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Lean Six Sigma Black Belt Training for Professionals: Analysis of Profiles, Projects and Academic Performance

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Abstract

Lean Six Sigma Black Belt (LSSBB) training represents a strategic investment for organizations developing internal capabilities to lead complex improvement projects. This study characterizes demographic profiles of participants in an LSSBB training program in Peru, analyzes project typology, and evaluates academic performance concerning demographic variables. A quantitative exploratory approach analyzed 151 participants from a private Peruvian institution (2012-2022). Data from academic records and final projects were analyzed using Minitab 22. K-means cluster analysis and Pearson's χ^2 test characterized demographic profiles, while ANOVA assessed academic performance factors. Four distinct participant profiles emerged: technical professionals from industrial sectors, female professionals in leadership roles, experienced service sector professionals, and senior executives with strategic perspectives. Academic performance analysis revealed modality and age as determining factors. Face-to-face participants achieved better results (M = 17.03, SD = 1.03) than online participants (M = 16.01, SD = 2.04). Significant interaction showed older professionals benefit more from online modality, while younger professionals perform better face-to-face. Analysis of 44 projects confirmed effective knowledge transfer, with implementations primarily in mining, manufacturing, and food sectors using balanced DMAIC tools for operational optimization, variability reduction, and quality improvement. This study provides essential insights for improving LSSBB training program design and implementation, offering valuable information for organizations promoting professional certification in continuous improvement methodologies.

Keywords

Lean Six Sigma, Professional Training, Black Belt, Continuous Improvement, Organizational Development.

1. Introduction

In today's business landscape, characterized by increasing global competitiveness and heightened demands for quality products and services, continuous improvement methodologies have become essential for process optimization and value creation within organizations. Lean Six Sigma (LSS) emerges as a holistic approach that integrates Lean's waste elimination principles with Six Sigma's statistical rigor and variability reduction (Antony et al. 2017). Consequently, training professionals in LSS, particularly at the Lean Six Sigma Black Belt (LSSBB) level, represents a strategic investment for organizations aiming to develop internal capabilities to lead complex improvement projects. The impact of such training is evident in key project indicators, such as quality, cost, delivery time, and customer satisfaction (Antony et al. 2018). Therefore, analyzing professional profiles, project characteristics, and participants' academic performance in LSSBB training programs is crucial for designing and implementing effective training initiatives.

Black Belt professionals serve as change agents who not only apply advanced statistical tools but also possess the ability to manage multidisciplinary teams and lead high-complexity projects (López-Soto et al. 2013). Therefore, developing advanced analytical competencies and leadership skills is fundamental during LSSBB training. Another important aspect of LSSBB training is the certification process. Globally, these certifications are recognized as valuable credentials in the job market, with organizations often offering incentives and professional development opportunities to certified personnel. However, a notable issue is the lack of standardization in the content of LSSBB training and certification programs (Louzada et al. 2023). This inconsistency raises concerns about the uniformity and quality of competencies developed by professionals during their training, highlighting the need for studies that analyze factors determining the success of LSSBB training programs.

The adoption of LSS in Peru mirrors trends observed in other countries, with growing interest across various sectors, including manufacturing, mining, and specialized services such as healthcare (Buestan et al. 2025; Gamal Aboelmaged 2010). Nevertheless, research on LSSBB training programs—specifically regarding participants' professional profiles and academic performance—remains scarce in the literature. This gap may hinder the knowledge necessary for designing effective LSSBB training programs within higher education and continuing education institutions. Therefore, this study aims to address this gap by characterizing the demographic profiles of participants in a Peruvian LSSBB training program, analyzing the typology of projects developed during the training process, and evaluating academic performance concerning demographic and academic variables. The goal is to provide valuable insights for enhancing LSSBB training programs.

1.1 Objectives

This study has three primary objectives: (1) to characterize the demographic profiles of participants in an LSSBB training program in Peru; (2) to analyze the typology of projects developed during the training program, including project types and tools used; and (3) to evaluate participants' academic performance in relation to demographic and academic variables.

2. Literature Review

2.1 Fundamentals of Lean Six Sigma and Black Belt Training

LSS is an integrated methodology that combines Lean principles, focused on waste elimination and value flow, with Six Sigma (SS) tools and methodology, oriented toward reducing process variability and leadership (Antony et al. 2017; Snee 2010). In the mid-1980s, Bill Smith developed SS, which is characterized by its methodology for defect reduction; subsequently, SS was established as a standard of operational excellence, characterized by its prevention approach and rigorous quality control, adopted by other organizations globally (Antony et al. 2017; Kwak and Anbari 2006). The integration with Lean Management (Lean Manufacturing, Lean Enterprise, or simply Lean) emerged as a response to the need to combine SS's rigorous statistics with operational agility, thereby consolidating LSS at the beginning of the present century (George 2002).

LSS training follows a belt model. Certification levels reflect progressive levels of competency and responsibility: Yellow Belt, Green Belt, Black Belt, and Master Black Belt (Pyzdek and Keller 2018). Particularly, Black Belt professionals have advanced training in the use of statistical tools (Pyzdek and Keller 2018) and the ability to implement complex projects using the DMAIC methodology (Define, Measure, Analyze, Improve and Control) (Kwak and Anbari 2006). Generally, the Body of Knowledge (BOK) for LSSBB professional certification, although it varies among training and certifying organizations, includes competencies in descriptive and inferential statistical analysis, multivariate analysis, project management, change management, among others (DeRuntz and Meier 2009). The American Society for Quality (ASQ) has proposed one of the most recognized reference frameworks for LSSBB certification. ASQ's proposal includes ten thematic areas with 108 recommended techniques that range from quality fundamentals to advanced statistical tools (Mcshane-Vaughn 2022).

LSSBB training is characterized by its focus on developing real improvement projects with measurable financial impact. In these projects, participants apply the tools and techniques learned to specific problem in their organizations (McDermott et al. 2024). During training, professionals usually employ the DMAIC methodology in developing their projects, that is, it is structured as an improvement process in five sequential phases: problem and objective definition, current performance measurement, root cause analysis, improvement implementation, and establishment of controls to ensure results sustainability (Schroeder et al. 2008). Likewise, LSSBB projects are characterized by their broad scope, analysis complexity, duration, and financial savings objectives (Hoerl 2001). This approach, based on high

complexity projects, distinguishes LSSBB training from other LSS professional development programs, as it combines concept deepening with immediate practical application that facilitates learning transfer in real organizational contexts.

2.2 Research on Lean Six Sigma and Lean Six Sigma Black Belt Training

A review of the literature on LSSBB training reveals several pertinent research areas. One significant area is the standardization of content across LSSBB training programs. For instance, a study analyzing LSSBB certification courses in Brazil found a lack of standardization, with only four of the 108 techniques recommended by the American Society for Quality (ASQ) covered by all courses analyzed (Louzada et al. 2023). The primary deficiencies were related to the "Design for Six Sigma framework and methodologies" macro area. This lack of standardization raises questions about the consistency of competencies developed by professionals and the transferability of learning to their organizations, underscoring the need for a common foundation in LSSBB professional training.

Regarding teaching modalities, recent reports have explored approaches such as Massive Open Online Courses (MOOCs) for certification at various LSS levels. For example, some programs have supplemented online theoretical instruction with real-case applications supported by lectures and mentoring (Hutwelker and Ott 2022). Additionally, other studies have examined experiential and collaborative learning in the classroom, emphasizing the importance of integrating practical experiments in Black Belt training to facilitate the understanding of complex concepts and highlighting the value of collaborative learning in LSSBB projects (Lee and Furterer 2021; Ramamurthy and Reyes 2006).

The literature also identifies other critical factors for the success of LSS training programs. Organizational factors such as lack of managerial support, insufficient time allocated for training, and undervaluation of training recognition are potential causes of failure (McDermott et al. 2024). Research on leadership in LSS has identified specific competency profiles for Black Belt professionals, distinguishing between skills required for team management and overcoming potential organizational barriers (López-Soto et al. 2013). Furthermore, within organizational contexts, there exists a gap between academic and professional perspectives regarding the roles and responsibilities of Black Belts (Karaminas et al. 2014). This suggests the need to align practical requirements with the training of LSSBB professionals.

Lastly, research on the relationship between participants' demographic and academic profiles and their performance in LSSBB training programs remains an underexplored area. While studies have analyzed the perspectives of Green Belt professionals (Green 2006), providing evidence on the nature of their training and projects developed, there is limited evidence on factors influencing the performance of Black Belt professionals. This gap in the literature, particularly pronounced in Latin American contexts such as Peru, justifies the present study, which seeks to provide valuable information on profiles, projects, and academic performance in LSSBB training programs to bridge this gap.

3. Methods

This exploratory study adopts a quantitative approach. Data were collected for the period 2012–2022 from a private institution in Peru that has been offering training and certification programs at the Yellow Belt, Green Belt, and Black Belt levels for over a decade, with a decentralized presence across the country. Data collection involved reviewing academic records from the selected training institution, specifically examining participants' demographic data and grade transcripts. Academic performance was assessed based on the final average score obtained during the LSSBB training program, which synthesizes evaluations from each of the program's five modules. The study population comprises all participants in the LSSBB training program conducted by the selected Peruvian institution during the 2012–2022 period. The final sample consists of 151 professionals.

The dependent variable in this study is the academic performance of professionals who participated in the LSSBB programs. Independent variables include demographic, academic, and organizational factors. Demographic variables encompass gender (male and female categories) and age group (categorized into 20–30 years old, 31–44 years old, and 45 years old and older). The academic variable is the modality, with two categories (online and face-to-face) corresponding to the modalities offered by the program during the selected period. Organizational variables include the sector of the organization and the participant's role within the organization. The sector variable is categorized into four groups: primary industry (sectors such as mining and agribusiness), manufacturing and production, commercial services, and general and specialized services (services related to less frequently represented sectors in the sample,

such as education or healthcare). The role variable is categorized into four groups: executive management (senior executives and managers), leaders and supervisors, analysts, and operational and support roles. The distribution of professionals according to these variables is presented in Table 1.

Table 1. Descriptive Statistics

Variable	Category	Frequency	Percentage
Modality	Online	28	18.5
	Face-to-face	123	81.5
Age	20 - 30 years old	24	15.9
	31 - 44 years old	82	54.3
	45 years old and older	45	29.8
Gender	Male	107	70.9
	Female	44	29.1
Work Sector	Primary industry	33	21.9
	Manufacturing and production	50	33.1
	Commercial services	43	28.4
	General and specialized services	25	16.6
Role	Executive management	22	14.6
	Leaders and supervisors	38	25.2
	Analysts	46	30.4
	Operational and support roles	45	29.8

To achieve the proposed objectives, statistical analysis was carried out using Minitab 22. First, a descriptive analysis was conducted through frequency and percentage distributions of the variables under study. To address the first objective, a K-means cluster analysis was performed along with Pearson's χ^2 test. For the second objective, a four-way ANOVA with one interaction was conducted to determine the statistical significance of the variables. Subsequently, graphical representations were generated for the significant results, including interval plots showing mean comparisons, main effects plots, and interaction plots.

4. Results and Discussion

4.1 Demographic profile of participants in LSSBB training program

To characterize the demographic profile of participants in the LSSBB training program, K-means cluster analysis was applied using standardized variables and squared Euclidean distance under Ward's method. The resulting clusters identified homogeneous groups based on participants' demographic and organizational characteristics. The analysis revealed four clusters comprising the151 participants. To validate statistical significance, Pearson's χ^2 test was applied, and all results were statistically significant ($p < 0.001$), indicating significant differences in the distribution of each variable across the clusters. The cluster distribution is presented in Table 2.

Cluster 1 consisted exclusively of men, mostly from the second age group (31–44 years old), primarily working in sectors related to primary industry, manufacturing, and production. They predominantly held technical roles such as analysts or operational and support roles. Cluster 2 consisted exclusively of women, also mainly from the second age group (31–44 years old), distributed across the manufacturing, production, and commercial service sectors. These professionals held analyst and operational and support roles, with a notable presence in supervisory and leadership roles. Cluster 3 was mostly composed of men from both the second (31–44 years old) and third (45 years old and older) age groups, primarily working in commercial and specialized service sectors. Professionals in this cluster held intermediate-level roles. Finally, Cluster 4 was mostly made up of men from the third age group (45 years old and older), primarily working in manufacturing and production sectors, and characterized by high-level leadership and management roles.

Table 2. Results of K-means cluster analysis

Variable	Category	Cluster 1 (n = 36)	Cluster 2 (n = 37)	Cluster 3 (n = 44)	Cluster 4 (n = 34)	Total
Age	20 - 30 years old	10	11	2	1	24
	31 - 44 years old	24	24	23	11	82
	45 years old and older	2	2	19	22	45
Gender	Male	36	0	40	31	107
	Female	0	37	4	3	44
Work sector	Primary industry	18	5	0	10	33
	Manufacturing and production	17	16	3	14	50
	Commercial services	1	13	21	8	43
	General and specialized services	0	3	20	2	25
Role	Executive management	1	1	2	18	22
	Leaders and supervisors	4	9	10	15	38
	Analysts	17	14	14	1	46
	Operational and support roles	14	13	18	0	45

The first profile suggests the presence of technical professionals in traditional industrial sectors seeking process improvement tools. The second profile highlights the participation of women in advanced continuous improvement programs. The third profile reflects experienced professionals in the services sector. The fourth profile represents senior executives with extensive experience who seek to incorporate LSS methodologies from a strategic and leadership-oriented perspective. The segmentation shows that the LSSBB training program attracts diverse yet complementary professional profiles, ranging from technical specialists to senior executives. Additionally, it covers industrial sectors historically associated with continuous improvement and process optimization. Finally, the presence of a female-only cluster reveals gender-specific patterns, while the age distribution shows that LSSBB training is valued by both professionals in the early stages of their careers and senior executives.

4.2 Academic performance of participants in LSSBB training program

To assess participants' academic performance in relation to their demographic, academic and organizational variables, a one-way ANOVA with one interaction was conducted (Table 3). This analysis helped identify which variables significantly influenced participants' academic performance in the LSSBB training program and allowed for the detection of possible interactions among factors affecting academic outcomes.

Table 3. Results of analysis of variance (ANOVA)

Factor	DF	Adj SS	Adj MS	F-Value	P-Value
Modality	1	9.105	9.1047	5.75	**0.018**
Age	2	18.26	9.1302	5.76	**0.004**
Gender	1	0.451	0.4511	0.28	0.594
Work sector	3	0.721	0.2405	0.15	0.928
Role	3	5.462	1.8208	1.15	0.332
Modality x Age	2	14.078	7.0389	4.44	**0.013**

The ANOVA results showed that two factors—modality and age—as well as one interaction (modality × age) had statistically significant effects. The significance of the modality indicates differences in academic performance between participants in online and face-to-face formats. Age also showed a significant effect, meaning that belonging to a specific age group influences academic performance. The significant interaction revealed that the impact of the modality on academic performance varies depending on the participant's age group. In contrast, gender, work sector, and role were not statistically significant, suggesting they are not determining factors in participants' performance within the LSSBB program.

Subsequently, mean comparison tests were conducted for the factors that showed statistical significance. Regarding modality, participants in the face-to-face modality achieved a higher mean score (M = 17.03, SD = 1.03) compared to those in the online format (M = 16.01, SD = 2.04). This indicates that the face-to-face modality yields better academic outcomes in the LSSBB training program. With respect to age, participants aged 45 years old and older obtained the highest academic performance (M = 17.17, SD = 1.16), followed by those aged 20–30 years old (M = 16.76, SD = 1.54), and lastly, participants aged 31–44 years old (M = 16.68, SD = 1.34). This distribution suggests that participants with more professional experience perform better during the training. At the same time, the strong performance of younger participants stands out, while the intermediate group shows the lowest performance. The differences in mean scores with confidence intervals for both modality and age are shown in Figure 1.

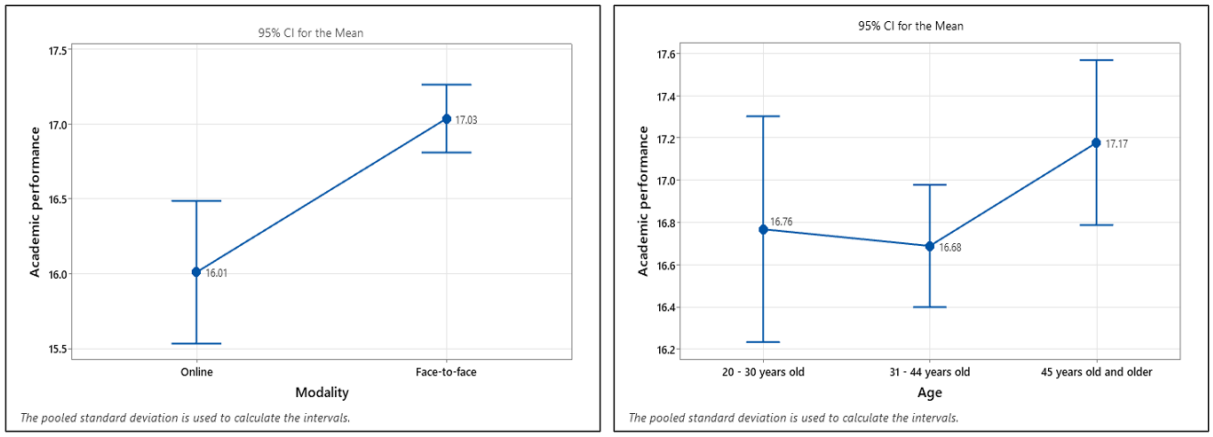

Figure 1. Interval plot of academic performance vs modality and academic performance vs age

Figure 2 presents the main effects plot for academic performance, including the factors that were statistically significant. The interval plot confirms the previously described trends. A clear difference is observed between the modalities: the line corresponding to the face-to-face modality consistently lies above that of the online modality. Regarding age, a non-linear pattern is evident: a slight drop in the middle group followed by a pronounced increase in the 45-year-old and older group. This suggests that accumulated experience in LSS project implementation and the professional maturity of senior participants have a notable effect on academic performance.

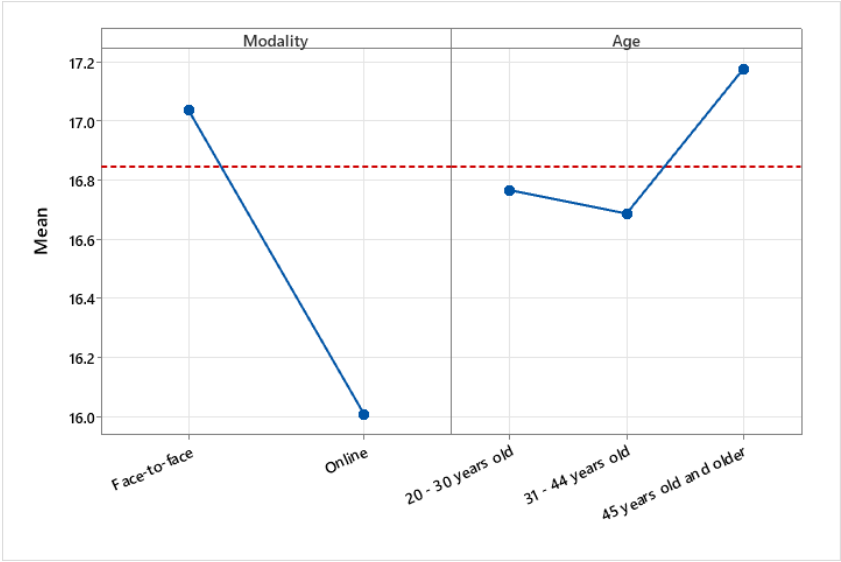

Figure 2. Main effects plot for academic performance

Figure 3 shows the interaction plot between modality and age, a statistically significant interaction in the ANOVA results. In the face-to-face modality, academic performance remains relatively stable across all age groups; notably, the 20–30 years old group performs the best in this format. In contrast, the online modality shows a different trend: performance decreases progressively from the youngest group to the intermediate group (31–44 years old), then increases sharply in the 45- years- old and older group.

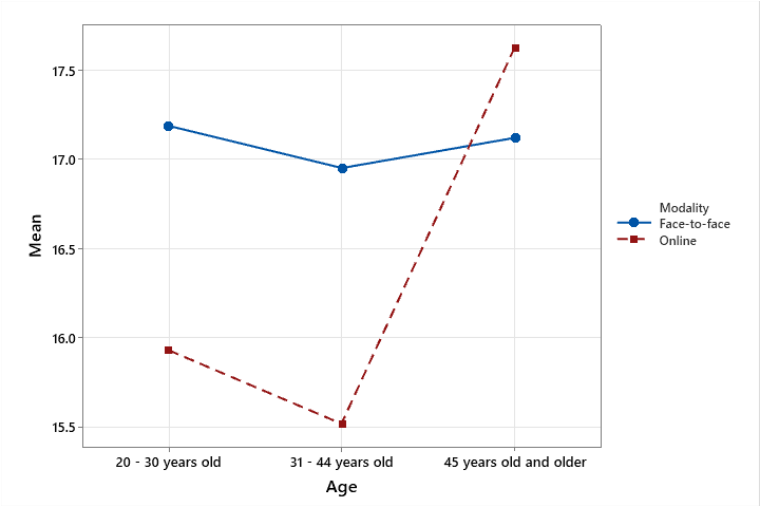

Figure 3. Interaction plot for academic performance

This interaction suggests that the effectiveness of each modality varies significantly depending on the participant's age. While the face-to-face modality maintains consistently high performance across age groups, the online modality shows greater variability. In the context of LSSBB training programs in Peru, these findings suggest that older professionals possess specific characteristics (such as prior experience, self-discipline, and higher motivation) that allow them to benefit more effectively from the online modality. Meanwhile, younger participants benefit from the structured environment and direct interaction provided by the face-to-face modality.

4.3. Projects by participants in LSSBB training program

The analysis of the projects developed in the program allows for the evaluation of the effective transfer of theoretical knowledge to practical applications within the students' business contexts. To this end, 44 projects developed between 2012 and 2022 were analyzed. Descriptive statistics were used to identify patterns in two dimensions: the sectoral distribution of the companies where the projects were implemented, and the most frequently used tools. This is shown in the following figure:

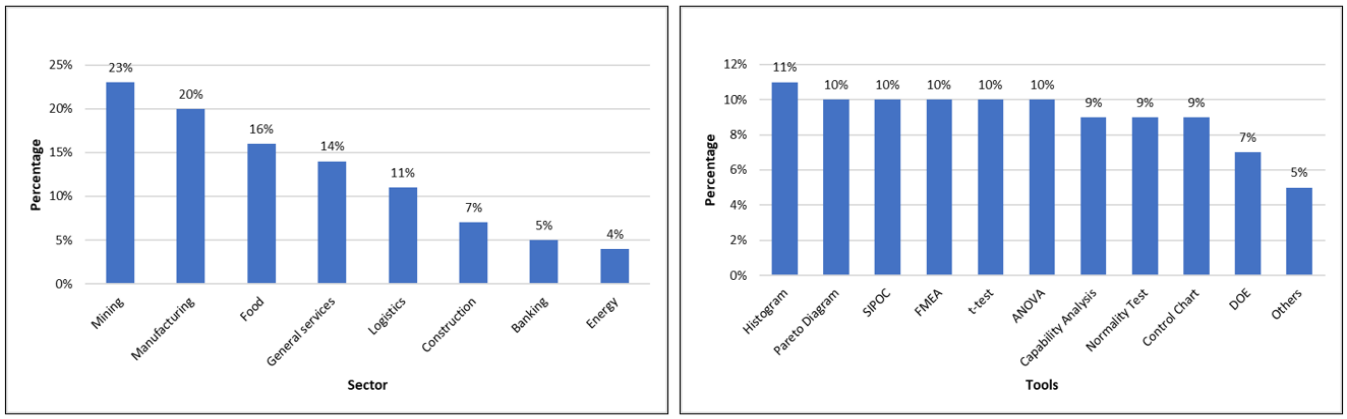

Figure 4. Distribution of projects by sector and most frequently used tools

The sectoral distribution shows that the mining sector accounts for the highest proportion of developed projects, followed by manufacturing and food. There is a concentration in traditional industrial sectors, which aligns with the methodological nature of LSS, closely related to production and manufacturing processes. The presence of other sectors such as construction, banking, or energy indicates the expansion of LSS applications into other fields. In terms of tools, there is a balanced distribution among the ten most frequently used tools. This reflects the comprehensive application of tools associated with the different phases of the DMAIC methodology.

Finally, projects developed in the program tend to focus on the optimization of the operational and logistical processes, variability reduction, and quality control improvement in sectors such as mining, manufacturing, and logistics. Additionally, projects address the efficient management of resources and inputs to reduce waste or unnecessary consumption, while proposing strategies to increase productivity and enhance the performance of teams and individuals. These initiatives reflect a structured approach to continuous improvement and statical process control, which are fundamental pillars of LSS.

5. Conclusion

The demographic characterization revealed four distinct participant profiles in the LSSBB training program: technical professionals from traditional industrial sectors, female professionals in leadership roles, experienced professionals from the service sector, and senior executives with a strategic perspective. This diversity demonstrates the program's capacity to attract and train professionals from various hierarchical levels within organizations. Additionally, the analysis of academic performance showed that modality and age are determining factors. Participants in the face-to-face modality achieved better results overall, with a significant interaction indicating that older professionals benefit more from the online modality, while younger professionals perform better in the face-to-face modality. Finally, the evaluation of 44 projects developed during the program confirmed the effective transfer of knowledge to practical applications in real organizational contexts. The projects were primarily implemented in companies from traditional industrial sectors (mining, manufacturing, and food), and the DMAIC tools were used in a balanced manner, reflecting the comprehensive training of participants. The projects focused on operational process optimization, variability reduction, quality control improvement, and efficient resource management. This reflects a structured approach to continuous improvement and validates the relevance and effectiveness of the LSSBB training program as a tool for professional development and organizational improvement.

Based on the Peruvian experience, some strategies are proposed to optimize future LSSBB training programs. First, it is important to implement hybrid and adaptive teaching models that capitalize on the identified strengths: developing intensive face-to-face programs that maximize direct interaction and collaborative learning, and designing online platforms with personalized and advanced tutoring. Second, developing specialized training modules according to the identified demographic profiles; for example, specific technical modules for primary industry and manufacturing professionals, leadership programs targeted at the female population, and specialized modules for executives that integrate the methodology with organizational management perspectives. Third, expanding sectoral application by not limiting it to traditional sectors.

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