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Evaluation of the Lean Approach Implementation in Engineering Education

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Abstract

This study aims to study the benefits of lean approach implementation in engineering education in Morocco by using three concrete case studies to present a comparative analysis between situations with and without Lean approach deployment. The first project focuses on improving internet access. The second project aims to improve the conduct of practicum sessions. The third project aims to identify and improve the performance of the processes implemented in the student affairs department. In this research study, deductive methodology is followed, also called the "*hypothetical-deductive approach*", First, we presented a synthetic analysis of Lean implementation studies existing in the literature between 2000-2023, then we presented three Lean implementation projects in the engineering school in Morocco. This research work allowed us to present, with concrete cases, the contribution of the approach to engineering education in Morocco, whether it is in the teaching processes or in the support and management processes within an engineering school. The involvement and sensibilization of the resources represent key success factors of this Lean transformation. This research work can serve as a baseline reference for other Lean implementation initiatives in the field of education in Morocco. On the one hand, while examining the literature, we found a scarcity of studies that have presented a comparison between the situation without and with the Lean approach. On the other hand, the Lean approach is a new concept that has never been discussed concretely in the context of Moroccan engineering; the present research fills that gap.

Keywords:

Performance;
Lean Approach;
Moroccan Engineering Education;
Internet Access;
Practicum Sessions;
Student Affairs Department.

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1- Introduction

In Morocco, engineering education is a pillar of economic growth [1], particularly since the launch of the "10,000 Engineers per Year" initiative in 2007. This initiative aimed to meet the growing demand for qualified engineers in the labor market and significantly increase the number of trained engineers in Morocco. However, despite this quantitative increase, challenges persist in terms of engineers' employability [2], as the professional world demands specific skills and adaptability to new challenges.

To improve the quality and evaluation of education and address these persistent challenges, Morocco has undertaken substantial efforts in the higher education sector [3]. In 2014, the National Agency for the Evaluation and Quality Assurance of Higher Education and Scientific Research (ANEAQ) was established, highlighting the country's commitment to strengthening educational standards and practices [4]. This initiative paved the way for broader reforms within the framework of the 2015-2030 education reform strategy, aiming to improve higher education governance and

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implement reliable performance measures. The initiative encompasses several aspects of higher education and scientific research, including (MEF 2016[*]; CSEFRS 2019[†]):

- Recruiting and training 15,000 teacher-researchers by 2030.
- Gradually increasing the GDP allocated to scientific research to 1% in the short term, 1.5% by 2025, and 2% by 2030.
- Developing an orientation and monitoring system within higher education institutions.
- Diversifying the language choices offered by higher education institutions.

Continuing these reform efforts in an economic context with limited resources, especially following the global pandemic and inflation [5], it becomes essential to find innovative approaches to maximize outcomes with limited means. It is within this context that our article aims to examine the impact of implementing the Lean approach in engineering education in Morocco. Lean, a well-known approach in the industry, aims to optimize various processes in a value-creating unit through a policy of continuous improvement based on the engagement and contribution of human capital [6, 7]. This transformation has been widely adopted by various training institutes in different application domains, such as administrative management, evaluation, and training [8, 9]. Bakkali et al. [8] conducted studies to define Lean in the context of engineering education. In this context, we constructed the SIPOC (Supplier Input Process Output Customer) model of a Moroccan engineering school. This model allowed us to define the value produced by the school from the perspectives of different stakeholders [10].

In this study, we critically analyze studies that aim to implement the Lean Higher Education approach. To do so, we primarily focus on two complementary studies, the first covering the period 2000–2015 and the second representing the period 2016–2020. To complete this study, we have conducted a complementary review that analyzes the papers published in SCOPUS, covering the period from 2020 to 2023.

Our thorough analysis of existing research on Lean implementation has revealed a lack of concrete studies evaluating its impact on the education system processes [11, 12]. Previous research has often been theoretical or limited to specific application cases [13-16]. Our study presents three concrete Lean implementation projects in a Moroccan engineering school to fill this gap. We rigorously assess the impact of these projects on the training processes by comparing before and after adopting Lean methodologies.

2- Research Methodology

In this section, we will describe in detail the research methodology used to evaluate the potential benefits of implementing the Lean approach in a Moroccan engineering school. We followed a deductive approach based on the following steps:

- ***Lean Theory***: We initiated our research by presenting the core principles of the Lean approach within the context of training process management. This theoretical framework provided us with a solid foundation to guide our study.
- ***Hypothesis Formulation***: Building upon the Lean theory, we formulated the following hypothesis: *The implementation of the Lean approach would improve the training processes in Moroccan engineering school*. Through this study, we will test this hypothesis to verify to what extent it can be valid in the Moroccan context.
- ***Selection of Study Subjects***: To ensure comprehensive insights, we carefully selected a Moroccan school as our research setting and identified three specific study subjects. This deliberate choice allowed us to observe the impact of the Lean approach within varied contexts and collect pertinent data for evaluating our hypothesis.
- ***Implementation of the Lean Approach***: For each study subject, we operationalized the Lean approach by identifying existing training processes, analyzing sources of inefficiencies, and proposing improvements based on Lean principles. We collaborated closely with the responsible teams to effectively implement the suggested changes.
- ***Observation and Results***: Following the implementation of Lean-based modifications, we meticulously observed the training processes within each study subject. This enabled us to gather both quantitative and qualitative data, facilitating a comprehensive assessment of the achieved improvements and benefits. Through in-depth analysis, we evaluated the extent to which the application of the Lean approach positively impacted the training processes.

By following this deductive methodological approach, we were able to evaluate the potential benefits of using the Lean approach in the context of a Moroccan school.

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† Report of CSEFRS (2019): Higher Council for Education, Training, and Scientific Research (CSEFRS), Rabat, Morocco.

3- Analytical Review of Lean Implementation Studies in Higher Education

In this paper, we suggest a synthetic review of different studies that have implemented the Lean thinking approach in the field of training from the period 2000 to 2023. To do so, we rely mainly on three complementary studies, the first covering the period 2000-2015 [11], the second one focusing on the period from 2016 to 2020 [12], and a complementary study of articles published on the *Scopus* database from 2020 to 2023.

3-1- Period 2000-2015

In this study, the authors analyzed studies published between 2000 and 2015 [11] that described the implementation of Lean within educational organizations. The studies are categorized into two types:

The authors classified the Lean thinking implementation studies according to two levels:

- Department-level publications: These describe the implementation of the Lean approach within a unit or department of the training institute (schooling service, document management, student service, course management…) [17-20].
- Institution level publications: They describe the generalization of the deployment of the Lean approach to the whole training institute [21-24].

Institution-wide publications accounted for 58% of the articles studied, while department-level publications accounted for 42%, as shown in Figure 1. The authors also examined the benefits of the adoption of Lean transformation in the educational system, which we have summarized in Table 1.

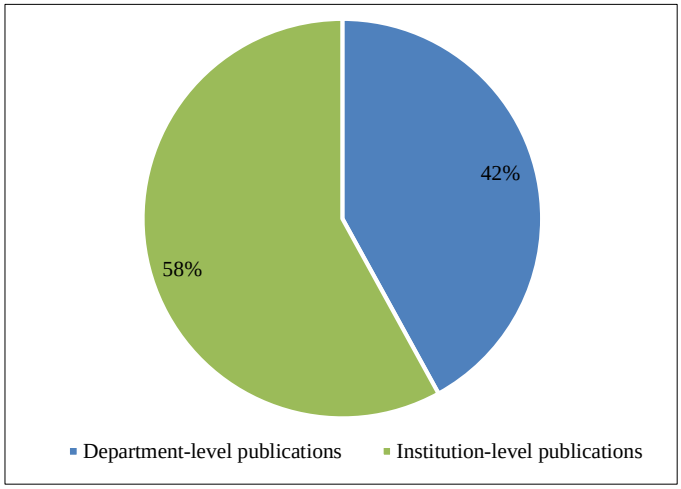

Figure 1. Levels of Lean implementation

Table 1. benefits of the Lean approach deployment

		Reported improvements
Department-level publications	Teaching, curriculum, and assessment [20]	• Reduction of the error rate in the teaching and assessment process • Waste reduction • Regularization of the workload • Improvement of educational and assessment process
	Administrative and student-support processes [25, 26]	• Improvement of student support services (admission, advising....) • Improvement of the quality of distance education • Achievement of financial savings through resource optimization • Improvement of student learning experiences
Institution-level publications	Executive leadership [27, 28]	• Importance of management engagement & support for the success of any Lean initiative • Use of a central office to lead Lean initiatives • Lean leaders should come from individual faculty members, who are at the heart of the education process
	Institutional readiness [29]	• Improvement of organizational development in order to have the right people for the Lean implementation. • Importance of using small-scale Lean projects for larger initiatives
	Organizational learning [30]	• The importance of engaging in a policy of continuous improvement
	Institutional culture considerations [31]	• Improvement of employee awareness and commitment to the Lean culture.
	Conceptual frameworks [22]	• The necessity to develop a conceptual framework for implementing the Lean approach
	A systemic approach to improvement [32]	• Importance of transparent communication • Necessity of good organizational change management

The Lean approach has significant contributions to improving the performance of different services within the training institute (learning, evaluation, administration...). Moreover, the success of this transformation requires good planning in time (long-term and medium-term planning) with a high level of awareness among human resources.

3-2- Period 2016-2020

The authors examined articles published in the period between 2016 and 2020 that focus on the implementation of Lean in education. They analyzed two types of studies [12].

- Conceptual studies: They refer to the studies that are interested in the development of new techniques, methods, frameworks, or guides.
- Analytical studies: They describe the studies based on the analysis of data derived from mathematical simulations, questionnaires, or interviews.

Analytical studies represented 69.57% of the articles analyzed, while conceptual studies represented 30.43%, as shown in Figure 2.

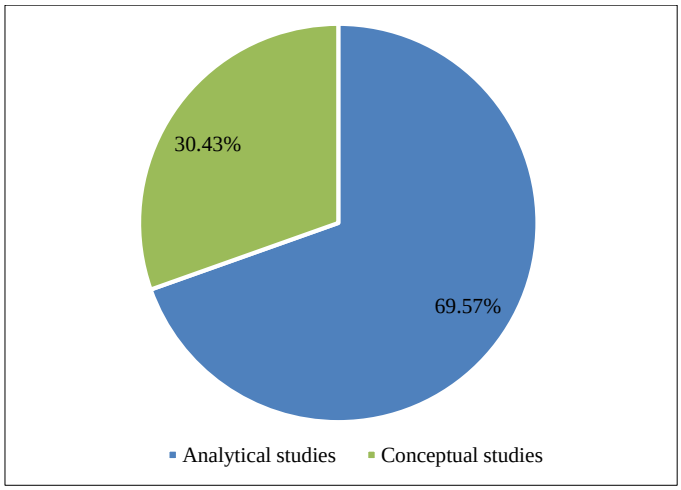

Figure 2. Types of Lean implementation studies

The authors suggested a multidimensional analysis based on several criteria, namely the area of application of the Lean approach, the Lean tools used, facilitating factors, constraints, and observed results [12]. This approach is presented in Table 2.

Table 2. Analysis of Lean implementation studies 2016-2020

Lean thinking implementation areas	Implementation of Lean in the educational, administrative and financial environment (23.33%) Implementation of Lean in the administrative sector (26.09%) Implementation of Lean in the classroom (26,09%) Implementation of Lean in the libraries (13.04%)
Lean Tools [12, 33]	The most present Lean tools in the articles: Lean six sigma is presented by 38.89% of the papers Voice of the Customer is discussed by 13.89% Kaizen is present within 11.11% of the studies
Facilitating factors	Good management system cited by 23.67% of studies, Engagement and qualification of stakeholders (teachers, students, staff…) with 23.33%, Leadership team with 20%.
Constraints	Ignorance of the Lean culture (16.13%) ineffective management system (16.13%) Insufficient funding (12.90%)
Benefits	Improvement of student service (31.37%), Improvement of education activities (17.64%)

This literature review allowed us to highlight that few studies provide a concrete evaluation of the contribution of Lean transformation to improving the performance of internal processes by suggesting a comparison between the situation before and after the deployment of the Lean approach. Our study fills this gap by proposing three Lean implementation projects in a Moroccan engineering school.

3-3- Period 2020-2023

In order to enhance our literature review with recent references from 2020 to 2023, we conducted a search for articles published in the Scopus database that address the implementation of Lean in education. Table 3 summarizes the identified articles, highlighting their contributions and limitations. It is noteworthy that only two articles in Morocco discuss this topic, underscoring the added value of our own article.

Table 3. Complementary literature review study (2020-2023)

Article title	Year	Country	Results	Limits
Identification and Prioritization of Lean Waste in Higher Education Institutions (HEI): A Proposed Framework [13].	2023	Indonesia	Proposes a framework for identifying and prioritizing waste in HEIs.	Lack of practical examples of Lean implementation.
Digitally Enabled Experiential Learning Spaces for Engineering Education 4.0 [34].	2023	Mexico	Using digital experiential learning in learning spaces for engineering 4.0 education.	The case study method used limits the external validity of the results, as they can only be applied to specific learning experiences.
Soft and hard skills development in lean management trainings [14].	2022	Brazil	Developing soft and technical skills in lean management training courses.	Lack of practical examples of Lean implementation
Critical success factors of Lean in Higher Education: an international perspective [35].	2022	Netherlands	Key success factors for Lean in higher education: an international perspective.	Study results based on participants' perceptions and opinions. No case studies to evaluate implementation of the approach.
The effect of teaching-learning environments on student's engagement with lean mind-set [36].	2021	England	Effect of teaching-learning environments on students' commitment to Lean mind-set.	The use of questionnaires and subjective data can introduce bias into the study. Students' personal opinions can influence responses, which can affect the reliability of results.
Employees' attitudes toward change with Lean Higher Education in Moroccan public universities [15].	2020	Morocco	The results of this study show that individual, organizational and group factors have a positive impact on employees' attitudes towards change with Lean in public universities in Morocco, with a greater emphasis on individual factors.	Study limited to the first stage of the process, i.e., resistance to change. -Results and conclusions are based on the analysis of questionnaires.
Developing a measurement scale of the public sector's ability to adopt lean [16].	2023	Morocco	The result of this study is the development of a scale to measure the public sector's capacity to adopt Lean, comprising five dimensions: leadership and team spirit, customer focus, communication, employee training and continuous improvement.	The study focuses mainly on the exploratory phase and does not provide concrete results on the actual application of the Lean approach.

4- Practical Cases of Lean Thinking Implementation in Engineering Education in Morocco

To evaluate the contribution of the Lean approach to the improvement of engineering education in Morocco, we have launched a field study in a Moroccan engineering school. The latter includes three projects of implementation of the Lean thinking approach, as described in Figure 3.

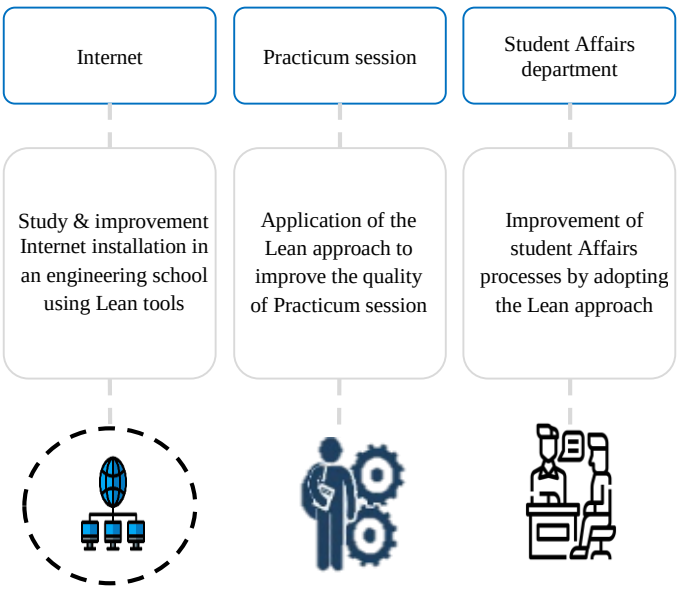

Figure 3. Case studies of Lean thinking implementation in the educational system

The first project consists of evaluating the contribution of Lean principles to accelerating the internet flow within the school. The second project aims to implement the Lean approach to improve the quality of practicum sessions. The third project focuses on deploying Lean thinking to improve processes within the student affairs department. In the following sections, we describe each of these projects and their respective benefits.

4-1- Improvement of the Internet Flow

We have carried out this study as part of a project in a Moroccan engineering school to improve the access of engineering students to the internet to facilitate their knowledge acquisition and skill development. Initially, we proposed a solution without implementing the Lean approach. This solution is based on the steps described in Figure 4.

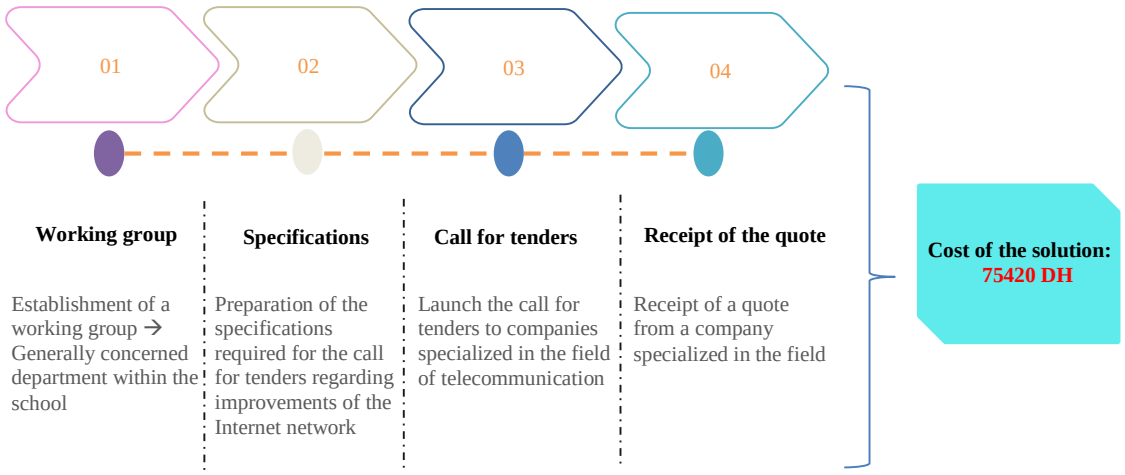

Figure 4. Process followed without Lean approach deployment

In order to develop better visibility in terms of budgets and required means, we compared the first solution to the one using the Lean approach. The Lean approach enabled us to utilize the existing resources from the old network installation in order to develop the new network configuration, which offers a better optimization of the resources. The optimization approach is presented in Figure 5.

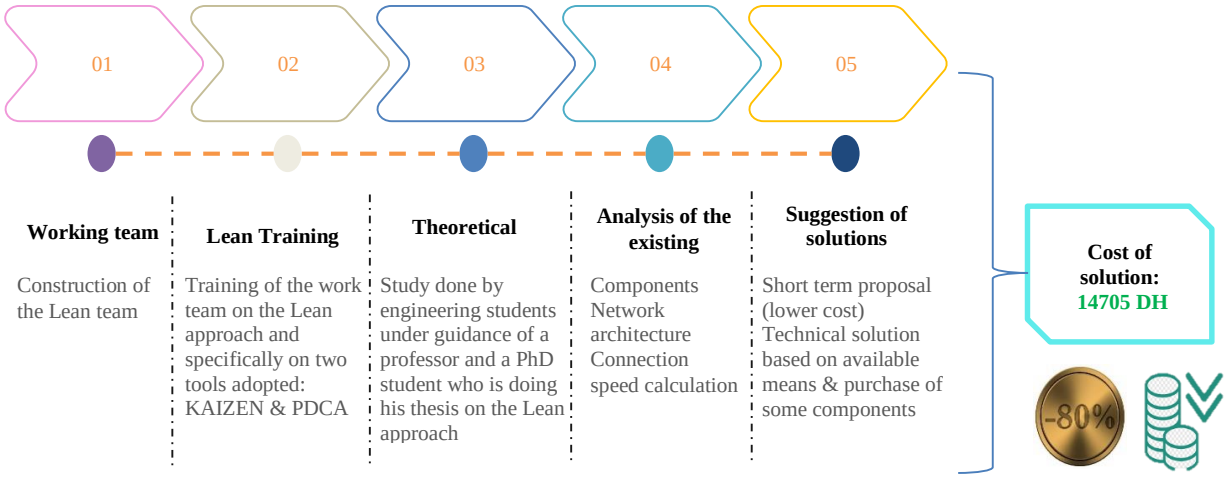

Figure 5. Process followed using the Lean approach

As illustrated in Figure 5, in our first Lean project implementation, we followed a series of five key steps. We began by creating a collaborative working team consisting of engineering students under the supervision of a professor specializing in embedded systems and telecommunications, alongside our dedicated Lean research team. Next, we provided Lean training to team members with the necessary knowledge and skills to increase their awareness of and integration into this important transformation. As the approach contains several tools, the choice of Lean tools often depends on the field of application [37]. For our case, we focused on two tools that are compatible with the project objectives, PDCA (Plan, Do, Check, Act) and Kaizen:

- PDCA: It is a problem-solving method based on four main steps. The first step is to plan improvement actions to solve a problem. The second step, 'Do', is the implementation phase of the solution. The third step, "*check*", is to

test the performance of the implemented solution. The latter is itself examined to find its points of improvement in the 'Act' phase. The PDCA method calls for a strategy of continuous improvement, [6, 7].

- Kaizen: It is not only a tool, it's a mindset, that not only helps to achieve the desired results but also involves human resources in the implementation of the transformation, [6, 7].

Below are the results and gains that we were able to achieve through this project:

- ***Cost Reductions and Financial Impact:***

  One of the notable outcomes of our Lean project was the significant cost reductions achieved. By implementing Lean methodologies, we were able to streamline processes and eliminate waste, resulting in substantial savings. Comparing our Lean solution, with zero investment costs but utilizing existing resources, to the non-Lean alternative involving a conventional tender process, we achieved cost reductions of up to 80%. This financial impact demonstrates the effectiveness of the Lean approach in optimizing resource utilization and minimizing expenses.

- ***Process Improvements and Efficiency Gains:***

  In addition to cost reductions, the application of Lean principles enabled us to achieve process improvements and efficiency gains. By leveraging Lean tools such as PDCA and Kaizen, we identified bottlenecks, eliminated non-value-added activities, and enhanced overall workflow. These process improvements not only increased productivity but also contributed to a culture of continuous improvement within the team.

- ***Skill Development and Future Applications:***

  The implementation of the Lean project proved to be a valuable learning experience for team members, enabling them to acquire and develop essential skills that will have long-lasting benefits in their future professional journeys. Through active participation in Lean training and the practical application of Lean methodologies, they honed their abilities in problem-solving, process optimization, and continuous improvement. By fostering a culture of Lean within our team, we instilled a mindset of ongoing growth and innovation, ensuring that the knowledge and skills gained from this project will be applicable and impactful in their future endeavors.

4-2- Improvement of the Quality of Practicum Sessions

The implementation of the Lean approach in the improvement of engineering practicum sessions is conducted according to the approach described in Figure 6.

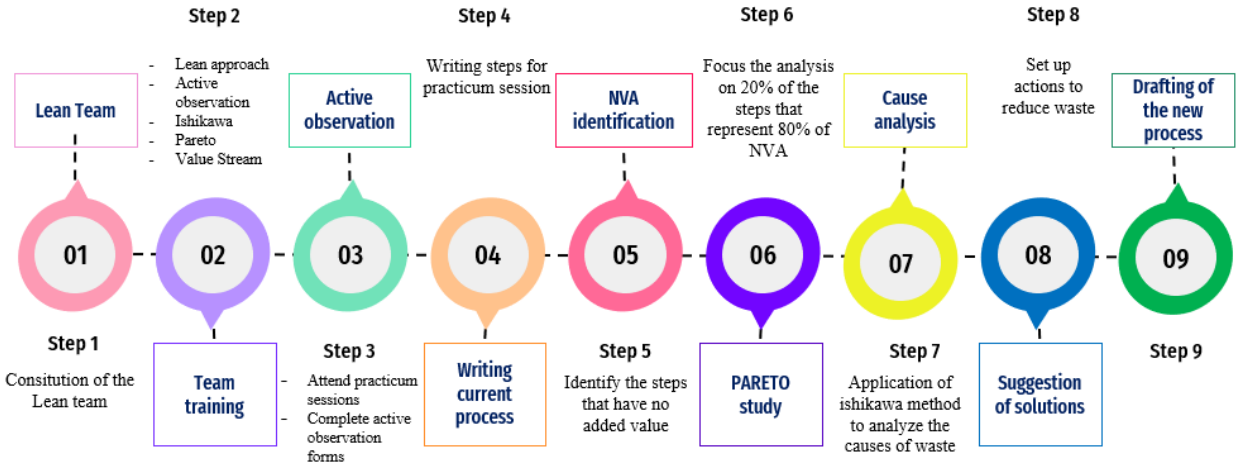

Figure 6. Lean implementation in practicum sessions

The first and most important step in implementing a Lean project is work team training. The team is trained in the principles and tools of the Lean approach, which is a strategic transformation requiring a strong commitment from the human resources of the education system. The axes of the Lean training in this project are:

- Increasing the team's awareness of the importance of the Lean transformation.
- Explanation of the Lean thinking principles
- Definition of Lean tools and their utility:
  - Active observation: A tool for observing the progress of a process in order to identify its non-value-added steps;

- Ishikawa: It allows to analyze the causes and sub-causes of a dysfunction in the process;
- Pareto: It enables decision-makers to prioritize tasks or steps according to their level of importance;
- Value stream: It describes the process without the non-value-added steps.

The next step is active observation. The Lean team attended the training sessions to get visibility of the process steps. The results of the practicum session' analysis are used to complete the active observation sheet. Based on the collected information, we then proposed a model of the current process of practicum sessions, as described in Figure 7.

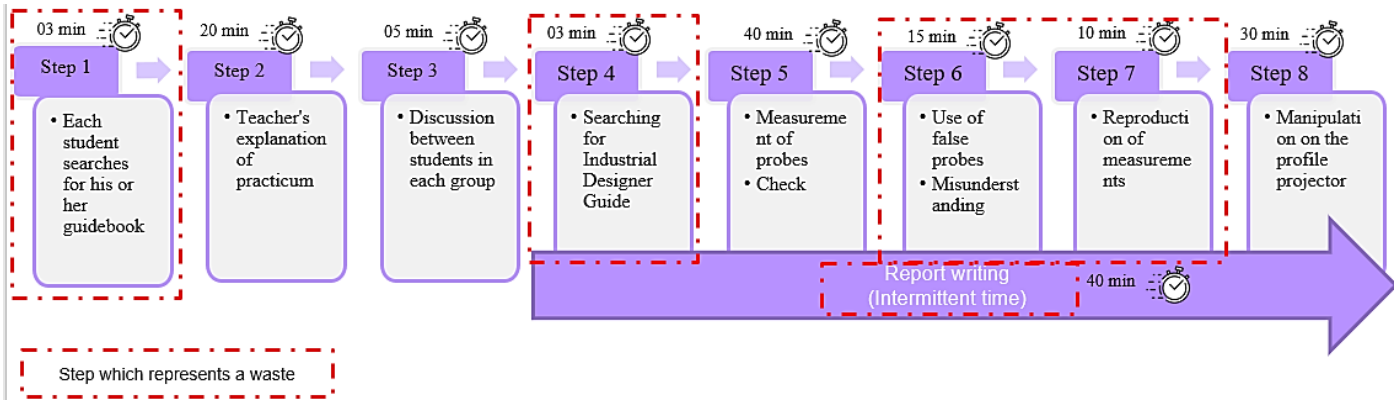

Figure 7. Progress of practicum session before Lean implementation

Once the process was well described, as shown in the figure above, the session overflowed by 6 minutes (the session was originally planned to finish within 2 hours). Following that, we made an analysis in order to distinguish between the steps with added value (VA) and those that have no added value in the process (NVA),

The active observation allowed us to identify several steps in the process of practical works. We decided to prioritize them in order to limit the study to the most important steps. To do this, we used the PARETO tool, which allowed us to limit our analysis to 20% of the steps that represent 80% of the NVA. The next objective is to conduct an analysis to better understand these NVA steps. Using the palette of tools offered by the Lean approach, we adopted the 5M method to examine the causes and sub-causes of these NVA steps.

After identifying the sources of waste in the process, we launched action plans to eliminate or reduce the NVA steps. The suggested solutions are presented below:

- Creation of a guide for the progress of a practicum session
- Drafting of a guide of good practices & FAQ (Frequently Asked Questions)
- Implementation of visual management.

In order to measure the impact of our approach in improving the performance of practicum sessions. We have suggested a model of the process after the implementation of the Lean thinking approach, as described in Figure 8.

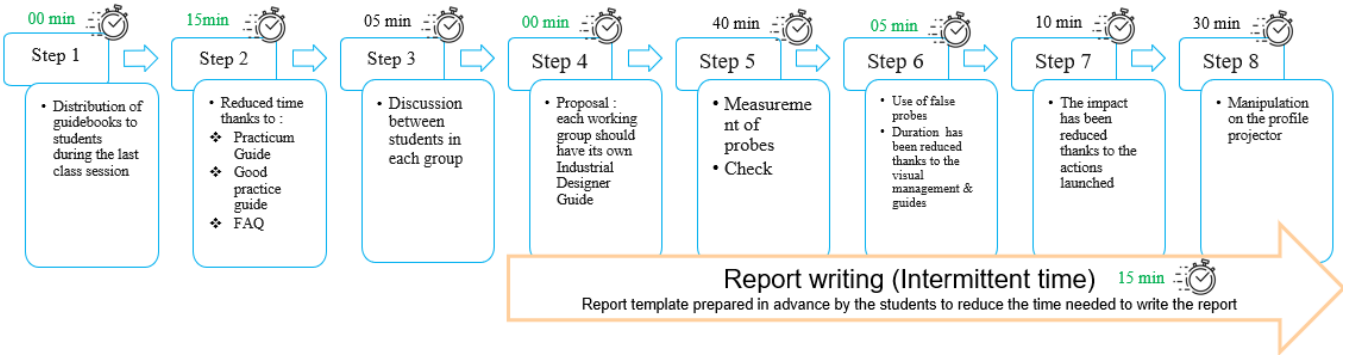

Figure 8. Practicum session after implementation of Lean thinking

The results of implementing the Lean approach in one practicum session show a time savings of 15 minutes over the whole session, and reducing report writing time by 25 min. This time savings was measured for a single training session. However, if the project is expanded to all engineering practicum sessions, this time savings will be more significant. The gained time can be effectively utilized for the following purposes:

- Ensure a better understanding of the theoretical concepts of the experiment: With the additional time, students can benefit from a more in-depth explanation of the theoretical principles underlying the practical manipulation. This helps reinforce their overall understanding of the subject matter and enhances their knowledge.
- Facilitate the development of expected skills from the experiment: The additional time can be allocated to providing guidance and support to students in refining the specific skills that the experiment aims to develop.

4-3- Improvement of the Processes in the Student Affairs Department

The last project in our field study involves implementing the Lean approach to improve the operational processes of the student affairs department. As illustrated in Figure 9, in order to carry out this project we have adopted the following steps:

Step 1*:* Building the Lean team that leads this transformation

Step 2*:* Training the team on the appropriate modules for the project requirements represents a key factor for success and achievement of the Lean desired results [38]. The team has been trained on the following topics:

- Lean Approach;
- Active Observation;
- SIPOC;
- PARETO;
- 7 MUDA;
- PDCA.

Step 3*:* Using active observation tools, the team, in collaboration with the head of the student affairs department made a global service process containing all deliverables, their inputs and outputs.

Step 4*:* After identifying the deliverables of the student affairs department, we conducted an PARETO analysis in order to focus on 20% of the deliverables that represent 80% of the hourly load of the service. As a result, three deliverables were identified.

Step 5*:* Next, the team created a SIPOC for each deliverable to control the process and its different steps.

Step 6*:* Using the 7 MUDA method, the team identified a list of non-value-added activities.

Step 7*:* This step involves defining improvement action plans to reduce or eliminate the different types of waste in the process using the PDCA method (Plan, Do, Check, Act).

Step 8*:* Based on the previous two steps, the team was able to make a list of recommendations to reduce or eliminate non-value-added steps in the process by implementing the following action plans, namely:

- Implementation of a reservation system by available computer means: Connection / Easy access display screen / Communication tools (Outlook/Teams);
- Creation of an Excel file to automate the maximum of manual operations for tracking absences;
- Elaboration of a less expensive clocking system to ensure the automatic follow-up of absences & attendance.

The university, like any organization, must leverage technology to meet its challenges [33]. The objective of the Lean approach is not to reduce staff or create free time. The objective is to be part of a policy of continuous improvement with increased commitment and support from human resources.

5- Discussion

The originality of this study stems from its application of optimization principles, widely recognized in the industrial sector, in the field of engineering education in Morocco. Drawing upon existing research on Lean thinking in education, we conducted a comprehensive multidimensional analysis of articles published between 2000 and 2023, specifically examining the implementation of Lean thinking in the field of education. Building upon the insights derived from this extensive literature review, we embarked on three simultaneous studies aimed at enhancing the Moroccan engineering training system through the adoption of the Lean approach, while considering diverse perspectives:

- In the context of improving Internet access within the school. We proposed a solution based on the principles of the Lean approach. Thanks to the latter we have achieved a gain of 80% compared to the traditional solution without the deployment of the Lean approach.

- The deployment of the Lean approach in the improvement of practicum sessions allowed us to save 15 min of lost time per session and reducing the report writing time by 25 min thanks to the pre-prepared template. This time will be exploited in the explanation of the principles of manipulation so that the engineers can develop the envisaged skills
- Lean not only aims to reduce and eliminate non-value-added steps but also to improve the working conditions of the employees. This is the context of our third 'Lean' improvement project. We proposed improvements based on the use of technology to improve the efficiency of the student affairs department.

The significant gains achieved in our projects are not solely attributed to the successful execution of the three initiatives; they also include the provision of intriguing topics for future engineering students to explore as part of their final-year projects. This endeavor contributes to nurturing future job market leaders who will embrace and apply this improvement approach in their future careers.

6- Conclusion

The successful implementation of this transformative endeavor requires active engagement from the entire academic community, with a particular focus on the participation of teachers. They play a critical role in driving the adoption of Lean principles and ensuring their integration within the education system. Providing teachers with the necessary training and support is essential to empowering them as agents of change and champions of Lean practices. Despite the challenges faced, such as the disruptions caused by the COVID-19 pandemic, our project has demonstrated resilience and adaptability. The transition to distance learning demanded additional time and effort from professors, who showcased remarkable dedication in adapting their teaching methods. Acknowledging the dedication and commitment of educators in navigating these obstacles is crucial.

Based on our research and experiences, we strongly recommend that all schools in Morocco embrace a cultural shift from a traditional mindset to a culture of continuous improvement based on Lean principles. By effectively utilizing available resources and embracing Lean methodologies, educational institutions can enhance the quality of education, optimize processes, and better prepare students for the demands of the modern world. This transition requires collaborative efforts, open communication, and a shared commitment to ongoing learning and improvement. Empowering teachers and fostering a culture of continuous improvement will pave the way for an educational system that excels at meeting the needs of students and prepares them for a successful future.

7- Declarations

7-1- Author Contributions

Conceptualization, A.H.; methodology, A.H.; validation, A.H., S.B., and S.A.; formal analysis, A.H.; investigation, A.H.; resources, A.H, S.B., and S.A.; data curation, A.H, S.B., and S.A.; writing—original draft preparation, A.H.; writing—review and editing, S.B. and S.A.; supervision, S.B. and S.A. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

The data presented in this study are available in the article.

7-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7-4- Institutional Review Board Statement

Not applicable.

7-5- Informed Consent Statement

Not applicable.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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