration

CONCLUSION

The ability to measure, analyze, and control processes is fundamental in the field of Industrial Engineering, and the real application in projects helps consolidate this theoretical knowledge into practical skills.

Microenterprises often have limited resources and typically do not dedicate time to identifying areas of opportunity within their business and/or structured problem-solving, which makes the work done by students to help them solve issues that allow for improving business profitability through cost reduction or increased profits very significant.

On the other hand, for Industrial Engineering students, working on applied projects using DMAIC provides invaluable practical experience. This methodological approach not only teaches them to identify and define problems but also allows them to develop analytical and problem-solving skills.

In conclusion, the meaningful learning of students is reinforced by achieving good results in their projects, benefiting microenterprises through their work, and these enterprises providing students with the opportunity to gain experience for their future careers.

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