



ASSESSMENT OF LEAN SIX SIGMA IMPLEMENTATION IN ADDRESSING INTERNAL COST OF POOR QUALITY IN SELECTED ELECTRONICS COMPANY IN LAGUNA

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ABSTRACT

In today's competitive corporate environment, strong competition, technological advances, and changing customer preferences affect financial performance and strategic goals. Companies used to believe that great quality meant high manufacturing costs, so they cut expenses while retaining quality to be reasonable. However, this strategy accidentally created the Cost of Poor Quality (COPQ), which thus emphasizes the importance of quality costs. A recognized electronics manufacturing unit in Binan, Laguna, has been using Lean Six Sigma (LSS) in machining and in printed circuit board (PCB) assembly to provide complete customer solutions. The fact that PCB manufacturing scrap and rework rates remain high highlights the need for continued analysis and evidence-based quality management improvements. This research focused on a Binan, Laguna, electronics company. The study used a descriptive research methodology with a quantitative approach to assess Lean Six Sigma's implementation in addressing the internal cost of poor quality, including scrap and rework. The electronics company's Lean Six Sigma success factors were examined. Data-driven suggestions for improving the internal scrap and rework were presented. A well-structured and verified survey checklist, intercontinental Lean Six Sigma implementation studies across industries, and secondary data from the specified research location were used to collect and validate the data. The study's analysis found only partial implementation of Lean and Six Sigma process controls, especially in scrap and rework, which thus required targeted interventions. Lean six-sigma process control methods, including value stream mapping, kanban systems, DMAIC (Define, Measure, Analyze, Improve, Control), and capability analysis, had low response scores. Training to improve staff skills and competency, supplier development and qualification, and supplier involvement in continuous

improvement initiatives effect implementation. Lean process control and Six Sigma deployment needed improvement, specifically the necessity for focused interventions to address internal challenges across the company. By analyzing these results, the application of the RESOLVE and ENHANCE frameworks was developed, and they served as a strategic response to the findings regarding the level of implementation of Lean Six Sigma and the factors affecting this implementation. The RESOLVE framework addressed the identified deficiencies in training and competency levels among employees. On the other hand, the ENHANCE framework targeted the improvement of supplier development and qualification processes while involving suppliers in continuous improvement activities.

Keywords: *Lean Six Sigma, Cost of Poor Quality, Scrap, Rework, Continuous Improvement*

INTRODUCTION

Companies attempted to reduce production expenses while maintaining high standards of quality, with the aim of making the products accessible to the intended market at reasonable prices. Unfortunately, many companies unintentionally gave the opportunity for one more concern, the cost of poor quality (COPQ). COPQ is the total cost that could be avoided if instances of poor quality did not occur. Even reducing quality costs could have significant effects on a business (Törnblom, 2022).

The electronics manufacturing sector in the Philippines accounts for approximately 60 percent of the country's total manufacturing output, making it one of the most important contributors to the industry's overall production (Statistica Research Department, 2023). Binan, Laguna, has been one of the focal points for electronics manufacturing enterprises in the region, drawing the attention of both domestic and foreign customers. The study was conducted at a company situated in Binan Laguna. Over the past months, the company has experienced a scrap ratio of 0.71% and a rework ratio of 0.40%. Additionally, the PCB final assembly line has maintained an average of 10,970 defective parts per million for the past 10 months.

Research Questions

This research identified and provided answers to the following research problems and objectives in terms of implementation of lean six sigma in addressing internal cost poor quality.

1. What is the level of implementation of Lean Six Sigma in addressing the internal cost of poor quality in terms of addressing the concerns for the following final products:
 - i. Scrap
 - ii. Rework

2. What is the degree of engagement of engineers on the factors contributing to the level of implementation of Lean Six Sigma to address the internal cost of poor quality in the final product's scrap and rework?
 3. What improvement initiatives can be recommended in addressing the cost of poor quality for internal issues related to the final product's scrap and rework?
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METHODOLOGY

Research Design

The study employed descriptive research and quantitative methods to examine engineers' assessments of the implementation of lean six sigma in addressing the cost of poor quality (COPQ) in a selected electronics company in Laguna. The study used a survey questionnaire as the primary data collection instrument, supported by secondary data from the research locale and a review of related literature.

Research Locale

The research focused on a Binan Laguna-based Japanese multinational company that manufactures electronics PCBs for storage devices. The research scrutinized the application of Lean Six Sigma in this organization to enhance internal quality and production processes. This research aimed to examine how Lean Six Sigma can improve electronics PCB manufacturing by reducing internal costs associated with poor quality, such as scrap and rework.

Population and Design

This study includes manufacturing engineers, who serve an essential role in implementing and evaluating Lean Six Sigma systems. Their experiences provided ideas for using Lean Six Sigma to reduce the cost of poor quality. The study used a total of 43 qualified manufacturing engineers who were actively involved in the company's manufacturing processes.

Research Instruments

This study employs a survey questionnaire as its research instrument, comprising two primary sections. Part 1 asked about the extent to which Lean Six Sigma process controls have been implemented to address the internal cost of poor quality, specifically the scrap and rework of the final product. Part 2 inquired about the degree of engagement with the factors contributing to the level of implementation of Lean Six Sigma. Standard practices in the industry and lean six-sigma literature served as the basis for the survey questionnaire. This second portion of the survey identified factors and asked respondents about their positive engagement. The questionnaires were pre-tested and validated through pilot testing and expert reviews to ensure their reliability and validity. The

researchers used Cronbach's alpha to confirm the reliability and validity of the questionnaires, ensuring their clarity and comprehensiveness.

Data Gathering Procedure

The researchers administered the questionnaires for the quantitative research through an online Google Form to the respondents, allowing them to access them through their personal email accounts or social media platforms. The researchers requested and gathered secondary data from the company to supplement significant information for the research. A thorough review of the relevant related literature was also conducted to support and substantiate the responses to the survey.

Management and Treatment of Data

The level of implementation of lean six-sigma process controls and the degree of engagement of the engineers were gathered both through the survey questionnaire and secondary sources. The researchers conducted the analysis using percentage frequency and weighted sum calculations. Based on data analysis and industry standards, recommendations were made to improve Lean Six Sigma deployment and advance continuous improvement programs.

Scope and Limitations

The study focused on a selected electronics company in Laguna and assessed the current procedures used by the chosen organization on the cost of poor quality (COPQ), with particular attention given to internal factors such as scrap and rework. The study's primary limitation was its narrow scope, as it only investigated one electronics company in Laguna. Only engineers employed by the organization participated in the assessments as respondents. The study's population did not include technicians and operators. The study only focused on the internal variables of scrap and rework, not thoroughly examining the external factors that contributed to the cost of poor quality. The study's exclusive reliance on quantitative methods for data acquisition and analysis also failed to adequately capture the qualitative complexities of Lean Six Sigma implementation.

RESULTS AND DISCUSSION

I. Level of Implementation of Lean Six Sigma in addressing Internal Cost of Poor Quality

A. Scrap

i. Lean

The engineers' evaluation indicated that 60% of most responses had only partial implementations. The researchers observed low implementation scores for lean process

controls in value stream mapping and Kanban, with consecutive responses of 5% and 2%. This observation implies a fundamental problem in the description of the operations' value chain and underscores possible avenues for enhancement and optimization in order to expedite scrap management processes.

Lee and Kim (2021) provided insights into why some companies have only partially implemented lean process control tools. The authors emphasized issues such as data complexity, limited analytical capabilities, and organizational reluctance to change as variables leading to the partial implementation of Lean Six Sigma. In their study on quality costs and application in a manufacturing enterprise, Eraslan (2021) also noted that the partial implementation of lean process control tools was due to management's lack of awareness about COPQ.

ii. Six Sigma

Overall engineering assessments described the implementation of Six Sigma as partially implemented. Statistical Process Control (SPC) and Control Charts revealed low scores in the implementation of six-sigma process control tools for addressing scrap, with 2% of the engineers assessing these controls as non-implemented. This highlighted a significant shortfall in leveraging advanced statistical techniques to enhance process efficiency and reduce scrap.

Studies by Chaurasia et al. (2019) and Ruiz et al. (2022) provided substantial support to the engineers' assessment of the application of Six Sigma control tools to reduce the internal cost of poor quality, specifically waste. The study by Chaurasia et al. showed the outcomes of their research into how to use Lean Six Sigma ideas to boost performance in the auto industry, focusing on completing tasks on the first try and getting rid of rejects. The study emphasized how effective Six Sigma methods are at finding and fixing the root causes of waste, which leads to big improvements in process efficiency and lower costs across the board.

B. Rework

i. Lean

About 56% of engineers reported moderate application of lean approaches to address rework issues, indicating a good effort. Few engineers employed lean process control methods for rework, such as value stream mapping and Kanban, with 2% confirming no implementation. In order to effectively address rework challenges and enhance operational efficiency, the evaluation emphasized the need for further implementation of lean process control tools.

Puteri and Zagloel's (2022) research, which focused on developing a supplier quality monitoring system in the electronics manufacturing sector, provided valuable insights into the moderate application of lean process controls to address rework concerns. The authors underscored the potential benefits of implementing a methodical strategy for supplier quality management, which included effective cost reduction through

rectification and increased operational efficiency. The results of the present study, which demonstrated a moderate level of implementation of lean process controls to address reprocessing issues, were consistent with the literature. In the world of electronics manufacturing, this showed how important it is to use proactive quality management strategies, like the ones suggested by Puteri and Zagloel (2022), to make processes more efficient and cut down on the need for reprocessing.

ii. Six Sigma

67% of respondents reported partial implementation. Despite applying some Six Sigma ideas, there was still a need for further integration and application of its approach to effectively address rework. Merely 2% of responses indicated no implementation of SPC and control charts. The results indicate that the company implemented Six Sigma principles and techniques. However, several methods could be improved.

Numerous studies validated the current level of Six Sigma implementation at the designated electronics company. In their investigation, Sodhi et al. (2019) identified process variability, design defects, and supplier issues as the fundamental causes of scrap. According to Alsada and Kumar (2022), Yemeni industrial organizations generate waste due to incoming material defects in production materials and finished products. According to Fogg (2022), organizations in the United States argued that manufacturers ought to take waste rates into account rather than exclusively prioritizing maximum output. A variety of factors can cause scrap, which frequently results from inefficient processes.

II. Degree of Engagement in the factors Affecting the Level of Implementation of Lean Six Sigma in Addressing Internal Cost of Poor Quality

The management's commitment and level of support throughout the organization's Lean Six Sigma implementation process engaged and positively impacted the engineers, as evident in the average responses to neutral engagements to all the assessed factors. The electronics company saw that its manufacturing engineers weren't very interested in training, supplier development, and activities that involved continuous improvement. This was shown by the fact that 9%, 28%, and 33% of them said they weren't engaged, respectively. This highlights the organization's need to confront and possibly readjust its approaches in order to promote increased employee engagement and efficiently support lean six-sigma goals. This is especially true when considering the raw material value chain in PCB manufacturing, which starts with the supplier's quality.

The survey findings highlighted the key factors influencing Lean Six Sigma implementation, with some aspects showing high engagement and others receiving neutral assessments. Mahmood (2021) identified critical success factors for minimizing the cost of poor quality in construction projects, emphasizing the pivotal role of management commitment. The survey's findings, which show a correlation between strong leadership support and higher levels of engagement in Lean Six Sigma initiatives, are in line with Mahmood's findings. Moreover, in quality review during product design and development, Galli (2021) discusses how the cost of poor-quality factors comes into

play in continuous improvement models. Effective quality review processes during product design and development, as indicated in the survey, aligned with Galli's emphasis on continuous improvement, thereby contributing to overall engagement in Lean Six Sigma practices.

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On the other hand, for factor training to raise the competency of employees, Srivastava's (2020) study highlighted the impact of Six Sigma methodologies on improving process output through employee competency enhancement. While the neutral assessment suggested a balanced focus on this factor, Srivastava's research underscored the importance of training initiatives for effective Lean Six Sigma implementation. Additionally, Bhushi et al. (2023) addressed the issue of poor quality costs in the auto industry, often attributed to supplier-related issues. Although the present study's survey indicated a neutral assessment, Bushi et al.'s insights underscored the significance of developing and qualifying suppliers to ensure quality inputs into the production process. Lastly, for the factor of supplier involvement in continuous improvement initiatives, which 45% of the respondents rated as neutral, Galli (2021) emphasized the importance of integrating suppliers into continuous improvement efforts. Galli's insights highlighted the importance of supplier involvement in addressing quality issues upstream in the supply chain.

III. Improvement Initiatives in Addressing the Cost of Poor Quality for Internal Issues related to the Final Product's Scrap and Rework

A. Enhancement of Lean Six Sigma Process Controls by Comprehensive Training Initiative

Figure 1 illustrates how the RESOLVE training framework provides a comprehensive strategy to address low training scores and enhance the skills and competencies of employees. The main goal of this method is to help people learn how to use the Kanban system, value stream mapping (VSM), and Six Sigma principles, which include the DMAIC approach and capability analysis. The organization should encourage employee evaluation of their current training methods and staff competencies to pinpoint areas for enhancement, guarantee the achievement of training objectives, enhance

learning methods, organize training content, apply the DMAIC methodology, validate through capability analysis, and continuously evaluate and iterate.

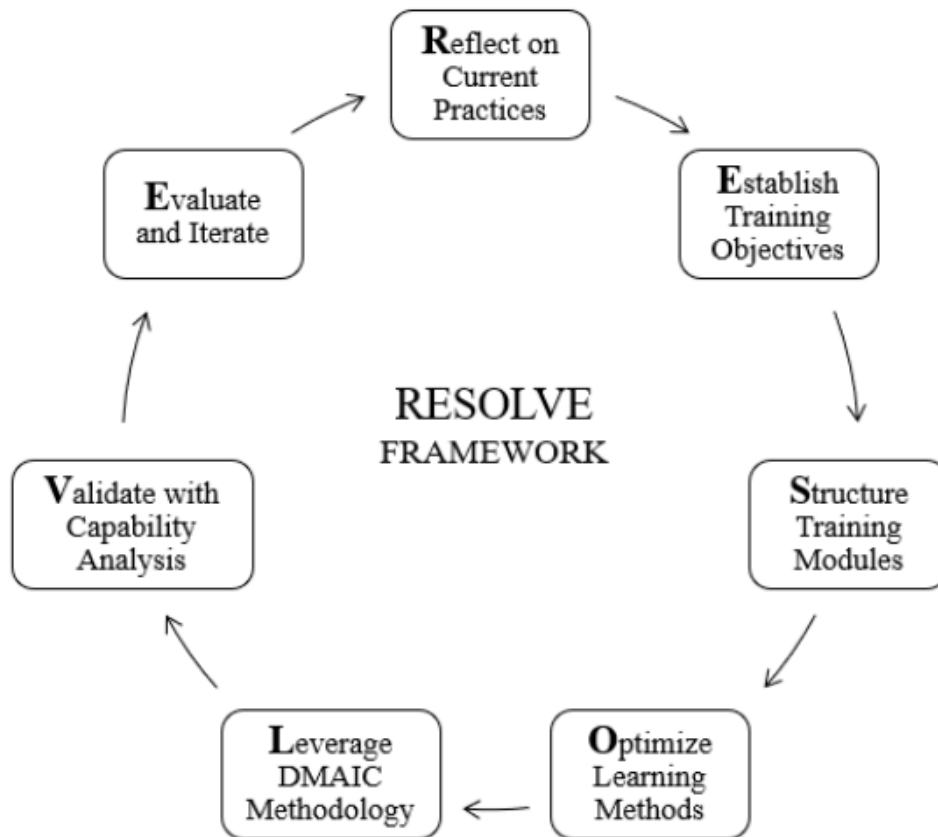


Figure 1. RESOLVE Training Framework

B. Strengthening Supplier Performance through Continuous Improvement Initiatives

A framework was developed to guide the organization in the possibility of applying this initiative towards supplier performance improvement which is shown in figure 2.

The company's suppliers are the primary focus of the organization's continuous improvement initiatives. In order to achieve this, it is imperative to engage suppliers in collaborative improvement initiatives, encourage them to submit proposals for process improvements and innovations, and work together to address common obstacles and opportunities.

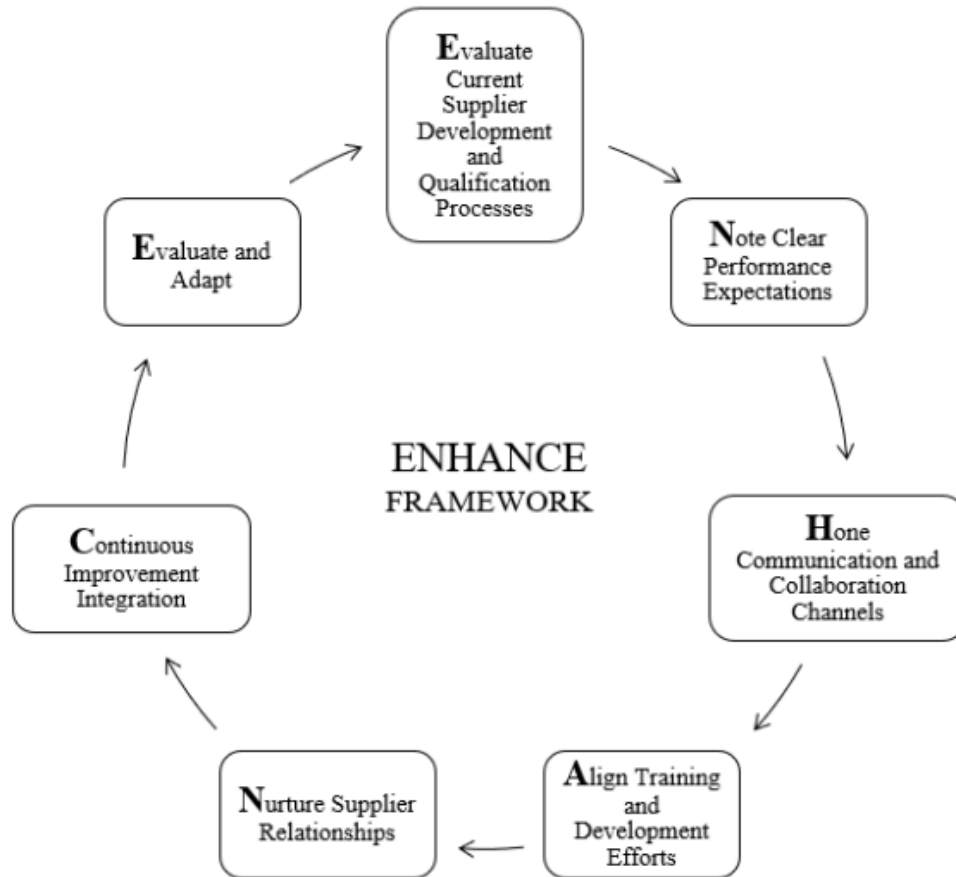


Figure 2. ENHANCE Framework

The organization is able to capitalize on the expertise of its suppliers and achieve significant improvements in both quality and efficiency by incorporating them into its efforts to achieve continuous improvement. The organization can effectively enhance supplier performance and reduce the cost of poor quality by involving these stakeholders in the implementation of the ENHANCE Framework.

Conclusions

After a comprehensive and data-driven study, the researcher had formulated the following conclusions :

1. The analysis revealed that the organization only partially implements Lean process control and Six Sigma to address the internal cost of poor quality, as evidenced by scrap and rework. This underscores the need for focused interventions to boost effectiveness and drive continuous improvement. The areas of focus for improvement include Values Stream Mapping, Kanban Systems for Lean Process Controls in DMAIC, and Capability Analysis for Six Sigma process control tools. Overcoming these

barriers and optimizing tool usage are crucial for achieving the desired outcomes of enhanced process efficiency and quality performance. Targeted interventions are important to enhance tool implementation and effectively address internal issues across the organization.

2. It is evident that the organization demonstrates a commendable level of engagement in certain aspects crucial to Lean Six Sigma implementation, particularly in management support and quality review during product design and development phases. However, the engineers' assessments indicate notable gaps in engagement across various other factors, leading to disengagement. These areas include employee training to improve skills and competencies, supplier development and qualifications, and involvement in the organization's continuous improvement initiatives. To effectively deal with issues related to rework, scrap, and overall quality improvement, it will be necessary to prioritize and increase organizational engagement in these areas. This will lead to long-lasting improvements in operational efficiency and quality performance.
3. The application of the RESOLVE and ENHANCE frameworks serves as a strategic response to the research findings regarding the level of implementation of Lean Six Sigma and the factors affecting it. It focuses on improving skills and knowledge in Lean Six Sigma principles like the Kanban system, value stream mapping, DMAIC methodology, and capability analysis. The RESOLVE framework fixes the problems that have been found with employees' training and knowledge. By systematically addressing these training gaps, organizations can equip their workforce with the necessary knowledge and abilities to effectively implement Lean Six Sigma practices. On the other hand, the ENHANCE framework aims to improve supplier development and qualification processes in order to involve suppliers in continuous improvement activities. By nurturing strong supplier relationships and integrating them into improvement initiatives, organizations can enhance the effectiveness and sustainability of their Lean Six Sigma implementation efforts.

Recommendations

1. The researchers recommended that the company conduct targeted interventions to boost the effectiveness of lean process control and Six Sigma implementation to address internal costs of poor quality, such as scrap and rework. The enhancement of value stream mapping and Kanban systems for lean process controls, as well as the application of DMAIC and capability analysis for Six Sigma process control tools, are among the areas of concentration highlighted. The Quality Assurance Manager, in charge of the Quality Management Department, must launch projects aimed at optimizing the use of these technologies to achieve this. This will include the implementation of specific training programs for employees participating in the improvement process, the provision of resources and support for ongoing skill development, and the establishment of clear performance objectives for tool use. If the organization addresses these impediments and enhances the use of tools, it may be

able to promote continuous improvement, improve process efficiency, and improve overall quality performance across all departments.

2. The findings recommended that the organization prioritize and strengthen its involvement in key areas critical to the adoption of Lean Six Sigma practices. It is important to prioritize the enhancement of engagement in training to improve employees' skills and competencies. Additionally, the Human Resources Department may prioritize the development and qualifications of suppliers, as well as their participation in continuous improvement initiatives. It is essential for the Human Resources Department, under the guidance of the Training and Development Manager, to spearhead the creation and execution of thorough training programs that focus on improving employee skills and competencies in Lean Six Sigma methodologies. The procurement management department, led by the procurement manager, should focus on improving supplier development and qualification processes, as well as promoting collaboration with suppliers in ongoing improvement initiatives. By focusing on engagement in these areas, the organization can effectively tackle issues related to rework, scrap, and overall quality improvement, resulting in long-term improvements in operational efficiency and quality performance.
3. It was recommended that the organization adopt and execute the RESOLVE and ENHANCE frameworks to augment the efficacy of Lean Six Sigma implementation. Under the direction of the Quality Assurance Manager, the Quality Management Department should assume primary responsibility to implement the RESOLVE framework. This entails methodically rectifying inadequacies in employee training and competency levels through the development and implementation of specialized training programs that center on Lean Six Sigma principles, including Capability Analysis, Value Stream Mapping, the Kanban system, and DMAIC methodology. Concurrently, the Procurement Department ought to take the lead in executing the ENHANCE framework, under the direction of the Procurement Manager. To enhance supplier development and qualification procedures, this framework incorporates suppliers into activities geared toward continuous improvement. By fostering robust supplier relationships and actively engaging them in improvement endeavors, the organization can bolster the sustainability and efficacy of its Lean Six Sigma implementation endeavors, and thereby facilitate the ongoing enhancements and attain operational excellence.
4. To enhance the comprehensiveness of the study and address factors not covered, it was recommended to the future researchers to adopt a mixed-method approach. This approach would involve conducting in-depth interviews among respondents to gain deeper insights into their perspectives and experiences related to Lean Six Sigma implementation and its impact on the internal cost of poor quality. Additionally, expanding the research locale to include other electronics industries in Laguna for comparative analysis would provide a broader understanding of the effectiveness of Lean Six Sigma practices across different organizational contexts. Furthermore, extending the study to examine the external cost of poor quality, such as customer returns, warranty claims, and reputation damage, would offer a more holistic view of the implications of quality issues beyond the organization's internal operations. By incorporating these recommendations, the study can provide more comprehensive

insights and recommendations for improving Lean Six Sigma implementation and quality management practices in the electronics industry.

Compliance with Ethical Standards

The authors affirm that this study was conducted in accordance with rigorous ethical standards, guaranteeing that all respondents provided informed consent and were also permitted to disengage from the study at any phase. Respondent anonymity was meticulously preserved to ensure their privacy, and their welfare was prioritized throughout the research process. The study was conducted without any conflict of interest, and all measures were taken to prevent plagiarism. The findings were interpreted with fairness, and the results were exclusively employed for research purposes.

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