UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

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Integrating Lean Principles into Teaching and Learning Processes: A Case Study in Higher Engineering Education.

.

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RESUMEN

Los profesionales de la ingeniería representan el núcleo del crecimiento y la transformación de la sociedad, por lo que deben estar dotados de conocimientos multidisciplinares y un conjunto completo de competencias tanto técnicas como interpersonales. Sin embargo, el enfoque actual de la enseñanza superior, basado en metodologías tradicionales centradas en el profesor, se centra en los conocimientos técnicos y teóricos, lo que da lugar a ingenieros graduados insuficientemente preparados. Este estudio pretende establecer un marco para responder a las necesidades de la industria de los estudiantes de ingeniería con un conjunto completo y multidisciplinar de competencias mediante la aplicación de la filosofía Lean en el ámbito académico. El modelo Lean Engineering Education se desarrolló con la integración de los principios Lean en estrategias activas de enseñanza y aprendizaje que incluyen el aprendizaje basado en proyectos, casos y juegos. Se utilizaron herramientas Lean como el análisis VOC, el despliegue de funciones de calidad, el análisis de causa raíz, el diagrama SIPOC y los ciclos PDCA. Se realizó un estudio piloto (n=33 estudiantes) para evaluar la implementación del modelo en un curso de ingeniería de la Universidad San Francisco de Quito. La recolección de datos cuantitativos se basó en una encuesta en línea compuesta por una sección de actitudes y una sección de desarrollo de habilidades multidisciplinarias. Los resultados indicaron un impacto positivo del modelo propuesto no sólo en la motivación intrínseca y el interés de los estudiantes, sino también en el desarrollo de sus habilidades, incluyendo el pensamiento lógico, innovador y crítico, el liderazgo y la resolución de problemas. Este estudio demostró que la integración de la filosofía Lean y la enseñanza de la ingeniería proporciona la plataforma ideal para formar ingenieros para el futuro lugar de trabajo, fomentando el desarrollo de un conjunto de habilidades multidisciplinares y representando una iniciativa hacia la mejora del sistema educativo.

Palabras clave: Enseñanza de la ingeniería, Educación Lean, Filosofía Lean, Principios Lean, Aprendizaje activo

ABSTRACT

Engineering professionals represent the core of the growth and transformation of society; thus, they must be equipped with multidisciplinary knowledge and a complete skillset with both technical and interpersonal skills. Nevertheless, the current higher education approach based on traditional teacher-centered methodologies focuses on technical and theoretical knowledge, resulting in underprepared graduated engineers. This study aims to establish a framework to address the industry needs of engineering students with a comprehensive, multidisciplinary set of competencies through the application of the Lean philosophy in the academic field. The Lean Engineering Education model was developed with the integration of Lean principles into active teaching and learning strategies including project, case and game-based learning. Lean tools such as VOC analysis, quality function deployment, root cause analysis, SIPOC diagram, and PDCA cycles were used. A pilot study (n=33 students) was conducted to evaluate the implementation of the model in an engineering course at Universidad San Francisco de Quito. Quantitative data collection was based on an online survey composed of an attitude section and a multidisciplinary skill set development section. The findings indicated a positive impact of the proposed model not only on student intrinsic motivation and interest, but also on their skill development including logical, innovative and critical thinking, leadership, and problem-solving skills. This study showed the integration of Lean philosophy and engineering education provides the ideal platform to educate engineers for the future workplace by fostering the development of a multidisciplinary skill set and representing an initiative toward the improvement of the education system.

Key words: Engineering Education, Lean Education, Lean philosophy, Lean Principles, Active Learning

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1. INTRODUCTION

The fundamental premise of this study is that engineering education is the engine of growth and transformation of society with a multiplier effect on all aspects of development. Engineering professionals are at the heart of technological, economic, and social innovation processes, endowing their education with an exceptional level of importance (Sheppard et al., 2009). Technical instruction has been subject to exponential growth globally, giving rise to Engineering Education, the academic branch focused on teaching concepts and knowledge related to the practice of engineering as a professional career (Valencia, 2010). To accelerate technological and educational innovation, and increase the performance of engineering graduates, Engineering Education merges research and teaching of engineering expertise (Soler, 2014). Nevertheless, engineering is going through a crisis due to the exclusive focus on the technical element of the profession and the lack of relationship with other areas of knowledge such as humanities and arts, resulting in a deficiency of soft skills and abilities for performance in working life (Valencia, 2010).

Factors such as accelerated globalization, technological development, and the fifth industrial revolution, require higher education to continuously evolve to meet the changing needs of society (Alves et al., 2017). Today's complex and volatile world requires "a new type of engineer, an entrepreneurial engineer, who needs a broad range of skills and knowledge above and beyond a strong scientific and engineering background" (Creed et al., 2002). In essence, engineering professionals must be equipped with interdisciplinary knowledge and practice-oriented soft skills for the 21st century, including (1) critical, whole-system, and problem-solving thinking, (2) effective communication skills, (3) strong ethical sense, (4) leadership and collaborative teamwork, and (5) continuous learning and knowledge building disposition (Parker et al., 2019; ABET, 2021; Voogt & Roblin, 2010).

According to the Accreditation Commission for Engineering Technology (2021), university degree programs are responsible for developing students' ability to apply knowledge as practicing professionals. However, there is increasing discussion of the ineffectiveness of traditional teacher-centered education in failing to develop students' critical thinking skills and their ability to solve problems as professionals (Berkel & Schmidt, 2005). Indeed, it has been established that current engineering education does not prepare graduates for engineering practice within the professional sector effectively (Brawner & Miller, 2003). Emerging literature indicates the benefits of learner-centered forms of instruction, where the student is an active participant in the learning process (Bransford et al., 2000). With increased emphasis on hands-on, project-based, and problem-solving learning, an immediate boost in student capabilities in engineering can be expected (Chiang & Lee, 2016).

As Naik (2004) states, to promote the development of technology and industry, it is essential to have highly qualified and competent human capital, thus, engineering education is key. Consequently, this study aims to address the gap between the demand for fully trained engineers and the educational capacity to provide them. The Lean Engineering Education model is developed through the application of the Lean philosophy to the teaching and learning processes in a higher education classroom. The model is implemented in an engineering course at Universidad San Francisco de Quito. Integrating Lean principles into these processes is a new research area. The present study sought to answer the following research questions:

- RQ1: To what extent can the application of the Lean philosophy in education foster the development of student interest, self-efficacy, and motivation within a classroom?
- RQ2: To what degree can the integration of Lean principles and active teaching and learning student-centered methodologies promote the development of a multidisciplinary skill set with interpersonal competencies?

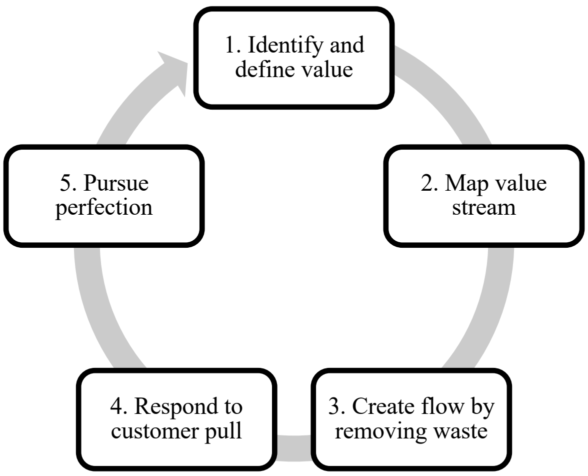
This introduction is followed by a theoretical section that sets the frame for the research. The subsequent section outlines the methodological development of the educational model. The methods section describes the case study conducted, including the implementation and evaluation of the model. The results section presents the answer to the research questions based on empirical findings. The discussion examines the results in light of the theoretical framework and the research questions, and provides some limitations and future research proposals. Lastly, a concluding section assesses the overall contribution of the paper.

2. LITERATURE REVIEW

2.1. Lean Education

Lean management is a customer-driven approach focused on waste reduction and continuous process improvement that finds its origin in the manufacturing sector (Womack et al., 1990). Lean Thinking, the underlying concept of Lean management, is crucial to the discipline's success as it implies a shift in mindset and culture driven by a continuous improvement effort (Monden, 1998). Since its consolidation, organizations across the world have adopted and adapted Lean Thinking to their unique contexts and cultures following its five principles: (1) identification of value, (2) mapping of the value stream, (3) creation of flow, (4) implementation of pull production and (5) pursuit of perfection (Womack & Jones, 1996), as shown in Figure 1. Under this philosophy, organizations are better equipped to handle the global issues that technological advancement cannot resolve, and people are transformed into truly active thinkers and learners (Alves et al., 2012). Consequently, Lean Thinking tools have been implemented in several disciplines, including the academic one with excellent success (Alves et al., 2017).

Figure 1. Five Lean principles



Lean Education is the methodical, student-centered approach to provide academic services that enable students to lead and meet individual, industrial, and societal needs through the use of concepts and tools of engineering practice based on continuous improvement (Flumerfelt et al., 2015). Hence, Lean Education is recognized as the best-aligned method to achieve (1) content-competency mastery, and (2) high engagement in education and continuous improvement through the strategic design of curriculum and student progress assessment in the engineering classroom (Alves et al., 2017). Indeed, Lean Education is proposed as the venue to bridge the gap between academy and industry (Kahlen et al., 2011).

Lean Education describes the application of Lean thinking to education, both in administration processes (e.g., admissions, financial decisions, logistics and facilities planning, student support and auxiliary processes), and academic activities (e.g., course and curriculum design, teaching approaches, and degree programs improvement) (Alves et al., 2017). Nevertheless, in a systematic literature review conducted by Vukadinovic et al. (2017), it was shown that contributions to Lean Education have primarily been focused on the application of Lean principles in administrative activities, neglecting key processes such as learning, teaching, evaluation, and research within educational institutions.

Indeed, when it comes to the educational delivery process, the literature is centered on theoretical frameworks for the implementation of this philosophy and its potential outcomes. For instance, Emiliani (2005) outlined the theoretical approach to employing Kaizen techniques on course development in a US University, and likewise, he (2006) conducted a case study to correct several issues in courses and degree programs and developed a set of 11 interconnected improvements (e.g., simplify curriculum and enhance relevancy and interest in the subject) to provide highly differentiated academic experiences more relevant to students and organization's needs. Uébe et al. (2017) proposed a model as a philosophical basis for Lean Education application to be implemented in the next few years at a Federal Institute of Applied Science in Brazil. Among the expected outcomes of this implementation were found student-centered learning methods as learning philosophies, a main focus on concerns of students and industry, learning-centered knowledge in cross-disciplines, the development of skills and abilities, and enhanced relationships among students, faculty, and society (Uébe et al., 2017). Moreover, in a literature review conducted by Alves et al. (2014), the term Lean Engineering Education (LEE) was proposed to define the concept of Lean applied to Engineering Education curriculum design, arguing that students who are taught in LEE must be able to think systematically, develop essential competencies and have content mastery.

Despite the steady increase in Lean Education research, the core of the studies centers on the application of Lean principles in non-teaching activities (i.e., administrative and support processes). Thus, the applied research on educational improvement in engineering classrooms using a Lean Thinking approach is very limited. One of the few recent cases is the study by Dinis-Carvalho and Fernandes (2017), who developed and implemented a model based on the integration of Lean concepts into teaching and learning processes within a graduate engineering course at the University of Minho, Portugal. Findings founded on students' perceptions suggested the model was beneficial and promoted the enhancement of teaching and learning processes, while encouraging continuous reflection of practice by the educator (Dinis-Carvalho & Fernandes, 2017). Similar results were obtained by Emiliani (2004) who implemented Lean tools such as 5S, JIT, standard work, respect for people, visual controls, Load Smoothing, and VOC in an MBA course in a US university, reporting positive improvements in student experience and instructor performance.

These studies show that incorporating Lean Thinking into the academic area may be a valuable proposition for students to develop competencies required in the industry. Among most of the literature, it is proposed that the implementation of Lean tools is the means of improving the educational delivery process visualized through high-quality results, increased student and professor performance, high level of engagement, and significant academic development (Vukadinovic et al., 2017). Nevertheless, the lack of applied research cannot be overlooked.

This limitation may be due to several factors, with the lack of understanding of the appropriate instructional approach to implement this philosophy being the main one (Vukadinovic et al., 2017). As stated in the book Lean Education: Overview of Current Issues (Alves et al., 2017), effective pedagogy relies on active learning estrategies that engage students in their own thinking, learning, and collaborative learning. Student-centered approaches enable learners to act as active constructors of knowledge and teachers as facilitators of this process, in contrast to traditional education where one-way communication occurs from the teacher to passive students (Brown, 2011). Through active learning strategies and techniques such as case-based or project-based learning, technology-based activities, and gamification, student performance, and engagement are highly increased (Weimer, 2002). For instance, in the study by Siriban-Manalang (2017), a simulation-based approach to structured learning exercises was implemented in a Lean undergraduate course, concluding that active learning techniques are powerful means of improving learning and motivating students, as they reflect on their learnings and apply them in real-life situations. Consequently, the proposed educational model is based on active learning methodologies, as they have proved to augment learning in the modern adult student by positively influencing their attitude, performance, and engagement, and showcasing an increased level of motivation, interest, and effort within the classroom (Barata et al., 2013; Buckley & Doyle, 2014; Burguillo, 2010; Hanus & Fox, 2015; Su & Cheng, 2015).

2.2. Engineering Requirements

The development of appropriate competencies is a core dimension of Engineering Education (Vukadinovic et al., 2017). A substantial body of study has been constructed on the subject of employees' skills, knowledge, and talents. Nguyen (1998) conducted a survey on the fundamental qualities required by engineering students and professionals in academia and industry to compare the specific abilities needed for each of those three groups. Through a similar survey, Lang et al. (1999) identified that the most important skills for engineers include critical, analytical, and communication competency, interpersonal skills, and technological proficiency. The findings of Lang et al. (1999) regarding interpersonal abilities were verified by Meier et al. (2000), who also emphasized the value of lifelong learning.

Extensive research on the industry needs and demands is conducted to define educational objectives and learning standards of higher education programs (Mejía et al., 2020). Compliance with these quality standards of a program is reviewed during the accreditation process by institutions with the proper authorizations. In the engineering and technology disciplines, ABET is the most recognized accreditation board that has determined the quality criteria that engineering programs must meet (ABET, 2021). The student outcomes (SOs), outlined in its Engineering Criterion 3, define the desired learning objectives as the set of skills that engineering graduates require to perform successfully on the industry (Pimmel, 2003). Some of the key requirements are that students must be knowledgeable in their respective engineering domains with technical and intellectual skills, but also showcase a high level of global, communication, teamwork, and critical thinking competencies in order to perform well in various types of multicultural work environments (ABET, 2021).

While technical abilities still play a significant role in an engineer's skill set, soft skills have grown to be just as crucial, according to Shuman et al. (2005) in their evaluation of contemporary engineers' skill sets. Indeed, Sharma and Sharma (2010), determined soft skills are now a critical component of success, particularly in the engineering industry, and these abilities may be successfully taught to students throughout the educational process. Nair et al. (2009) studied the gap between engineering graduates' skills and industry expectations and stated the key characteristics for employers included interpersonal skills, social ethics, and emotional intelligence. Thus, as stated by Balaji and Somashekar (2009), employers are more likely to hire candidates that exhibit greater levels of soft skills than those who just show highly developed technical talents.

Based on the preceding literature analysis, it is evident that engineers must possess a complete skill set with a variety of abilities including technical, interpersonal, and leadership skills in order to succeed. Nevertheless, the engineering education system continues to place a strong and exclusive emphasis on methodical knowledge resulting in graduated engineers underprepared for the industry. Hence, higher education programs and educational institutions must explore new options to integrate transferable skills that can be used in diverse industry settings and allow engineering students to work more effectively within social and global contexts (Crebert et al., 2004; Fuchs, 2006).

3. LEAN ENGINEERING EDUCATION MODEL

3.1. First Lean Principle: Customer Value

Lean Thinking is a quality management and improvement approach that defines quality as the ability to meet customer demands (Womack and Jones, 1996), thus, defining value from a customer's perspective is the starting point in the Lean process. Identifying the customer in academic settings can be challenging as there seem to be multiple stakeholders in the education process. The literature review demonstrates that most studies that highlight the implementation of quality tools to enhance the performance of higher education institutions include three customer groups for education: (1) students, (2) academic staff, and (3) employers of the private or public sector (Owlia & Aspinwall, 1998; Jiang et al., 2007; Nygaard et al., 2008). In the present case, the aforementioned three groups are considered customers as they interact directly with education services.

An analysis of the voice of the customer (VOC), employed to describe customer needs and expectations (Griffin & Hauser, 1991), is performed to specify customer value. The student outcomes (SOs) outlined by ABET (2021) describe the desired learning objectives capturing a specific set of hard and soft skills. Table 1 summarizes the alignment of the ABET's SOs with the corresponding soft skills and competencies.

Table 1. Alignment of ABET SOs and Soft Skills

Item	ABET's Student Outcomes*	Skills and Competencies
1	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	Logical thinking Problem-solving skills
2	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	Innovative thinking Problem-solving skills
3	an ability to communicate effectively with a range of audiences.	Communication skills
4	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	Critical reasoning Integrity

5	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	Leadership Teamwork Collaboration
6	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	Critical reasoning Organizational skills
7	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	Life-long learning

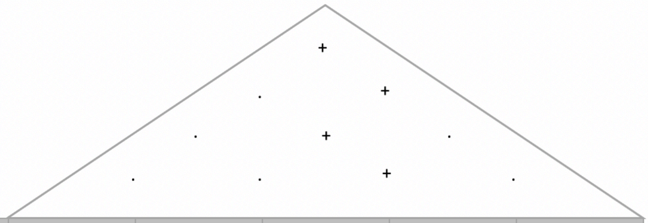
Note. * Retrieved from 2022 – 2023 Criteria for Accrediting Engineering Program (ABET, 2021)

The Quality Function Deployment (QFD) tool enables to further analyze the Voice of the Customer (VOC) by identifying and translating the key customer requirements into the appropriate quality characteristics of a product or service (Akao & Mazu, 2003). Through the implementation of QFD, one can identify the appropriate teaching and learning strategies to enhance students' knowledge and skills and thus, satisfy the desired customer outcomes. Singh & Rawani (2018) conducted a literature review on the application of QFD in the education sector and highlighted the case study performed by Prabhushankar et al. (2015) on the implementation of QFD for curriculum redesign. They used an analytical hierarchical process (AHP) for the prioritization of customer requirements considering stakeholders faculty, alumni, employers, students, and accreditation boards (Prabhushankar et al., 2015). In the present study, the importance rating of the customer requirements (i.e., key student skills and competencies) is determined based on the aforementioned case study.

The relationship between the customer requirements and the functional requirements (i.e., teaching and learning techniques) is established and indicated in the relationship matrix. The most widely preferred weighting methodology in literature is applied with the categories of 'strong, medium, weak, and no relationship' given by the values of 9, 3, 1, and 0 respectively (Owlia & ASpinwal, 1998). Considering these weightings are subjective (Owlia & Aspinwal, 1998), the relationship is determined based on the literature review of case studies and previous research on the application of different teaching methodologies (i.e., game, case and project-based learning, flipped teaching and traditional lectures) and the outcomes in regards of student performance and attitude development (Barata et al., 2013; Buckley & Doyle, 2014; Burguillo, 2010; Hanus & Fox, 2015; Siriban-Manalang, 2017; Su & Cheng, 2015; Weimer, 2002).

Figure 2 displays the QFD matrix. Several functional requirements show a strong relationship with the customer requirements. For instance, case-based learning shows a strong relationship with the development of logical and innovative thinking; problem-based learning exhibits a very strong relationship with problem-solving, organizational and teamwork skills; and game-based learning displays a very strong relationship with commitment to lifelong learning. Thus, the proposed model is centered in the implementation of the following active teaching methodologies as they seem to promote the development of the expected student soft skills: project-based learning (PBL), case-based learning (CBL), and game-based learning.

Figure 2. Quality Function Deployment Matrix

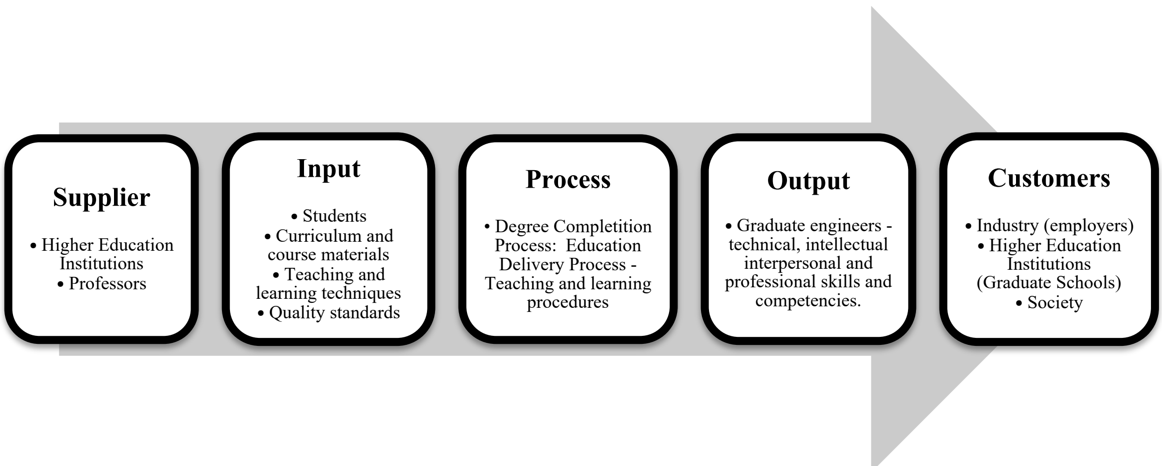


	1: low, 5: high Customer importance rating	**Functional Requirements:** Teaching and Learning Techniques (How's) → **Customer Requirements:** Required student skills and competencies (What's) ↓	Lectures	Game-based learning	Case-based learning	Project-based learning	Flipped teaching	Weighted Score
1	4	Logical thinking	1	3	3	3	1	44
2	5	Problem-solving skills	1	9	9	9	1	145
3	3	Innovative thinking		9	1	3		39
4	5	Communication skills		1	3	9	3	80
5	5	Critical reasoning	1	1	3	3	3	55
6	4	Leadership			3	9		48
7	5	Teamwork and collaboration		1	9	9		95
8	3	Organizational skills		1	3	9	3	48
9	3	Commitment to lifelong learning	1	9	9	9	3	93
		Technical importance score	17	129	183	261	57	647
		Importance %	3%	20%	28%	40%	9%	100%
		Priorities rank	**5**	**3**	**2**	**1**	**4**	

3.2. Second Lean Principle: Value Stream Analysis

Mapping the "value stream" includes all the activities and processes involved in the procurement, processing, and delivery of a product or service (Womack and Jones, 1996). The higher education process can be compared to a manufacturing process, where raw materials are processed via a series of steps to produce and deliver finished goods. Accordingly, higher education institutions are part of the process where new students become intellectual graduates with a set of skills that are later employed in the industry. To understand the process variables, a version of the SIPOC diagram from the engineering education global view perspective is provided in Figure 3.

Figure 3. SIPOC of Engineering Education process



The idea behind the value stream analysis is to examine the business process to determine steps that do create value and eliminate the ones that do not (Alves et al., 2017). In Lean terminology, a product that does not satisfy customer expectations is referred to be defective and must be reworked to comply with the specifications (Womack & Jones, 1996). Mapping this concept in the academic field enables us to visualize that new workforce is being generated without the appropriate knowledge and skills, thus, not meeting industry requirements.

Additionally, since minimizing waste is one of the main goals of Lean Manufacturing, waste must be defined in the higher education system of processes. As established by Womack and Jones (1993), waste is any human activity that consumes resources but creates no value and can be categorized into 8 different types of waste: defect, duplication, over-production, over-processing, waiting, transportation, inventory, and under-utilized talent. Waste in education typically happens when time, resources, and effort are expended, but the final results do not meet the standards set by key performance indicators (i.e., students do not acquire new knowledge or required skills). Considering the core idea in Lean is maximizing customer value while minimizing waste (Womack & Jones, 1993), to produce high-quality graduates, efforts to minimize waste must be undertaken throughout the academic process with consideration of stakeholders' requirements. Table 2 shows examples of waste within the classroom in the Higher Education environment with potential solutions.

Table 2. Examples of Waste in Higher Education Classrooms and Respective Solutions

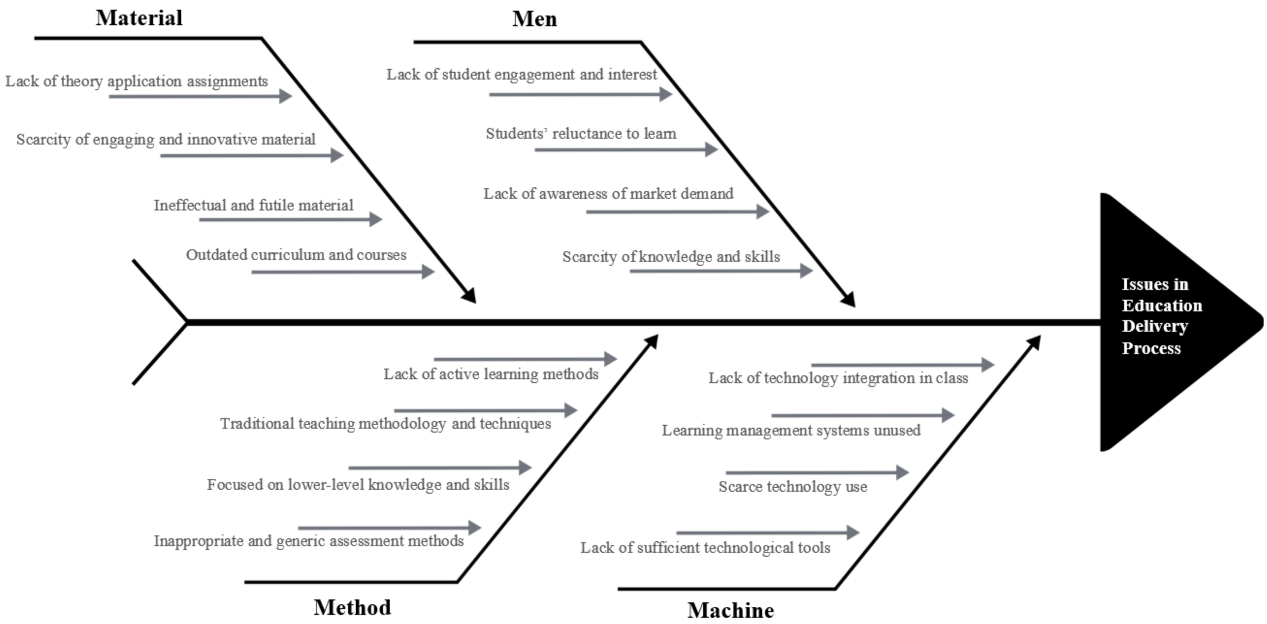
Waste Category	**Examples within the Classroom**	**Potential Solution**
Over-production	Teaching topics already taught in other courses Unbalanced workload Over-assessment	Prevent accumulation of material through an appropriate course planning
Over-processing	Excessive review of prerequisite material Repetitive teaching and discussion of understood topics Teaching obsolete topics Excess of information Unnecessary and redundant introductions Repetitive work and tasks	Assure proper planification of the course, considering the expected learning outcomes, the teaching strategies and the assessment methods
Waiting	Late grading Delayed evaluation Long waiting time to receive evaluation results and feedback	Ensure punctuality in the evaluation and delivery of feedback
Defect	Poor knowledge acquisition Mistakes in teaching materials, activities and preparation process. Learning not relevant to industry requirements Frequent modification of course schedule Failure in examinations	Focus on the needs, abilities, interests, and learning styles of the students through the application of student-centered teaching methods.

Under-utilized talent	Student as a passive spectator Spoon-feeding Underutilization of a highly talented and educated lecturer Non-use of teacher and students abilities Knowledge or expertise that is not shared	Implement student-centered teaching and learning methodologies to ensure students have an active role and are involved in the educational process.

3.3. Third Lean Principle: Flow

After waste removal from the value stream, one must ensure that the remaining activities flow smoothly with no interruptions, delays, or bottlenecks (Womack & Jones, 1996). Hence, the focus is on organizing a continuous flow through the process, which in the academic field refers to a smooth and leveled workload without waste pushing back students, faculty, and society (Alves et al., 2017). In general, with enhanced flow, the delivery of service improves, and the level of productivity increases. To identify the root causes of common issues, delays, and bottlenecks that impact the education delivery process and determine the need for corrective actions, a root cause analysis is conducted through the construction of a cause-effect diagram shown in Figure 4.

Figure 4. Cause and Effect Diagram



3.4. Fourth Lean Principle: Pull System

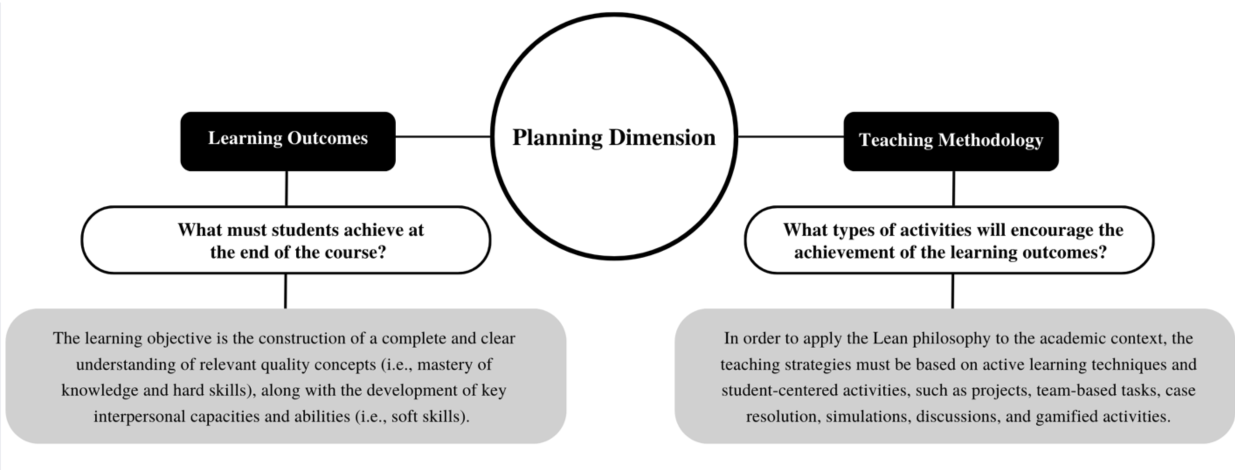
In a pull system, customer demand triggers the services, delivery, and content intending to produce the value that is needed by the customer to avoid overwork, overproduction, and waste (Womack & Jones, 1996). As previously established, engineering students are required to have a complete skill set with both technical (i.e., hard skills) and interpersonal competencies (i.e., soft skills) in order to perform appropriately in the industry. In light of this, it can be said that the demand for a high-quality education is present and must be addressed.

3.5. Fifth Lean Principle: Pursue Perfection

The management of non-value-adding elements and waste is a process of continuous improvement, thus, reducing time, cost, space, mistakes, and effort is a constant process. Hence, the fifth Lean principle is focused on enhancing the activities that generate the most value for the customer and sustaining the process with continuous improvements (Womack & Jones, 1996). In this case, this principle is supported by the integration of the PDCA (Plan, Do, Check, Act) cycle, a four-stage iterative process for constant improvement of a product or service by potential solutions testing, results analysis, and process enhancement (Chakraborty, 2016). The PDCA cycle is implemented as explained below.

- **Plan**: The planning process is an essential phase that directly impacts the teaching and learning procedures within a classroom. Two main components of the curriculum must be given special attention, including (1) learning outcomes and (2) teaching methodologies (Tyler, 1949). According to Biggs (2003), these dimensions must be aligned and can be addressed through the respective questions shown in Figure 5.

Figure 5. Planning Dimension in the PDCA Cycle



- **Do**: The second stage in the PDCA cycle is centered specifically on the class unfolding, thus, the teaching strategies employed are the primary focus of analysis (Chakraborty, 2016). The proposed methodology is based on active learning through the implementation of student-centered methods. Table 3 shows the teaching methodology, the application method through different activities and tasks, and the skills and attributes aimed to address with this implementation.

Table 3. Active learning student-centered methods implementation

Active Learning Student-Centered Method	Implementation	Skills and Attributes Addressed
Case-Based Learning (CBL)	Students analyze and solve cases, often taken from real-life situations, through the application of their knowledge and experience. Group work promotes discussion, idea sharing, and a richer and more comprehensive analysis of the case.	Critical reasoning Logical thinking Problem-solving skills Teamwork and collaboration Organizational skills
Project-Based Learning (PBL)	Students work in group in the completion of a project relevant to the learning objectives, meaningful to students, and aligned with real-world issues. Guidelines, objectives, and expectations must be provided.	Problem-solving skills Communication skills Organizational skills Leadership Teamwork and collaboration
Game-Based Learning	Instructor incorporates game-based activities, such as simulations, role-playing, and problem-solving games to reinforce key concepts and skills. The use of elements such as leaderboard, points, and badges is encouraged to motivate students, recognize achievements, and track progress. Technology tools (i.e., game-based apps, educational games, and virtual reality) can be used to create an immersive and interactive learning experience.	Innovative thinking Continuous learning Problem-solving skills Teamwork and collaboration

- **Check:** It is considered the most important phase of the cycle, as it allows us to evaluate the implementation of a plan, avoid recurring errors, and apply continuous improvement successfully. In the context of education, this dimension is aligned with the assessment methods used in the classroom and can be addressed through the following question: What types of tasks and assignments can students do to demonstrate the acquisition of the intended learning outcomes? (Biggs, 2003).

  Formative and continuous assessment processes are recognized as tools for effective content delivery and reception (Felder & Brent, 1999; Yorke, 2003). Thus, designing assessment methods that promote student learning includes the use of several frequent tasks in a build-in-steps structure instead of one end-of-course evaluation. Furthermore, feedback is crucial to both the teaching and learning process as it may be used to evaluate student and teacher performance and serve as a guide for improvement (Gibbs & Simpson, 2004). Hence, instructors must provide timely and detailed feedback to students, and feedback from students must be solicited throughout the course (e.g., at the midpoint and at the end of the course). Student evaluations, open discussions, and the teachers' own experience with the course are some of the useful sources of information that can provide important inputs for improving the teaching and learning process.

- **Act:** Action research is the process used by educational practitioners and professionals to examine, and ultimately improve, their pedagogy and practice, thus it is aimed to enhance practice and promote professional development (Dinis-Carvalho & Fernandes, 2017). According to Creswell (2008), action research has four stages: planification, action, observation, and reflection. After performing the first two steps (i.e., planning and execution) in an adequate and strategic manner, the teacher observes and evaluates the methodology used and the results it has brought within the classroom. Based on the insights obtained through the student assessment processes, decisions must be taken. The element of critical reflection on the educational approach is key, thus, it must be undertaken by the instructor. Action research is the proposed systematic approach to guarantee the continuous improvement of the educational experience through the evaluation of the current methodology and the development of more effective classroom strategies.

A key summary of the application of Lean principles in the education framework is provided in Table 4.

Table 4. Lean Principles and Tools in the Education Framework

Lean Principle	**Lean Tools Applied**	**Education Framework**
Identify Customer Value	Voice of Customer (VOC) Analysis Quality Function Deployment (QFD)	Effective learning process Mastery of knowledge (hard-skills) complemented by interpersonal competencies (soft-skills) Ability to integrate and apply knowledge and skills in the workplace and industry
Map Value Stream	SIPOC Diagram Identification of waste	Proper course planification considering expected outcomes, teaching strategies and assessment methods Application of student-centered teaching methodologies where students have an active role in the learning process.
Flow	Cause and Effect Diagram	Monitoring the learning process Regular assessment Timely feedback
Pull System	PDCA cycles	Taking into account student's needs and interests to design and develop teaching and learning processes.
Pursue of Perfection	PDCA cycles	Active learning student-centered methodologies Formative and continuous assessment Action research

4. METHODOLOGY

This study utilized an observational methodology based on a case study that included the implementation and evaluation of the proposed model.

4.1. Participants

A total of 33 students from an industrial engineering course participated in the study. The participants were male (n=17) and female (n=16) regular students aged between 18 and 24 years old.

4.2. Experimental Procedure

The educational model was implemented in the course "Quality Engineering" offered by the industrial engineering program at the Universidad San Francisco de Quito in Quito, Ecuador. During the 10 weeks of the course duration, there was room for a total of 28 sessions of 80 minutes each. Over this period of time, students took part in a varied set of activities, including case studies resolution, development of projects to apply theory learned, and dynamic tasks focused on learning key subject matter and concepts. Specific guidelines were provided for each case study, project and task. To complete them, students had to review course materials, comprehend the specific scenario requirements, apply both learned and researched theory, and work strategically to resolve emerging issues.

For instance, students participated in a role-playing activity on effective communication in a simulated office environment, highlighting common communication problems. In groups of 6 students, each member had a role based on a vertical organizational structure and received a particular set of instructions. Through effective communication and the application of knowledge, the groups worked collaboratively towards a common goal. Figure 7 depicts the snapshots of this activity.

Figure 7. Snapshots of a game-based activity.

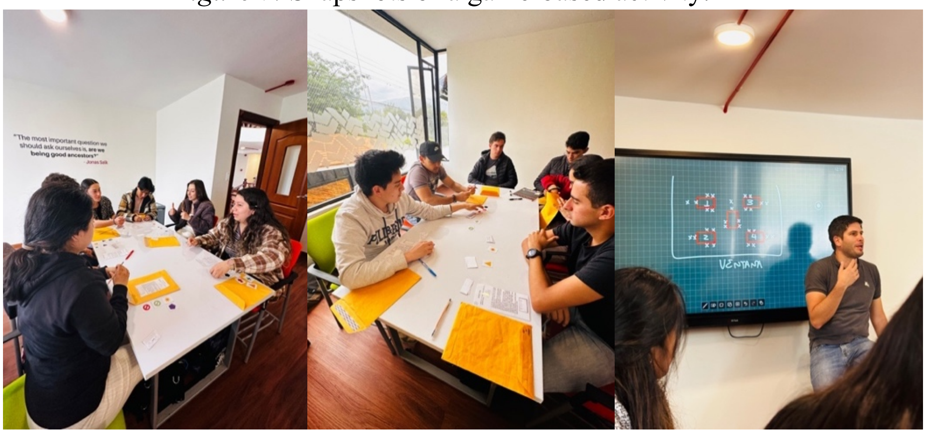


Table 5 summarizes the approach used to implement the model.

Table 5. Case Study Implementation

PDCA Stage	Category	Implementation
Plan	Learning Outcomes	Development of hard skills: Mastery of relevant quality engineering topics including analytical and management tools, both theoretical and practical, to effectively perform quality engineering functions in manufacturing/service organizations. Learning course core - DMAIC methodology (Six Sigma's core data-driven improvement methodology). Development of soft skills: Integration of a comprehensive set of interpersonal competencies and abilities necessary to solve manufacturing quality problems, implement effective quality systems, and perform successfully in the workplace and industry.
	Teaching Strategies	Active and student-centered teaching and learning methods, including case, project and game-based learning.
Do	Case-Based Learning (CBL)	Resolution of 3 cases based on real industrial situations adapted to the educational context. Instructions and guidelines of objectives based on the DMAIC methodology to reinforce key concepts of the stage of the methodology being studied at the time.
	Project-Based Learning (PBL)	A longitudinal project with partial deliverables based on the application of the DMAIC methodology in the context of industry. Guidelines of project management allow students to apply theory to the resolution of a necessity in the business context. An oral executive presentation was conducted where students showcase analysis, results and conclusions.
	Game-Based Learning	• Effective communication role-play: Office work scenario highlighting communication problems and how to solve them efficiently. Groups worked collaboratively to solve a shared objective. • Measurement System Analysis (MSA) simulation: Evaluation of a measurement system in a pilot plant for food elements where metrics such as weight, volume, pH, diameters, and quality control attributes were analyzed. • Yield game: 4-step process where process constraints are defined. Students throw playing cards into a defined square and measure yield by stages to understand key concepts such as rework and quality issues. • Dynamic activity on decision making: use of Legos in a game scenario to analyze situations with multiple options, prioritization and decision making on actions to solve a problem.
Check	Assessment Approach	Formative evaluation through assessment of partial deliveries of the course project. Provision of the respective feedback for its integration in the next delivery. Summative evaluation through the assessment and grading of cases and class activities. Use of rubrics in the grading of cases, activities and projects.
Act	Action Research	At the end of the learning period, a dynamic evaluation of the course was carried out. Students answered three questions that address: (1) positive aspects of the course, (2) negative aspects of the course and (3) expectations that a student who is going to take this course should have. Thus, the instructor was able to evaluate the educational experience and identify areas of improvement for the teaching and learning process.

4.3. Evaluation Procedure

A quantitative data collection method was used to evaluate the model implementation. A survey was developed to obtain insightful information and measure students' perception about the class unfolding. The survey data collection method was utilized as it is cost effective and allows to gather data to perform both a descriptive and inferential statistical analysis to answer research questions associated with a practical experiment (Goundar, 2013). Upon course completion, students filled out the questionnaire on a voluntary and anonymous basis.

The survey consisted of 80 questions divided into two sections: (A) an attitude section, and (B) a multidisciplinary skill set development section. The items of the first section were adapted from the Motivated Strategies for Learning Questionnaire (MSLQ), a self-report instrument designed to assess college students' motivational orientations and their use of different learning strategies for a college course (Pintrich et al., 1991). Twenty-seven items measured five dimensions: (1) intrinsic goal orientation, (2) authentic interest, (3) task value, (4) control of learning beliefs, and (5) self-efficacy for learning and performance. The original questionnaire included an evaluation dimension to assess test anxiety, which was substituted by the authentic interest dimension to examine students' perceptions of their personal interest deployment. This survey has been used in studies on college students, and substantial correlations between the subscales' associations were found, supporting the instrument's convergent validity (Pintrich et al., 1991).

The second section evaluated the development of soft skills as a function of the implementation of active and student-centered teaching methodologies. Fifty-two items measured nine dimensions corresponding to the key attributes: (1) logical thinking, (2) problem-solving skills, (3) innovative thinking, (4) communication skills, (5) critical reasoning, (6) leadership, (7) teamwork and collaboration, (6) organizational skills, and (9) commitment to lifelong learning. An additional dimension was included to assess the students' perceptions of the general teaching method and strategy used in class. Participants rated their agreement with each assertive statement on a 7-point Likert scale ranging from "1-Completely disagree" to "7-Completely agree". Previous research has found that a 7-point Likert scale is readily comprehensible to respondents and enables to measure their attitude by measuring the extent to which they agree or disagree with a particular statement, reporting higher reliabilities compared to scales with fewer or greater items (Ferguson, 1941; Ghiselli, 1955; Symonds, 1924).

Table 6 lists the dimensions and sample items for each section of the questionnaire. The complete questionnaire is presented in Appendix A.

Table 6. Section, Dimensions, and Sample Items of Evaluation Instrument

Section	**Dimension**	**Sample Item**
(A) Attitude	Intrinsic Goal Orientation	In a class like this, I prefer course material that really challenges me so I can learn new things.
	Authentic Interest	I try to play around with ideas of my own related to what I am learning in this course.
	Control of Learning Beliefs	If I study in appropriate ways, then I will be able to learn the material in this course.
	Task Value	I am very interested in the content area of this course.
	Self-Efficacy for Learning and Performance	Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.
(B) Multidisciplinary Skill Set Development	Teaching and Learning Methodology	I believe the teacher uses effective instruments during the class, useful to clarify, simplify and facilitate the learning process.
	Logical thinking	I believe the teaching methodology used in this class encourages me to use reasoning skills to objectively study any problem.
	Problem-solving skills	The process of solving a case/project/problem helps me objectively weigh the costs and benefits of each possible solution when making a decision.
	Innovative thinking	I think the resolution of cases and problems encourages me to think “out of the box.
	Communication skills	I believe the teaching methodology used in this class encourages my ability to listen, repeat, recollect, and interpret information in an active manner.
	Critical reasoning	I think the teaching methodology helps me to treat the course material as a starting point and try to develop my own ideas about it.
	Leadership	I believe the development of the class project encourages me to inspire, delegate and direct my peers in the team
	Teamwork and collaboration	When making a decision in the process of solving a case or project, I seek others' perspectives to view it from multiple angles.
	Organizational skills	In the process of conducting a project/case, I set a goal and create a plan with milestones to show my progress toward the goal.
	Commitment to lifelong learning.	I believe the teaching methodology in this class encourages meaningful and autonomous learning.

5. RESULTS

The results of the case study are summarized in two sections that parallel the research questions.

5.1. Attitude, Engagement and Performance

One of the objectives of this study was to evaluate the impact of the educational framework built from the application of the Lean philosophy on the interest, attitude and motivation of students within a classroom. Table 7 provides the key statistics of the retrieved results of section A, including the mean, standard deviation, and the validation and reliability analysis coefficients. The complete results are in Appendix B.

First, the mean values of each dimension are analyzed. As Pintrich et al. (1991) reported in the development of the Motivated Strategies for Learning Questionnaire (MSLQ), an average value greater than 4 represents a fair manifestation of an attitude and a value greater than 6 a significant demonstration of an attitude. In this case, the mean value of each dimension is around 5, ranging from 5.253 (Control of Learning Beliefs dimension) to 5.758 (Task Value). Thus, students in the class report a considerable degree of attitudes such as intrinsic motivation, personal interest and self-efficacy. As each dimension measures a student's attitude that directly affects their performance, behavior and acting in the classroom, the implications of high-value results are studied. For example, since task value describes students' perceptions of the course material in terms of interest, importance, and utility; high task value leads to greater involvement in their learning (Pintrich et al., 1991). Similarly, control of learning reflects students' beliefs that their efforts to learn result in positive outcomes. Hence, if students believe they can control their academic performance, they are more likely to perform strategically and effectively to achieve the desired results (Pintrich et al., 1991). Even though Pintrich et al. (1991) reported the original dimensions to be in the acceptable range of internal consistency, a validation and reliability analysis of the adapted questionnaire is performed.

Second, the composite and internal reliabilities of the survey are analyzed. According to George and Mallery (2003) a Cronbach's alpha coefficient greater than 0.7 means that internal consistency is high, and reliability is high. Similarly, Hair et al. (2019) stated the composite reliability (CR) over 0.7 indicates good external reliability. Table 7 displays that Cronbach's alpha and CR are both above 0.7, with Cronbach's alpha ranging from 0.749 to 0.924 and CR ranging from 0.759 to 0.928. As the values of each dimension meet the threshold, there is reasonable factor validity.

Third, convergent validity is determined by the average variable extraction (AVE) and the factor load (FL) of each observed variable. According to Hair et al. (2019) and George and Mallery (2003), the AVE and FL for each observed dimension should be higher than 0.5. Table 7 shows that both AVE and FL of each dimension are greater than 0.5, with AVE values ranging from 0.533 to 0.699 and FL values ranging from 0.732 to 0.896. This indicates the convergent validity of each dimension is acceptable.

Table 7. Attitude Section Results

Dimension	**Mean**	**SD**	**Cronbach's α**	**CR**	**FL**	**AVE**
Threshold	--	--	> 0.7	> 0.7	> 0.5	> 0.5
Intrinsic Goal Orientation	5.275	1.325	0.775	0.778	0.754	0.568
Authentic Interest	5.266	1.132	0.749	0.759	0.766	0.584
Control of Learning Beliefs	5.253	1.405	0.767	0.769	0.732	0.533
Task Value	5.758	0.853	0.886	0.891	0.896	0.699
Self-Efficacy	5.358	1.090	0.824	0.828	0.842	0.616

5.2. Development of a Multidisciplinary Skill Set

The second objective of this study was to evaluate the impact of the educational framework built from the application of the Lean philosophy on the development of a multidisciplinary skill set with interpersonal competencies in students. Table 8 provides the key statistics of the results of section B, including the mean values, the standard deviation, and the respective validation and reliability analysis coefficients. The complete results are in Appendix 2.

Similar to previous results, the average value of each dimension is around 5, ranging from 4.475 (Innovative thinking skill dimension) to 5.770 (Organizational skills dimension). Based on Pintrich et al. (1991) interpretation of the results of a 7-point Likert scale, students report a considerable degree of skill development. Regarding the Teaching and Learning Methodology dimension, students seem to have a positive perception towards the teacher's strategies. Considering the assertive items this dimension evaluates, students perceive the methodologies applied in the course propitiate and enhance the development of different skills.

Table 8 shows that Cronbach's alpha and CR are both above the threshold value of 0.7, with Cronbach's alpha ranging from 0.721 to 0. 932 and CR ranging from 0.724 to 0.935. Similarly, both the AVE and the FL of each dimension are greater than 0.5, with AVE values ranging from 0.502 to 0.696 and FL values ranging from 0.689 to 0.865. As the values of each dimension meet the respective threshold, there is reasonable internal and composite reliability and convergent validity.

Table 8. Multidisciplinary Skill Set Development Section Results

Dimension Threshold	**Mean** --	**SD** --	**Cronbach's α** > 0.7	**CR** > 0.7	**FL** > 0.5	**AVE** > 0.5
Teaching Methodology	5.164	1.340	0.756	0.757	0.743	0.577
Logical thinking	5.500	1.210	0.739	0.741	0.865	0.673
Problem-solving skills	5.586	1.152	0.745	0.747	0.755	0.522
Innovative thinking	4.475	1.260	0.834	0.837	0.797	0.502
Communication skills	5.511	1.113	0.932	0.935	0.721	0.560
Critical reasoning	5.545	1.013	0.898	0.901	0.764	0.573
Leadership	5.665	1.025	0.755	0.758	0.689	0.554
Teamwork and collaboration	5.685	1.019	0.721	0.724	0.732	0.549
Organizational skills	5.770	0.960	0.725	0.727	0.843	0.696
Commitment to lifelong learning	5.538	1.172	0.743	0.747	0.831	0.605

6. DISCUSSION

6.1 Application of Lean philosophy in the educational context

This study found that Lean principles and practices have the potential to be applied in teaching and learning processes. Previous research suggests that Lean methodology has been successfully implemented in a vast variety of institutions to improve business processes and deliver greater value to end-use customers (Balzer et al., 2016). However, there is a scarcity of research that shows Lean philosophy can be effectively employed in key processes that take place within classrooms in programs at institutions of Higher Education (Vukadinovic et al., 2017). This study shows how each of the five Lean principles can be integrated to enhance teaching and learning processes.

Based on the first Lean principle of defining customer value, it was determined that the customer in the academic setting includes three groups: (1) students, (2) faculty, and (3) the industry, as they interact directly with education services. An analysis of the voice of the customer (VOC) was performed based on the student outcomes (SOs) outlined by ABET (2021) to identify the soft skills and competencies considered valuable by the customers. The key interpersonal abilities include logical and innovative thinking, problem-solving skills, critical reasoning, leadership, teamwork and collaboration, organization, knowledge-building disposition, and communication skills. These findings align with a multi-year project conducted by Hundley et al. (2015) who developed a set of abilities required by engineers in order to successfully operate in a global context while reflecting the voice of industry. The "Attributes of a Global Engineer" included personal skills (e.g., critical and creative thinking, individual and cooperative reasoning, initiative and willingness to learn), interpersonal skills (e.g., teamwork abilities), and cross-cultural skills (e.g., understanding of political and social perspectives and ethical and business norms, possession of a multidisciplinary and global perspective) (Hundley et al., 2015).

To achieve desired student outcomes and the development of interpersonal competencies, the proposed approach was based on student-centered learning methodologies. An extensive literature review was performed on the outcomes in regard to student performance and attitude development of active teaching methods. The Quality Function Deployment (QFD) tool was used to evaluate the relationship between the expected student outcomes and academic methodologies and establish that case, game and project-based learning were the appropriate approach to meet the expected results. Thus, this study demonstrated the potential of the QFD tool in understanding the voice of the customer in the education sector in order to improve the learning process. This finding is corroborated by Raissi (2017), who concluded that educational institutions can gain insights into the preferences of students and design and deliver education services that are more effective and meet the needs of students through the application of QFD. Similarly, the exploratory study conducted by Hafeez and Mazouz (2011) showed that QFD was effective in identifying key characteristics of education services that were important to students, such as quality of teaching, course content, and assessment methods.

With the application of the second and third Lean principles, waste was defined in the Higher Education system. It was established that waste includes unbalanced workload, over-assessment, delayed evaluation and late grading, poor knowledge acquisition, learning not relevant to industry requirements, and students as passive spectators. Furthermore, a cause-effect diagram was constructed to determine the root causes of these issues and bottlenecks that impact the education delivery process and recognize the need for corrective actions. Several comprehensive studies on waste management in Higher Education institutes (Douglas et al., 2015; Fagnani & Guimarães, 2017; Vargas & de Souza, 2020) identified issues in both academic and administrative processes, including excessive movement of people, overproduction of materials, wasteful use of human resources, and extensive inventory. Nevertheless, as Mota et al. (2021) established, if Lean concepts are implemented in earnest, the elimination of waste can be expected making the learning process more responsive to industry needs.

Finally, based on the fifth principle of pursuing perfection, this study implemented the PDCA cycle as the base of the framework. In line with previous work (Knight & Allen, 2012), the PDCA cycle of continuous improvement seems to be a systematic approach to incrementally move closer to a particular goal. This assumption is reinforced by previous studies on the application of PDCA cycles in different industries. For instance, Maruyama (2016) applied the PDCA cycle on leadership education with graduate engineering students, resulting in seven years of continuously improved quality of the program where students met their learning objectives. Similarly, Chakraborty (2016) conducted a case study on the implementation of the PDCA cycle in an automobile manufacturing company and concluded that this data-based framework drives continuous and ongoing efforts to achieve measurable improvements in the efficiency, effectiveness, performance, accountability, and outcomes in any process.

This paper proposed the development of the Lean Engineering Education model based on the application of the five Lean principles to the teaching and learning process in a Higher Education environment. Accordingly, the first contribution of the present study is providing information and empirical evidence on the adoption of the Lean philosophy on educational methodologies in engineering class settings. Not only that, but this study provides the framework to identify underlying factors that influence educational outcomes and, ultimately, modify the procedures in order to deliver the best learning outcomes. Thus, this Lean Education framework fills the gap in the literature on the application of Lean in the academic area and provides a means of achieving the ultimate goal of education, which is enhanced student learning. These findings are novel and of added value as they are part of the limited literature body of empirical studies in Higher Education institutions in Ecuador and in the American system education field as well.

6.2 Development of interest, attitude and multidisciplinary engineering skill set

The proposed model was implemented in a quality engineering course at Universidad San Francisco de Quito in Quito, Ecuador. The experimental results indicated that the educational methodologies proposed in the model enhanced students' perception of their own learning process and development of soft skills.

Regarding students' perception of their learning process, results showed that the implementation of the model based on active methodologies (i.e., case, project and game-based learning) had a positive impact on the intrinsic goal orientation, motivation, and interest in the course. This finding is supported by the longitudinal study performed by Hanus & Fox (2015) who found that gamified courses tended to increase intrinsic motivation, satisfaction, effort, social comparison, and empowerment relative to non-gamified courses. This is corroborated by Barata et al (2013) who pointed out that students perceived a gamified environment to be more interesting, motivating, and easier to learn compared to other contexts. The implications of high motivation and interest degree are significant, since students that perceive the value of the course, tasks and content learned tend to have a remarkable level of engagement with their learning process translated into better performance and attention (Pintrich et al., 1991). Furthermore, the student-centered teaching methodologies seemed to have a positive impact on the self-efficacy for learning and performance of students. Previous research reported that active teaching methods encourage students to set goals for their learning, apply their knowledge in a supportive environment, and reflect on their progress while building confidence in their abilities (Abdullah et al, 2019; Buckley & Doyle, 2014; Siriban-Manalang, 2017; Su & Cheng, 2015). Thus, the literature and this study revealed that active and student-centered methodologies provide opportunities for students to take an active role in their own learning and to experience success through their own efforts.

In terms of the development of soft skills, this study found that active and student-centered methodologies foster the development of interpersonal skills from the student's perspective. Participants indicated that project development and case resolution promote their critical thinking and problem-solving skills. Nkhoma et al. (2016), who investigated the value of creating case-based learning activities based on Bloom's Taxonomy of thinking skills, support these findings by arguing that this strategy promotes deep learning through critical thinking. They concluded that case-based learning encourages learning through action and problem-solving, so it strengthens information retention and prepares students for assessment and interpretation of multifaceted problems (Nkhoma et al, 2016). Similarly, Andreassen and Holmsen (2018) recommended both project and case-based learning as teaching methods, as they promote acquisition of knowledge and develop critical thinking through problem solving in simulated contexts. Hence, previous research and this study showed that the implementation of case and project-based learning promote students' critical thinking and problem-solving skills.

Furthermore, experimental data indicated that the implementation of project and game-based learning have a positive impact on the development of leadership and teamwork skills, as they often involve group work and collaboration. Lima et al (2007) stated that in project development students take on different roles and responsibilities within their group, so they learn to delegate tasks and responsibilities, and motivate others to work towards a shared vision. Similarly, the case study performed by O'Donovan et al (2013) concluded that in game-based activities students learn to recognize each other's strengths and weaknesses, and assign roles accordingly, promoting effective delegation and leadership. Thus, the nature of project and game-based learning makes them effective tools for developing leadership and teamwork skills.

In alignment with the development of collaboration skills, this study showed that active learning have a positive impact on the development of communication and organizational skills. Oliveira (2007) supports this finding by stating that dynamic activities give students the opportunity to practice communication skills such as active listening, expressing ideas clearly and persuasively, and providing constructive feedback. Similarly, their research revealed the importance of student-centered methodologies in the development of commitment to lifelong learning promoted by consideration of students' issues, needs, and preferred teaching strategies (Oliveira, 2007). As defined by the present and previous research (Nes et al, 2021) students show more commitment to their learning if they are able to see how their knowledge can be applied in real life.

Overall, the present study demonstrated the use of student-centered methodologies promotes the development of interpersonal skills, fosters the development of interpersonal skills, which are key to an engineering professional's skill set. As stated by Harman et al. (2015), active teaching strategies allow students to see real-world issues, value the relevance of fields and apply knowledge of theories and personal skills to practice. Indeed, as concluded in previous research (Harman et al., 2015; Nes et al, 2021; Nkhoma et al, 2016; Yadav et al., 2014), the concurrent use of different active and student-centered methodologies is attributed to high potential for promoting and enhancing professional skills development.

6.3 Limitations and future research

The first limitation encountered in this study was the fact that there was very little research to build on due to the lack of previous studies on the topic. Antony et al., (2012) discuss the misconception that the Lean philosophy can only be applied to manufacturing and service industries and cannot be transferred to academia. Thus, as with any new approach, there will be implementation issues associated with the proposed framework. As Emiliani (2004) stated, integrating Lean principles into course design and delivery requests educators to question their views about what and how they teach. The solution to this problem lies in raising awareness that Lean is a system of philosophy based on an iterative process of continuous improvement. Hence, future research can examine the issues surrounding the model implementation, as well as the required training that faculty might need in order to apply the proposed methodology.

Furthermore, even though Lean principles have been successfully applied in the industry, it has to be recognized that the academic environment is very different from the industry. In academia, we are not dealing with inanimate objects, but students who represent both the customer and the product as valuable employees for the industry. Another limitation of this study is to solely rely on self-reported survey data to measure students'development of skills and abilities. Soft skills are difficult to be quantified as they are closely connected with personal attitudes which are intangible. Thus, more data-driven research projects with both qualitative (i.e., focus groups or structured interview) and quantitative (i.e., surveys or grade evaluation) methods should be conducted to triangulate the data and validate the findings.

Findings provide other directions for future action, such as the extent to which other Lean tools like 5S or Kaizen can be applied to further improve the teaching and learning experience. Finally, there is an opportunity for future research to be undertaken on a broader scale. The umbrella of educational process can be expanded to include High School education processes, considering its outcomes are the input for the Higher Education system.

7. Conclusions

In this study, the Lean Engineering Education model was built and proposed to develop the complete and comprehensive skill set that engineering students need to succeed in their professional life. Thus, this study demonstrates that Lean principles and tools can be applied to the teaching, learning, and assessment processes in engineering education. This framework allows faculty to identify industry needs in terms of student skills and competencies necessary in the workplace. Not only that but the proposed model has the potential to mitigate issues concerning content delivery, knowledge acquisition, abilities development, and assessment methods. The strategic implementation of the model within a classroom can be expected to enhance the teaching and learning processes while fostering the development of a multidisciplinary engineering skill set. By engaging the students in the learning process through active and student-centered methodologies, positive results can be expected in regard to the targeted learning outcomes. The paper extended the existing research that primarily focused on the implementation of the Lean philosophy into administrative processes in the academic context. Thus, this study represents an initiative toward the improvement of the education system.

REFERENCES

Abdullah, M. Y., Hussin, S., & Ismail, K. (2019). Investigating the effects of the flipped classroom model on Omani EFL learners' motivation level in English speaking performance. *Education and Information Technologies, 24*(5), 2975-2995.

ABET. (2021). *2022 – 2023 Criteria for Accrediting Engineering Program.* Baltimore: ABET

Akao, Y., & Mazur, G. (2003). The Leading Edge in QFD: Past, Present and Future. *International Journal of Quality & Reliability Management, 20*(1), 20–35. https://doi.org/10.1108/02656710310453791.

Alves, A. C., Carvalho, D., & Sousa, R. (2012). Lean Production as promoter of thinkers to achieve companies' agility. *The Learning Organization: An International Journal, 19*(3), pp. 219–237. DOI: 10.1108/09696471211219930

Alves, A. C., Flumerfelt, S., & Kahlen, F. J. (2017). *Lean Education: An Overview of Current Issues.* Switzerland: Springer International Publishing.

Andreassen, H. M., & Holmsen, T. L. (2018). Case-based learning in nursing education. *Nordisk sygeplejeforskning, 8*(3), 219–229. https://doi.org/10.18261/issn.1892- 2686-2018-03-05.

Antony, J., Krishan, N., Cullen, D., & Kumar, M. (2012). Lean Six Sigma for higher education institutions (HEIs): Challenges, barriers, success factors, tools/techniques. *International Journal of Productivity and Performance Management, 61*(8), pp. 940-948. https://doi.org/10.1108/17410401211277165

Balaji, K. V., & Somashekar, P. (2009). A Comparative Study of Soft Skills among Engineers. *IUP Journal of Soft Skills, 3*(4), 50-57.

Balzer, W.K., Francis, D.E., Krehbiel, T.C. and Shea, N. (2016), A review and perspective on Lean in higher education. *Quality Assurance in Education, 24*(4), pp. 442-462. https://doi.org/10.1108/QAE-03-2015-0011

Barata, G., Gama, S., Jorge, J., & Gonçalves, D. (2013). Engaging Engineering Students with Gamification. *2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), Poole, United Kingdom*, 1-8. DOI: 10.1109/VS-GAMES.2013.6624228.

Berkel, H., Alves, A. C., Kahlen, F., Flumerfelt, S., & Siriban-Manalang, A. (2014, August). *The lean production multidisciplinary: from operations to education*. Paper presented at the 7th International Conference of Production Research Americas, Lima, Peru. DOI: 10.13140/2.1.1524.0005

Berkel, H.V., & Schmidt, H. (2005). On the Additional Value of Lectures in a Problem-Based Curriculum. *Education for Health, 18*(1), pp. 45-61. DOI: 10.1080/13576280500042648

Biggs, J. (2003). *Teaching for Quality Learning at University.* SHRE Open University Press.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (2000). *How people learn: Brain, mind, experience, and school*. National Academy Press.

Brawner, C.E., & Miller, T.K. (2003). *Engineering Design using an Entrepreneurial Model.* Research Triangle Educational Consultants

Brown Wright, G. (2011). Student-Centered Learning in Higher Education. *International Journal of Teaching and Learning in Higher Education*, *23*(3), 92–97. http://www.isetl.org/ijtlhe/

Buckley, P., & Doyle, E. (2014). Gamification and student motivation. *Interact. Learn. Environ, 22*(6), 1–14. DOI: 10.1080/10494820.2014.964263

Burguillo, J.C. (2010). Using game theory and Competition-based learning to stimulate student motivation and performance. *Comput. Educ, 55*(2), 566–575. DOI: 10.1016/j.compedu.2010.02.018

Chakraborty, A. (2016). Importance of PDCA cycle for SMEs. *International Journal of Mechanical Engineering, 3*, 30-34. DOI: 10.14445/23488360/IJME-V3I5P105.

Chiang, C. L., & Lee, H. (2016). The Effect of Project-Based Learning on Learning Motivation and Problem-Solving Ability of Vocational High School Students. *International Journal of Information and Education Technology, 6*(9), 709–712. https://doi.org/10.7763/IJIET.2016.V6.779

Crebert, G., Bates, M., Bell, B., Patrick, C. J., & Cragnolini, V. (2004). Developing generic skills at university, during work placement and in employment: graduates' perceptions. *Higher Education Research and Development, 23*(2), 147-165.

Creed, C., Suuberg, E., & Crawford, G. (2002). Engineering Entrepreneurship: An Example of A Paradigm Shift in Engineering Education. *Journal of Engineering Education*, 91. DOI: 10.1002/j.2168-9830.2002.tb00691.x.

Creswell, J. (2008). *Educational research: planning, conducting and evaluating quantitative and qualitative research* (2nd Ed.). New Jersey: Merrill/Prentice Hall.

Dinis-Carvalho, J. & Fernandes, S.R. (2017). Applying lean concepts to teaching and learning in higher education: Findings from a pilot study. *International Journal of Engineering Education, 33*(3), 1048-1059.

Douglas, J., Antony, J., & Douglas, A. (2015). Waste identification and elimination in HEIs: the role of Lean thinking. *International Journal of Quality & Reliability Management, 32.* DOI: 970-981. 10.1108/IJQRM-10-2014-0160.

Emiliani, M. L. (2004). Improving business school courses by applying lean principles and practices. *Quality Assurance in Education, 12*(4), 175-187.

Emiliani, M. L. (2005). Using kaizen to improve graduate business school degree programs. *Quality Assurance in Education, 13*(1), 37-52.

Emiliani, M. L. (2006). Improving Management Education. *Quality Assurance in Education, 14*(4), pp. 363-384.

Fagnani, E., & Guimarães, J. (2017). Waste management plan for higher education institutions in developing countries: The Continuous Improvement Cycle model. *Journal of Cleaner Production, 147.* DOI: 10.1016/j.jclepro.2017.01.080.

Felder, R., & Brent, R. (1999). How to Improve Teaching Quality. *Quality Management Journal, 6*(2), 9-21.

Ferguson, L. W. (1941). A study of the Likert technique of attitude scale construction. *Journal of Social Psychology, 13(*1), 51-57

Flumerfelt, S., Kahlen, F. J., Alves, A. C., & Siriban-Manalang, A. (2015). *Lean Engineering Education: Driving Content and Competency Mastery.* New York: ASME Press

Fuchs, W. (2006). A Way to the International Comparability of Engineering Education. *IDEAS, 13*, 16-21.

George, D. & Mallery P. (2003). *SPSS for Windows step by step: A Simple guide and reference.* (4th ed.). Allyn and Bacon.

Ghiselli, E. E. (1955). *The measurement of occupational aptitude.* Berkeley: University of California Press.

Gibbs, G., & Simpson, C. (2004). Conditions under which assessment supports students learning, *Learning and Teaching in Higher Education, 1*, pp. 3-31.

Goundar, S. (2013). Research Methodology and Research Method. In S. Goundar (Ed.), *Cloud Computing* (pp. 2-43). Victoria University of Wellington.

Griffin, A., & Hauser, J. (1991). The Voice of the Customer. *Marketing Science, 12*(1). DOI: 10.1287/mksc.12.1.1.

Hafeez, K., & Mazouz, A. (2011). Using Quality Function Deployment as a higher education management and governance tool. *Verslo ir teisės aktualijos, 6*(1). DOI: 10.5200/1822-9530.2011.02.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage.

Hanus, M.D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: a longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Comput. Educ*, *80*, 152–161. DOI: 10.1016/j.compedu.2014.08.019

Harman, T., Bertrand, B., Greer, A., Pettus, A., Jennings, J., Wall-Bassett, E., & Babatunde, O. T. (2015). Case-based learning facilitates critical thinking in undergraduate nutrition education: students describe the big picture. *Journal of the Academy of Nutrition and Dietetics, 115*(3), 378–388. https://doi.org/10.1016/j.jand.2014.09.003

Hundley, S., Brown, L., Fox, P., & Jacobs, Alan. (2015). The Attributes of a Global Engineer. *International Faculty Development Considerations, 17*(46), 1-17. DOI: 10.18260/1-2--17061.

Jiang, J., Shiu, M., & Tu, M. (2007). DFX and DFSS: How QFD Integrates Them. *Quality Progress, 40*(10), 45-51.

Kahlen, F., Flumerfelt, S., Siriban-Manalang, A. & Alves, A. C. (2011). Benefits of lean teaching. In American Society of Mechanical Engineers (Ed.), *Proceedings of ASME International Mechanical Engineering Congress & Exposition* (pp. 351-358). ASME. DOI: https://doi.org/10.1115/IMECE2011-63150

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education.* San Francisco, CA: John Wiley & Sons.

Knight, J. & Allen, S. (2012). Applying the PDCA Cycle to the Complex Task of Teaching and Assessing Public Relations Writing. *International Journal of Higher Education, 1*(2). DOI: 10.5430/ijhe.v1n2p67.

Lang, J. D., Cruse, S., McVey, F. D., & McMasters, J. (1999). Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers. *Journal of Engineering Education, 88*(1), 43-51.

Lima, R., Carvalho, D., Flores, M. A., & van Hattum-Janssen, N. (2007). A case study on project led education in engineering: Students' and teachers' perceptions. *European Journal of Engineering Education, 32*(3), 337–347.

Maruyama, T., & Inoue, M. (2016). Continuous Quality Improvement of Leadership Education Program Through PDCA Cycle. *China-USA Business Review, 15*. DOI: 10.17265/1537-1514/2016.01.004.

Meier, R. L., Williams, M. R., & Humphreys, M. A. (2000). Refocusing our efforts: assessing non-technical competency gaps. *Journal of Engineering Education, 89*(3), 377-385.

Mejía, G., Caballero, M. M., Huggins, kevin, & Bautista, L. X. (2020). ABET Accreditation in Colombian Higher Education Institutions: Opportunities and Barriers. *Revista UIS Ingenierías*, *19*(4), 239–250. https://doi.org/10.18273/revuin.v19n4-2020020

Monden, Y. (1998). *Toyota production system: An integrated approach to just-in-time* (3rd ed.). Engineering and Management Press.

Mota, A. C., Shenoy, D., & Cárdenas-Barrón, L. E. (2021). Application of lean manufacturing concepts to evolving a policy for engineering education. *Education Sciences, 11*(11). DOI: https://doi.org/10.3390/educsci11110755

Naik, B.M. (2004). Technological Innovation in Education Institutes. *The Journal of Technical Education, 27*(2), 59-61.

Nair, C.S., Patil, A., & Mertova, P. (2009). Re-engineering graduate skills: a case study. *European Journal of Engineering Education, 34*(2), 131-139.

Nes, A., Høybakk, J., Zlamal, J., & Solberg, M. (2021). Mixed teaching methods focused on flipped classroom and digital unfolding case to enhance undergraduate nursing students' knowledge in nursing process. *International Journal of Educational Research, 109*. DOI: https://doi.org/10.1016/j.ijer.2021.101859

Nguyen, D. (1998). The essential skills and attributes of an engineer: a comparative study of academics, industry personnel and engineering students. *Global Journal of Engineering Education, 2*(1), 65-73.

Nkhoma, M., Lam, T., Richardson, J., Kam, K., & Lau, K. H. (2016). Developing case-based learning activities based on the revised Bloom's Taxonomy. In *Proceedings of Informing Science & IT Education Conference* (In SITE) 2016, 85-93. Retrieved from http://www.informingscience.org/Publications/3496

Nygaard, C., Hojlt, T., & Hermansen, M. (2008). Learning-based curriculum development. *Higher Education, 55*(1), 33-50. DOI: 10.1007/s10734-006-9036-2

O'Donovan, D., Gain, J., & Marais, P. (2013). A case study in the gamification of a university-level games development course. In *Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference* (SAICSIT '13). Association for Computing Machinery, New York, NY, USA, 242–251. DOI: https://doi.org/10.1145/2513456.2513469

Oliveira, J. M. (2007). Project-based learning in engineering: The Águeda experience. In Erik de Graaff & Anette Kolmos (Eds.), *Management of change implementation of problem-based and project-based learning in engineering* (pp. 169–180). Rotterdam: Sense Publishers.

Owlia, M. S., & Aspinwall, E. M. (1998). Application of quality function deployment for the Improvement of Quality in Engineering Department. *European Journal of Engineering Education, 23*(1), 105-115.

Parker, A. M., Watson, E., Ivey, M., & Carey, J. P. (2019). Approaches to Graduate Attributes and Continual Improvement Processes in Faculties of Engineering Across Canada: A Narrative Review of The Literature. *Proceedings 2019 Canadian Engineering Education Association (CEEA).* https://doi.org/10.24908/PCEEA.VI0.13736

Pimmel, R. L. (2003). Student Learning of Criterion 3 (a) – (k) Outcomes with Short Instructional Modules and the Relationship to Bloom's Taxonomy, *Journal of Engineering Education, 92*(4), p. 351- 359. DOI:10.1002/j.2168-9830.2003.tb00780.x

Pintrich, P., Smith, D., Garcia, T., & McKeachie, W. (1991). *A Manual for the Use of Manual Motivated Strategies for Learning Questionnaire Manual (MLSQ).* The Regents of the University of Michigan.

Prabhushankar, G.V., Shankar, B.L., Veena, T.R. (2015). Curriculum Redesign in Higher Education Using QFD: A Case Study. In: Natarajan, R. (eds) *Proceedings of the International Conference on Transformations in Engineering Education.* Springer, New Delhi. https://doi.org/10.1007/978-81-322-1931-6_30

Raissi, N. (2017). Using QFD method for assessing higher education programs: an examination of key stakeholders' visions. *International Journal of Management in Education, 12*(1), 70-93. DOI: 10.1504/IJMIE.2018.10008713.

Sharma, G., & Sharma, P. (2010). Importance of soft skills development in 21st century curriculum. *International Journal of Education and Allied Sciences, 2*(2), 39-44.

Sheppard, D.S., Macatangay, K., Colby, A., & William, W.M. (2009). *Educating Engineers: Designing for the Future of the Field*. Jossey-Bass.

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET Professional Skills - Can They Be Taught? Can They Be Assessed? *Journal of Engineering Education, 94*(1), 41-55.

Singh, A. & Rawani, A.M. (2018). Application of QFD in education sector: A review. *International Journal of Mechanical Engineering and Technology, 9,* 592-599.

Siriban-Manalang, A.B. (2017). Lean Education in a University in the Philippines. In Alves, A., Flumerfelt, S., & Kahlen, F. (Eds.), *Lean Education: An Overview of Current Issues* (pp. 41-52). DOI: 10.1007/978-3-319-45830-4_3

Soler, L.C. (2014). Educación en ingeniería e ingeniería en educación. *Revista Clepsidra, 9*(1), 103-109. DOI: 10.26564/19001355.32.

Su, C.H., & Cheng, C.H. (2015) A mobile gamification learning system for improving the learning motivation and achievements. J. Comput. *Assist. Learn., 31*(3), 268–286. DOI: 10.1111/jcal.12088

Symonds, P. M. (1924). On the Loss of Reliability in Ratings Due to Coarseness of the Scale. *Journal of Experimental Psychology, 7*(6), 456–461. https://doi.org/10.1037/h0074469

Tyler, R.W. (1949). *Basic principles of curriculum and instruction.* The University of Chicago Press.

Uébe, A.F., Carvalho, F., & Pereira, H. (2017). Lean Education for Applied Science Universities: A Proposal by Federal Institutes of Applied Sciences in Brazil. In Alves, A., Flumerfelt, S., & Kahlen, F. (Eds.), *Lean Education: An Overview of Current Issues* (pp. 25-40). DOI: 10.1007/978-3-319-45830-4_2

Valencia, R.D. (2010). Crisis y futuro de la ingeniería. *Ingeniería y Sociedad, 1*(1), 1-6.

Vargas, D. B. & de Souza Campos, L. (2020). Waste Management in Higher Education Institutions: A State-of-the-art Overview. In *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management*, Detroit, Michigan, USA.

Voogt, J., & Roblin, N.P. (2010). 21st Century Skills. *Kennisnet, 3*(23), 1-52.

Vukadinovic, S., Djapan, M., & Macuzic, I. (2017). Education for lean & lean for education: A literature review. *International Journal for Quality Research, 11*(1), 35-50. DOI: 10.18421/IJQR11.01-03

Yorke, M. (2003). Formative Assessment in Higher Education: moves towards theory and the enhancement of pedagogic practice. *Higher Education, 45*(2), 201-228.

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice.* San Francisco, CA: Jossey-Bass.

Womack, J., & Jones, D. (1996). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Simon & Schuster.

Womack, J., Jones, D., & Roos, D. (1990). *The machine that changed the world.* Rawson Associates.

Yadav, A., Vinh, M., Shaver, G., Meckl, P., & Firebaugh, S. (2014). Case-based instruction: Improving students' conceptual understanding through cases in a mechanical engineering course. *Journal of Research in Science Teaching, 51*, 659–677. DOI: https://doi.org/10.1002/tea.21149

ANEXO A: ENCUESTA

Section A: Attitude

The following questions ask about your motivation for and attitudes about this class. Use the scale below to answer the questions. If you think the statement is very true of you, select 7; if a statement is not at all true of you, select 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1. In a class like this, I prefer course material that really challenges me so I can learn new things.
2. If I study in appropriate ways, then I will be able to learn the material in this course.
3. I often find myself questioning things I hear or read in this course to decide if I find them convincing.
4. I think I will be able to use what I learn in this course in other courses.
5. I believe I will receive an excellent grade in this class.
6. I'm certain I can understand the most difficult material presented in the readings for this course.
7. When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.
8. It is my own fault if I don't learn the material in this course.
9. It is important for me to learn the course material in this class.
10. I'm confident I can learn the basic concepts taught in this course.
11. I treat the course material as a starting point and try to develop my own ideas about it.
12. I'm confident I can understand the most complex material presented by the instructor in this course.
13. In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.
14. I am very interested in the content area of this course.
15. If I try hard enough, then I will understand the course material.
16. I try to play around with ideas of my own related to what I am learning in this course.
17. I'm confident I can do an excellent job on the assignments and tests in this course.
18. I expect to do well in this class.
19. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
20. I think the course material in this class is useful for me to learn.
21. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.
22. If I don't understand the course material, it is because I didn't try hard enough.
23. I like the subject matter of this course.
24. Understanding the subject matter of this course is very important to me.
25. Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.
26. I'm certain I can master the skills being taught in this class.
27. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

Section B: Teaching and Learning Methodologies

The following questions ask about the teaching and learning methodologies applied in this class. Before we begin, let us clarify a few important points: a teaching methodology is essentially the way in which a teacher chooses to explain and teach the course material to students so they can learn the material. Use the same scale to answer the remaining questions. If you think the statement is very true of you, select 7; if a statement is not at all true of you, select 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

Dimension: Teaching methods

28. I believe the teacher adopts effective teaching methods.
29. I think the teacher proposes different types of teaching strategies related to the target and needs of the students.
30. I believe the teacher introduces a new method/teaching strategy showing clearly the rules and the aims.
31. I believe the teacher adopts different strategies in order to alternate the individual work with that of the group.
32. I think the teacher employs adequate teaching instruments to the class's needs.
33. I believe the teacher uses effective instruments during the class, useful to clarify, simplify and facilitate the learning process.
34. I think the dynamic activities carried out in class contribute to the adequacy, clarity, and understanding of information.

Dimension: Logical Thinking

35. I believe the teaching methodology used in this class encourages me to use reasoning skills to objectively study any problem
36. I believe the resolution of cases in this class encourages me to analyze a situation and come up with a sensible solution.
37. I think the analysis and solution of cases in this class encourage me to use the available facts in order to solve a problem
38. I feel that the development of the class project helps me to use reasoning skills to make a rational conclusion about how to proceed.

Dimension: Problem-solving skills

39. I believe the execution of cases and projects in this class encourages me to find and solve effectively routine and non-routine problems
40. I feel that the use of cases encourages me to anticipate common problems and reflect on the outcomes
41. I think the dynamic activities carried out in class helped me can make sense out of ambiguous and complex problems.
42. The process of solving a case/project/problem helps me objectively weigh the costs and benefits of each possible solution when making a decision.
43. When approaching a problem, I ask "What else could be the problem?" to help identify the root cause.

Dimension: Innovative thinking

44. I believe the teaching methodology used in this class encourages me to come up with new solutions and approaches in different situations
45. I think the resolution of cases and problems encourages me to think "out of the box".
46. I believe the dynamic activities carried out in class encourage the development of creativity
47. Prior to making a decision or using a particular approach in the resolution of cases and projects, I provide new and sometimes unconventional perspectives.

Dimension: Communication skills

48. I believe the teaching methodology used in this class encourages oral expression
49. I believe the teaching methodology used in this class encourages written expression
50. I feel that the dynamic activities carried out in class boost argumentation skills and promote social interaction
51. I believe the resolution of cases contributes to disseminating and sharing content
52. I believe the execution of the project in class encourages me to present information clearly and in a style easily understood
53. I believe the activities in class encourage me to speak clearly and politely to any typology of public
54. I feel that the development of the project in class improves my ability to communicate in public
55. I think the dynamic activities carried out in class help me understand and interpret data (tables, figures, statistical data) accurately to support my work effectively
56. I believe the teaching methodology used in this class encourages my ability to listen, repeat, recollect, and interpret information in an active manner.

Dimension: Critical reasoning

57. I believe the teaching methodology used in this class encourages me to analyze and valorize information.
58. I believe the teaching methodology helps me to treat the course material as a starting point and try to develop my own ideas about it.
59. When solving a case/project/problem, I research information to help support my viewpoint when proposing an idea or solution.
60. Before making decisions in a case/problem resolution, I think through both expected and unexpected outcomes.

Dimension: Leadership

61. I believe the activities and methodology applied in this class encourage me to offer support to others when asked for
62. I believe the development of the class project encourages me to inspire, delegate and direct my peers in the team
63. I think the cases, projects and dynamic activities carried out in class encourage me to produce an impact through solution proposals.
64. I feel that the teaching methodology used in this class encourages me to give and receive feedback on good/poor performance and behaviors

Dimension: Teamwork and collaboration

65. I believe the activities carried out in this class help me understand the benefits of working in a team
66. I feel that the development of the class project and cases encourages me to work in a collaborative style with others to achieve results
67. I think the activities carried out help me maintain a good level of performance when dealing with environmental pressures and difficulties
68. I think the activities carried out allow me to be aware of my behavior and how it can affect others and the working climate.
69. I believe the teaching methodology encourages me to accept constructive criticism
70. I feel that the execution of the class project and cases help me recognize and use diverse perspectives according to different values, beliefs and behaviors
71. I feel that the development of the class project and cases allow me to take appropriate actions to minimize cultural, gender or other diversity difficulties, actual or perceived
72. When making a decision in the process of solving a case or project, I seek others' perspectives to view it from multiple angles.

Dimension: Organizational skills

73. In the process of developing a project/case, I define the importance and urgency of tasks in order to prioritize them.
74. When solving a case or developing a project, I look for more efficient ways to do things.
75. In the process of conducting a project/case, I set a goal and create a plan with milestones to show my progress toward the goal.

Dimension: Commitment to lifelong learning

76. I believe the teaching methodology in this class encourages meaningful and autonomous learning
77. I think the teaching methodology promotes curiosity (i.e., questioning and looking for information)
78. I believe the teaching methodology pursues and organize my own learning according to my needs
79. I believe I am responsible for my own learning and self-development
80. I feel that the resolution of cases and project help me be aware of opportunities

ANEXO B: RESULTADOS ENCUESTA

Section A: Attitude

Dimension	Item	Mean	Standard Deviation	Variance
Intrinsic Goal Orientation	1	5.28	1.28	1.65
	13	5.25	1.45	2.12
	19	5.48	1.30	1.70
	21	5.10	1.27	1.61
		5.278	**1.325**	**1.770**
Authentic Interest	3	5.79	1.06	1.13
	7	4.97	1.56	2.45
	11	5.66	1.21	1.47
	16	4.59	1.79	3.21
	25	**5.253**	**1.405**	**2.065**
Control of Learning Beliefs	2	4.75	1.43	2.04
	8	5.34	0.99	0.98
	15	5.34	1.35	1.81
	22	5.52	1.00	1.01
		5.38	0.89	0.79
		5.266	**1.132**	**1.326**
Task Value	4	5.86	0.82	0.67
	9	5.86	0.86	0.74
	14	5.59	1.00	1.00
	20	5.76	0.77	0.60
	23	5.62	0.89	0.79
	24	5.86	0.78	0.60
		5.758	**0.853**	**0.733**
Self-Efficacy for Learning and Performance	5	4.66	1.15	1.33
	6	5.36	1.04	1.09
	10	6.07	0.91	0.82
	12	5.07	1.44	2.06
	17	5.21	0.92	0.85
	18	5.52	1.19	1.42
	26	5.45	1.00	1.01
	27	5.52	1.07	1.15
		5.358	**1.090**	**1.216**

Section B: Teaching and Learning Methodologies

Dimension	Item	Mean	Standard Deviation	Variance
Teaching Methods	28	5.19	1.25	1.56
	29	5.19	1.39	1.93
	30	5.07	1.33	1.77
	31	5.26	1.46	2.12
	32	4.96	1.32	1.74
	33	5.04	1.29	1.67
	34	5.44	1.34	1.80
		5.164	**1.340**	**1.799**
Logical Thinking	35	5.00	1.39	1.93
	36	5.67	1.25	1.56
	37	5.63	1.19	1.42
	38	5.70	1.01	1.02
		5.500	**1.210**	**1.483**
Problem-solving	39	5.56	1.13	1.28
	40	5.70	1.24	1.54
	41	5.52	1.20	1.43
	42	5.56	1.03	1.06
	43	5.59	1.16	1.35
		5.586	**1.152**	**1.332**
Innovative thinking	44	1.00	1.41	1.98
	45	5.78	1.37	1.88
	46	5.7	1.08	1.17
	47	5.42	1.18	1.40
		4.475	**1.260**	**1.608**
Communication skills	48	5.41	0.99	0.98
	49	5.37	1.39	1.94
	50	5.52	1.10	1.21
	51	5.67	1.12	1.26
	52	5.44	0.99	0.99
	53	5.52	1.03	1.06
	54	5.48	0.96	0.92
	55	5.78	1.13	1.28
	56	5.41	1.31	1.72
		5.511	**1.113**	**1.262**
Critical Thinking	57	5.62	1.08	1.16
	58	5.63	1.06	1.12
	59	5.52	0.92	0.84
	60	5.41	0.99	0.98
		5.545	**1.013**	**1.025**
Leadership	61	5.37	1.13	1.27
	62	5.59	1.06	1.13
	63	5.7	1.01	1.02
	64	6.00	0.90	0.81
		5.665	**1.025**	**1.058**

Teamwork and collaboration	65	5.62	1.22	1.48
	66	5.38	1.19	1.41
	67	5.72	0.91	0.82
	68	5.69	0.83	0.7
	69	5.83	1.05	1.11
	70	5.72	0.98	0.96
	71	5.55	0.97	0.94
	72	5.97	1.00	1.00
		5.685	**1.019**	**1.053**
Organization	73	5.9	0.92	0.85
	74	5.86	0.86	0.74
	75	5.55	1.1	1.21
		5.770	**0.960**	**0.933**
Commitment to lifelong learning	76	5.48	1.33	1.77
	77	5.28	1.2	1.44
	78	5.24	1.36	1.84
	79	5.72	1.08	1.17
	80	5.97	0.89	0.79
		5.538	**1.172**	**1.402**