Enhancing Engineering Education Through Reflective Practice in a Public University in Nigeria

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Abstract

This work-in-progress paper presents emerging empirical findings of an ongoing comparative research effort that hypothesizes that Reflective Practice (RP) enables engineering educators to better serve students in the Nigerian higher education context. It considers RP as a pedagogical intervention and presents the results of an evaluation of its impact on student learning at a public university in Nigeria. Seventy-six (76) undergraduate engineering students participated in the study. The research questions (RQ) guiding this study were: What is the impact of RP on students' learning experiences (RQ1), and how do these experiences compare with the control courses that did not employ RP (RQ2)? Utilizing Kolb's reflective cycle as the theoretical framework, a causal-longitudinal approach was adopted to design two pre- and post-intervention surveys on Qualtrics, each comprising items that explored student engagement, perceptions of instructional design, and impacts on learning outcomes. The instructors' reflections and pedagogical interventions were tracked using Penzu, an online diary. Preliminary findings, comparing RQ1 and RQ2 with the control and treatment courses, suggest that students had better learning experiences. This study argues that RP enhances educators' teaching styles and positively influences students' learning experiences and the result using the Wilcoxon Signed-Rank Test showed a statistically significant difference in student experience ($p < 0.05$) but no significant difference in student engagement ($p > 0.05$), suggesting that the intervention had a positive impact on student experience but not on engagement.

Keywords: Reflective Practice, Applied Thermodynamics, Students Learning Experiences

1 Introduction

A strong educational foundation in engineering, one that produces superior graduates, directly impacts any nation's economic growth, prosperity, and development (Igbokwe et al., 2019). The achievement of these goals requires a shift towards student-centered learning, where students play a critical role in identifying which teaching and learning methods best suit their context (Wong, 2021). Traditional teacher-centered learning, characterized by passive information delivery, can lead to student disengagement and lower academic performance in STEM fields (Freeman et al., 2010). To foster a deeper understanding and align teaching practices with learning objectives, a strategic approach is needed to facilitate this shift (Weimer, 2013). One such approach is Reflective Practice, a widely recognized tool for professional and educational development that involves critically examining one's thoughts and actions to improve knowledge, skills, and practices (Schön, 2017).

While Reflective Practice is a valuable tool for educators to enhance teaching styles and foster critical thinking, its empirical application in engineering education within the Nigerian context remains underexplored. This gap limits the understanding of how such interventions can be effectively implemented in underrepresented educational settings. This study addresses this gap by adopting Reflective Practice as a pedagogical intervention to enhance engineering education in a public university in Nigeria. Guided by Kolb's reflective cycle (Ivala, 2013; Kolb et al., 2014).

1.2 Research Questions (RQ) and Hypotheses (H_o)

This work-in-progress paper aims to assess the impact of reflective teaching on student learning, with a focus on two key areas. The research questions guiding this study are:

RQ1: What is the impact of Reflective Practice on students' learning experiences?
RQ2: How do students' learning experiences in a course employing Reflective Practice compare with a

control course?
H₀: Our null hypothesis states that Reflective Practice has no significant impact on students' learning experiences, specifically regarding student engagement and overall experience.

1.3 Kolb's reflective cycle as the theoretical framework

Kolb's Reflective Practice has been adopted and discussed in the literature to highlight three distinctive styles of reflection: reflection-in-action, reflection-on-action, and reflection-for-action (Ivala, 2013; Journal, 2018). Reflection-in-action refers to instances where instructors or practitioners reflect on their practices while they are ongoing. Reflection-on-action typically occurs afterward, allowing for a better understanding of what transpired, which practices were effective, which were counterproductive, and which had no impact on the intended goals. Reflection-for-action is a proactive approach that looks forward, anticipating the steps necessary to achieve a desired objective. This study aims to employ Kolb's reflective cycle (Ivala, 2013; Kolb et al., 2014) alongside two of the three distinctive styles of Reflective Practice (as shown in Figure 1) to assess the impact of reflective teaching on student learning at a Nigerian public university, using students enrolled in an applied thermodynamics course as a case study. A description of Kolb's reflective cycle in the context of education follows below.

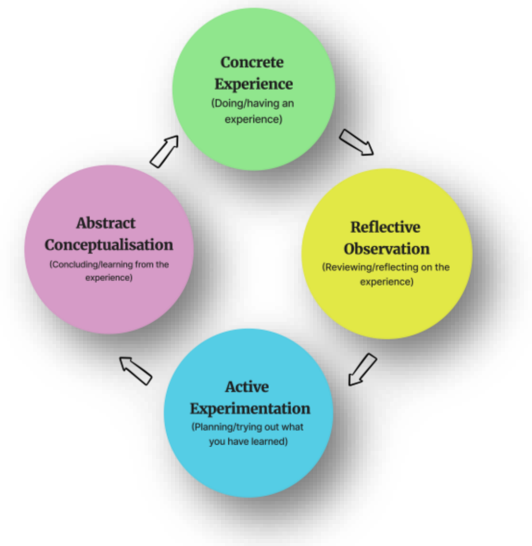


Figure 1:Kolb's Reflective Model

Concrete experience is an area of interaction between educators and students, whether in-person or virtual. At this initial stage, both students and educators share observations, thoughts, and perceptions about their interactions (Loughran, 2002; Osterman, 1990). *Reflective observation* helps educators assess what worked and what did not in their interactions with students and in the students' learning experiences. *Active experimentation* requires educators to apply all reflections and ideas for improvement back into practice by testing new strategies. *Abstract conceptualization* concludes with a follow-up action plan derived from the active experimentation stage. Here, educators reflect on the strategies implemented for improvement and seek input from experts and/or colleagues to build on successful ideas from similar situations.

2 Literature Review

Reflective Practice can serve as a valuable tool in both undergraduate and postgraduate training. However, in Nigeria and throughout Africa, research studies on the application of Reflective Practice within the engineering education ecosystem are limited. For example, Omosule et al. (2021) aimed to evaluate Reflective Practice and its benefits for resident doctors and their professional development. They suggested integrating Reflective Practice into postgraduate training programs. Furthermore, Hyacinth and Mann (2014) examined the use of Reflective Practice among 19 teachers, with each participant documenting their reflections to better understand Reflective Practice.

These examples illustrate the scarcity of studies on the application of Reflective Practice in Nigeria. There is a pressing need for more research on the effective use of Reflective Practice in Nigeria to enhance student-centered learning and improve teaching practices.

2.1 Impact of RP on student learning

Research from South Africa (Von Solms & Nel, 2017), linking RP to project-based learning, and from Vietnam (Hoa & Tuấn, 2020), addressing the theory-practice gap in graduates, show that RP aids students in transferring academic knowledge to workplace problem-solving. The text proposes using student engagement metrics - particularly feedback on course structure and delivery - as key indicators of RP's effectiveness.

The impact of Reflective Practice on student learning can be measured in several ways. One of the most common methods is through student engagement (Davis et al., 2009; Mathew, 2012). In this paper, we define student engagement as the feedback received from students regarding the design and execution of the Thermodynamics course. By examining the students' perceptions of the instructional design, we aim to explore their attitudes toward changes in course structure, attendance, tutorials, and learning outcomes.

3 Methodology

The data for this study is derived from the classroom experiences of a single instructor (Third Author) while teaching two Applied Thermodynamics courses over two semesters at a public university in Nigeria. This section aims to explain the methodology used in the research, starting with the first course, Applied Thermodynamics (I), taught by the instructor to participants in their 300-level second semester. Subsequently, the second Applied Thermodynamics course (II) was delivered by the same instructor to the same group of students in their 400-level first semester. Approval for this study was granted by the institution's administrative board. Also, this section explains the research design, sampling, and data collection process, with a focus on how the theoretical framework guided the study.

3.1 Sampling and Participant Recruitment

Students were recruited for the study using a consent form to eliminate hierarchical bias and ensure voluntary participation (Thorne, 1980). Additionally, they were assured that their grades would not be influenced by their involvement in the study. Participants were selected through purposive sampling, a non-probability technique where researchers intentionally choose participants based on specific characteristics or criteria (Creswell, 2009). For this research, enrollment in Applied Thermodynamics (I) and (II) served as the selection criterion to ensure that the sample was most relevant to the research question. This method was preferred over random selection from a larger population within the department, as it focused on students directly engaged with the subject of study.

3.1.1 Data Collection

Data collection occurred in two phases: Phase 1 spanned from November 2022 to February 2023, with 67 students participating in the Applied Thermodynamics (I) course. The initial survey included ten questions, six of which were analyzed for this paper. Phase 2 ran from May to August 2023, and included 76 students in the Applied Thermodynamics (II) course. At the end of this semester, a second survey with 14 questions was administered, with seven questions selected for analysis in this paper to assess the impact of the new strategies

3.2 Research Design

Using Kolb's reflective cycle as the theoretical framework, a causal longitudinal approach was employed to design two pre- and post-intervention surveys on Qualtrics. A causal longitudinal approach in research refers to a study design used to examine cause-and-effect relationships over an extended period (Biazoli Jr. et al., 2024). This approach combines two elements: causality, which seeks to understand whether one variable influence or causes changes in another, and longitudinal study design, which involves collecting data from the same subjects or groups at multiple time points.

A quasi-experimental design was adopted to evaluate whether changes in students' learning outcomes resulted from the Reflective Practice conducted. This design is a research approach that tests the causal consequences of long-lasting treatments. But unlike "true" experiments where treatment assignment is at random, assignment in quasi-experiments is by self-selection or administrator judgment (Maciejewski, 2020). In this research, students were not randomly assigned to the control and treatment courses; instead, their grouping was naturally determined based on the courses they were studying.

3.2.1 Research Design Limitations

It is important to acknowledge that the control courses (other subjects the students were taking) were not a true control group due to inherent differences in subject matter and instructor. This makes a direct, causal comparison problematic. Our analysis, therefore, focuses on the effects of the intervention over time within the treatment courses, rather than a direct comparison with a true control group. This approach allows us to observe changes in student learning and experience that may be attributed to the RP intervention, while recognizing the limitations of a perfect causal inference.

3.3 Operationalization of Kolb's Reflective Cycle

Kolb's reflective cycle served as the guide for the entire research process, from intervention design to data collection. We operationalized each stage of the cycle to create a continuous loop of teaching, reflection, and refinement, as follows:

- **Concrete Experience:** This stage was operationalized as the zone of interaction between the instructor and students. These interactions took place both physically in-class and virtually via Zoom throughout the course.
- **Reflective Observation:** Following these interactions, a weekly Google feedback form was designed to gather students' feedback. The instructor then used a free online digital diary, Penzu, to document reflections on this feedback. These reflections provided insights into effective teaching practices and identified areas for improvement, such as hard-to-comprehend topics and student requests for learning interventions.
- **Active Experimentation:** To implement this stage, a comprehensive end-of-semester survey was designed using Qualtrics. This survey evaluated the overall impact of the weekly interactions and reflections on students' learning experiences. The results from this survey guided the refinement of teaching strategies for the next course.
- **Abstract Conceptualization:** This final stage involved using the follow-up action plan from the first phase of the research to refine strategies and enhance student learning experiences in the next

semester’s Applied Thermodynamics course (Thermo II). The instructor used the data from the initial survey to build on successful ideas and develop new strategies for the new course.

Figure 2: Application of Kolb’s Reflective Model in Data Collection

Figure 3: Snapshot of a journal entry on Penzu

The second research process was also based on Kolb's reflective model. The abstract conceptualizations documented for a follow-up plan from the active experimentation stage of the first phase of the research, aided by the comprehensive data obtained from using Qualtrics, were utilized by the educator in the following semester’s applied thermodynamics course to refine strategies and enhance student learning experiences in this new course.

Finally, member checking involved weekly mentorship meetings held throughout the research study. During these meetings, the primary instructor answered clarifying questions to ensure the research's accuracy.

3.4 Data cleaning

A proper data cleaning process was carried out by anonymizing the participants and by deleting missing data (see Table 5 in Appendix).

3.5 Analysis of Qualitative Data

The weekly Penzu journal entries and Google feedback forms served as a continuous source of qualitative data. The instructor analyzed this data to identify recurring themes related to student comprehension, engagement, and suggested improvements. This analysis directly informed the "active experimentation" stage of the study, guiding the adjustments to teaching methods and curriculum for the following course. The open-ended comments from students provided rich insights that supplemented the quantitative survey data, helping to diagnose learning challenges and track the evolution of student perspectives over the two semesters. The instructor's journal entries also showed a clear shift in pedagogical approach, moving from a focus on content delivery to a more responsive, student-centered style. This is evidenced by entries that detail changes made in real-time, such as creating a more collaborative problem-solving session in response to student feedback. These themes from the qualitative data provide a deeper, more nuanced understanding of how the Reflective Practice intervention led to a statistically significant improvement in the student experience

4 Statistical Analysis

Before selecting a statistical test, we first examined the structure of our dataset. The data consisted of two sets of engagement scores: one collected before the intervention and one after. Since each student had a corresponding score in both conditions, this confirmed that we were working with paired data, where each observation in the "pre-intervention" group has a directly related counterpart in the "post-intervention" group. A paired t-test is typically used to compare two related datasets and determine whether their means significantly differ (Gravetter & Wallnau, 2017). This test assumes that: a) the differences between paired observations follow a normal distribution; b) the data is continuous and measured on an interval scale.

Given that our study measured engagement scores on a numerical scale, the paired t-test initially seemed appropriate. To validate the use of a paired t-test, we conducted a normality test using the Shapiro-Wilk test, the Anderson-Darling test, and the Kolmogorov-Smirnov (KS) tests on the differences between the pre- and post-intervention scores. From the results of the Python code (see Appendix A), we observed that the Shapiro-Wilk and Anderson-Darling tests suggested normality, indicating that our data did not significantly deviate from a normal distribution. However, our data failed the Kolmogorov-Smirnov normality test. Since two out of three tests confirmed normality, we performed a final check using a Q-Q (Quantile-Quantile) plot to visually assess whether the data follows a normal distribution (see Appendix B).

In conclusion, our dataset meets the normal assumption of the difference between the "pre-" and "post-intervention" scores, allowing us to proceed with the paired t-test as the suitable statistical test.

A paired t-test was conducted to compare the two conditions under study. To ensure accuracy, we utilized both Microsoft Excel and Python (SciPy) for statistical analysis. The purpose of this test was to determine whether there was a significant difference between the two paired datasets. The paired t-test was applied under the assumption of normality, which was verified through a Q-Q plot analysis. The test was executed using both Excel and Python (SciPy) codes. The results from the two tools were cross-validated to ensure consistency and accuracy.

5 Results & Discussions

The results obtained from both methods are summarized in Table 1. The p-values from both Excel and Python confirm a statistically significant difference ($p < 0.05$) between the two groups. This leads to the rejection of the null hypothesis (H_0), supporting the assertion that the observed differences are unlikely to be due to randomness, which suggests that Reflective Practice played a role in the students' learning experiences.

Table 1: Paired T-test Results (Excel vs Python)

Method	t-Statistic	p-Value	Decision ($\alpha = 0.05$)
Excel	-12.7512	4.48×10^{-19}	Reject H_0 ✅
Python (SciPy)	-12.6527	< 0.0001	Reject H_0 ✅

5.1 Analyzing Student Experience & Engagement Differences

We decided to investigate further the effect of Reflective Practice on students in two areas: their experiences and the engagement/activities carried out to ensure understanding of the course. This additional assessment would determine whether the students have experienced an increase in their interactions with the educator and in their engagement with activities. We grouped specific items on the survey into two categories: student experience and student engagement. The students' mean scores on each of these variables is presented in Tables 2a and b.

Table 2a and 2b: Simple Descriptive Statistics of Before and After Data

Q	Thermo 1 "Before"	Mean(μ1)
1	Opinion_expressed	4.190
2	learning_materials_organized	3.825
3	IU_GroupAssessment	4.270
4	IU_Tutorials	4.603
5	IU_ClassActivities	4.492
6	Feedback_clarity	4.762

n =65

Q	Thermo 2 "After"	Mean(μ2)
1	Opinion_expressed	4.406
2	learning_materials_organized	4.344
3	IU_Lectures	4.469
4	IU_Tutorials	4.578
5	IU_ClassActivities	4.328
6	IU_Assessments	4.500
7	Feedback Clarity	4.797

n = 76

Before conducting a t-test on the student experience and engagement categories, we needed to check for normality in each subgroup. This check was essential to determine if both subgroups adhered to a normal distribution. The normality tests for student experience and engagement yielded p-values below 0.05 after performing the Shapiro-Wilk and Kolmogorov-Smirnov Tests. These results demonstrated that the data did not conform to a normal distribution.

Table 3: Normal Distribution tests result on the subcategories

Test	Experience (p-value)	Engagement (p-value)	Interpretation
Shapiro-Wilk Test	0.0419	0.0304	❌ Not normal
Kolmogorov-Smirnov Test	0.0000	0.0121	❌ Not normal

Since the Shapiro-Wilk and Kolmogorov Smirnov tests rejected normality ($p < 0.05$), we selected a nonparametric test that does not assume normality to ensure accurate analysis.

5.2 Wilcoxon Signed-Rank Test on Subcategories

Based on the Wilcoxon Signed-Rank Test, the two subgroups—Student Experience and Student Engagement were analyzed to determine if a significant difference existed between their "Before" and "After" scores. The results are summarized in Table 4.

Table 4. Results of the Wilcoxon signed-rank test

Metric	Wilcoxon Statistic (W)	p-value	Statistical Significance	Mean Difference ($\|\mu1 - \mu2\|$)	Conclusion
Student Experience	0.0	4.2924e-12	Significant ($p < 0.05$)	5.246	Significant difference
Student Engagement	481.0	0.6741	Significant ($p > 0.05$)	0.092	No significant difference

The Wilcoxon statistic for student experience was 0.0, while for student engagement, it was 481.0 with an extremely small p-value (≈ 4.29e-12), indicating that the "After" responses are significantly higher from the "Before" responses. This shows the educator reflective practice had a significant impact on student experience but not on student engagement. Since the Wilcoxon test assesses whether the median differences are significantly different from zero, these results confirm that the changes in student responses were not due to random chance (see figure 6 in Appendix).

Based on the results of the statistical test, we can infer the following about student experience:
a) the extremely small p-value (4.29e-12) indicates a highly significant difference between the "Before" and "After" scores; b) the mean difference of 5.246 suggests a substantial improvement in student experience following the intervention; and c) this result confirms that the intervention had a **positive impact** on student experience.
Similarly, based on the results of the statistical test, we can infer the following regarding student engagement: a) the p-value (0.6741) is greater than 0.05, meaning the difference is not statistically significant; b) the mean difference of 0.092 is very small, suggesting little to no change in student engagement/activities after the intervention; and c) this implies that the intervention did **not** have a statistically significant effect on engagement levels.

5.3 Impact on Student Experience and Engagement

Our statistical analysis, using the Wilcoxon Signed-Rank Test, revealed a significant positive impact on student experience ($p < 0.05$), with a Wilcoxon Statistic of 0.0. This suggests a substantial improvement in how students perceived the course, from the organization of learning materials to the clarity of feedback. This improvement can be directly linked to the instructor's process of reflection-on-action. Each week, the instructor reflected on the feedback from students and the Penzu journal entries to identify which teaching practices were most effective and where improvements were needed. This process of reviewing past interactions and data helped to diagnose challenges and refine instructional strategies.

However, the same test showed no statistically significant difference in student engagement ($p > 0.05$), with a Wilcoxon Statistic of 481.0. This is an important finding, as it suggests that while the reflective intervention enhanced the overall student experience, it did not have a measurable impact on the level of student engagement and participation

5.4 Analysis of Open-ended Questions and their Connection to Kolb's Cycle

The analysis of open-ended questions provides a deeper understanding of these results, particularly in relation to the "active experimentation" and "abstract conceptualization" stages of Kolb's cycle. After the first phase, the instructor performed reflection-on-action by analyzing student feedback from the weekly Google forms and Penzu journal entries. This led to the identification of five key areas for improvement, including the need for more breaks, balanced study groups, and active learning activities.

These findings were then used in the next semester's course as a basis for active experimentation and abstract conceptualization. The instructor used the data from the first semester to develop a follow-up action plan and implement refined strategies in the second semester, effectively closing the reflective cycle. The results from the second survey, which showed a significant improvement in student experience, indicate that these data-driven, reflective adjustments were successful in positively impacting the student experience

6. Limitations, and Implications

Several limitations affected our study, with the primary one being the *inability to track individual survey responses without identifying participants.* One of the key challenges was the inability to track individual participants across both surveys while maintaining their anonymity. This limitation became evident during data cleaning, as we discovered that some participants had completed the second survey without having participated in the first. Specifically, 11 additional responses were recorded in the second survey, but we lacked any means of determining whether these responses came from new participants or from those who had previously completed the first survey. This discrepancy complicated the decision of whether to retain or exclude these overlapping responses, as we could not verify if they were exclusively from carryover students. To address this issue, we decided to analyze the average responses per question instead of the total number of responses. By concentrating on the average, we ensured that the extra 11 responses did not unduly impact our statistical analysis.

The second limitation of this study was the *unequal number of questions in the first and second surveys.* Another limitation arose from the inconsistency in the number of questions across both surveys. The first survey contained six questions (Q1 - Q6), while the second survey included a seventh question (Q1 - Q7). This discrepancy affected our ability to perform the Wilcoxon Signed-Rank Test, as it introduced an imbalance in the two main analytical categories: Student Experience and Student Engagement. The additional question in the Student Experience category may have significantly influenced the results, potentially skewing the comparative analysis. Upon reviewing the survey questions, we observed that two questions addressed similar aspects of the student experience. To ensure analytical consistency and maintain data integrity, we removed one of the redundant questions. This adjustment facilitated a more balanced comparison between the two surveys, ensuring that the statistical analysis remained valid and meaningful. By systematically addressing these limitations, we improved the reliability of our findings and ensured that our conclusions were grounded in a rigorous and well-structured analytical approach. To address the issue of tracking individual responses in a survey, Qualtrics can assign an identifier to each respondent by providing a unique link that can be reused by the respondent.

7 Conclusion

This study, a work-in-progress, presents preliminary findings on the use of Reflective Practice as a pedagogical tool in a Nigerian public university. The results suggest that the intervention had a statistically significant positive impact on students' learning experiences, although it did not show a similar significant effect on student engagement. These findings indicate that Reflective Practice, particularly when integrated using Kolb's cycle, can serve as a valuable tool for instructors to enhance student experience in engineering courses.

The insights gained from this study contribute to the limited body of knowledge on Reflective Practice in African engineering contexts. This work highlights the potential for reflective teaching to improve student-centered learning in underrepresented educational settings.

Future work will involve a more controlled experimental design to validate these findings and further investigate the nuanced relationship between Reflective Practice, student experience, and engagement. Our hope is that this study serves as a foundation for subsequent research on adapting and implementing effective pedagogical strategies that enhance engineering education in Africa and beyond.

References

Biazoli Jr., C. E., Sato, J. R., & Pluess, M. (2024). Causal relationships in longitudinal observational data: An integrative modeling approach. *Psychological Methods*, *29*(6), 1132–1147. https://doi.org/10.1037/met0000648

Boud, D., Keogh, R., & Walker, D. (Eds.). (2015). *Reflection: Turning experience into learning* (First issued in paperback). Routledge.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed). Sage Publications.

Davis, D., Beyerlein, S., Thompson, P., McCormack, J., Harrison, O., Trevisan, M., Gerlick, R., & Howe, S. (2009). *Assessing Design And Reflective Practice In Capstone Engineering Design Courses*. 14.237.1-14.237.21. https://peer.asee.org/assessing-design-and-reflective-practice-in-capstone-engineering-design-courses

Freeman, C., O'Malley, K., & Eveleigh, F. (2010). *Australian teachers and the learning environment: An analysis of teacher response to TALIS 2008: Final report* (p. 120). Australian Council for Educational Research. http://research.acer.edu.au/talis/1

Gravetter, F. J., & Wallnau, L. B. (2017). *Statistics for the behavioral sciences* (10th edition). Cengage Learning.

Hoa, N. H., & Tuấn, N. A. (2020). (PDF) Learning Strategies for Improving Reflection in Engineering Education in Vietnam. *ResearchGate*, *10*(1). https://doi.org/10.9790/7388-1001030609

Huba, M. E., & Freed, J. E. (2000). *Learner-Centered Assessment on College Campuses: Shifting the Focus from Teaching to Learning*. Allyn & Bacon, 160 Gould St.

Hussin, H., Ramachandran, S. D., & Bakri, N. (2009). Reflective Practice and Professional Development in Engineering Education. *International Journal of Learning*, *16*(3), 465–475.

Hyacinth, T., & Mann, S. J. (2014). Reflective Practice in Nigeria: Teachers' voices and experiences. *TESOL E-Journal*, *18*(3), Article 3. http://www.tesl-ej.org/wordpress/issues/volume18/ej71/ej71a4/

Igbokwe, N. C., Godwin, H. C., & U-Dominic, C. M. (2019). Engineering Education in Nigeria for Engineering Graduates: Issues and Strategies. *Journal of Scientific Research and Reports*, *22*(2), 1–10. https://doi.org/10.9734/JSRR/2019/29895

Ivala, E. (2013). *Online-offline system of evaluating teaching and courses for professional development.*

Journal, M. (2018, September 19). *Reflective Teaching as a Form of Professional Development*. https://mextesol.net/journal/index.php?page=journal&id_article=4433

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2014). Experiential Learning Theory: Previous Research and New Directions. In R. J. Sternberg & L. Zhang (Eds.), *Perspectives on Thinking, Learning, and Cognitive Styles* (0 ed., pp. 227–248). Routledge. https://doi.org/10.4324/9781410605986-9

Larrivee, B. (2000). Transforming Teaching Practice: Becoming the critically reflective teacher. *Reflective Practice*, *1*(3), 293–307. https://doi.org/10.1080/713693162

Loughran, J. J. (2002). Effective Reflective Practice: In Search of Meaning in Learning about Teaching. *Journal of Teacher Education*, *53*(1), 33–43. https://doi.org/10.1177/0022487102053001004

Maciejewski, M. L. (2020). Quasi-experimental design. *Biostatistics & Epidemiology*, *4*(1), 38–47. https://doi.org/10.1080/24709360.2018.1477468

Mathew, N. G. (2012). Reflective Classroom Practice for Effective Classroom Instruction. *International Education Studies*, *5*(3), p205. https://doi.org/10.5539/ies.v5n3p205

Moon, J. A. (2006). *Learning Journals: A handbook for Reflective Practice and professional development* (0 ed.). Routledge. https://doi.org/10.4324/9780203969212

Omosule, B., Muhammed, A.-A., Somiari, A., Agiri Jr., U., Worgu, G., Ezeme, C., Obazenu, L., Uyilawa, O., Adebayo, O., Williams, A., & Ishaya, D. (2021). Reflective Practice and resident doctors. *Nigerian Journal of Medicine*, *30*(5), 625. https://doi.org/10.4103/NJM.NJM_124_21

Osterman, K. F. (1990). Reflective Practice: A New Agenda for Education. *Education and Urban Society*, *22*(2), 133–152. https://doi.org/10.1177/0013124590022002002

Prudhomme, G. (2003). *Toward Reflective Practice in Engineering Design Education*.

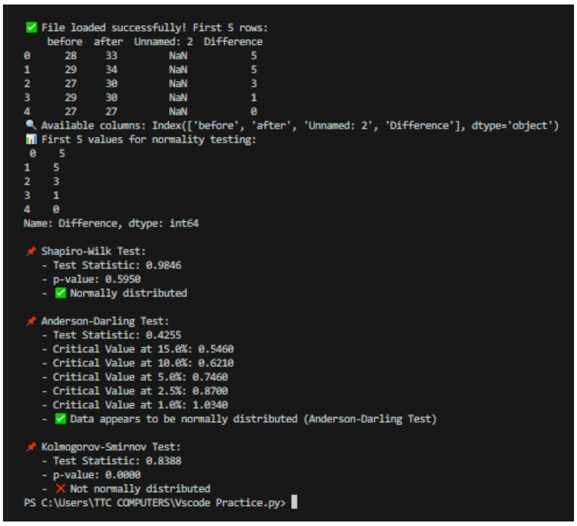
Schön, D. A. (2017). *The Reflective Practitioner: How Professionals Think in Action*. Routledge. https://doi.org/10.4324/9781315237473

Thorne, B. (1980). “You Still Takin’ Notes?” Fieldwork and Problems of Informed Consent. *Social Problems*, *27*(3), 284–297. https://doi.org/10.2307/800247

Von Solms, S., & Nel, H. (2017). Reflective learning in engineering education: A case study of shell ECO-marathon. *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 274–278. https://doi.org/10.1109/IEEM.2017.8289895

Weimer, M. (2013). *Learner-centered teaching: Five key changes to practice* (Second edition). Jossey-Bass, A Wiley Imprint.

Appendix A: Summary of Normality Test Results



```
✅ File loaded successfully! First 5 rows:
   before  after  Unnamed: 2  Difference
0      28     33         NaN           5
1      29     34         NaN           5
2      27     30         NaN           3
3      29     30         NaN           1
4      27     27         NaN           0
🔍 Available columns: Index(['before', 'after', 'Unnamed: 2', 'Difference'], dtype='object')
📊 First 5 values for normality testing:
 0    5
1    5
2    3
3    1
4    0
Name: Difference, dtype: int64

📌 Shapiro-Wilk Test:
   - Test Statistic: 0.9846
   - p-value: 0.5950
   - ✅ Normally distributed

📌 Anderson-Darling Test:
   - Test Statistic: 0.4255
   - Critical Value at 15.0%: 0.5460
   - Critical Value at 10.0%: 0.6210
   - Critical Value at 5.0%: 0.7460
   - Critical Value at 2.5%: 0.8700
   - Critical Value at 1.0%: 1.0340
   - ✅ Data appears to be normally distributed (Anderson-Darling Test)

📌 Kolmogorov-Smirnov Test:
   - Test Statistic: 0.8388
   - p-value: 0.0000
   - ❌ Not normally distributed
PS C:\Users\TTC COMPUTERS\Vscode Practice.py>
```

Figure 4: Normal Distribution Tests Result on Python

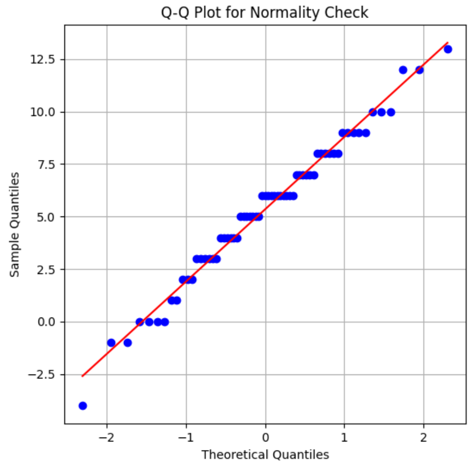


Figure 5: Q-Q Plot for Normality Check from Python

1. Shapiro-Wilk Test
   a. p-value = 0.5950 (> 0.05) → Fails to reject normality
   b. Indicates the data is normally distributed.
2. Anderson-Darling Test
   a. Test statistics are lower than all critical values at conventional significance levels.
   b. This suggests that the data does not significantly deviate from normality.
3. Kolmogorov-Smirnov Test
   a. p-value = 0.0000 (< 0.05) → Rejects normality
   b. However, this test is highly sensitive to sample size, and given that the other two tests confirm normality, this result may not be as reliable.
4. Q-Q Plot Analysis
   a. The data points mostly align with the diagonal line, indicating normality.
   b. Minor deviations at the tails suggest some potential outliers, but these do not significantly affect the overall normality.

Appendix B: T-Test Results

Python Code

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from scipy.stats import ttest_rel

# Load dataset (use pd.read_csv for CSV files)
file_path = "C:/Users/TTC COMPUTERS/Documents/RESEARCH WITH DR MO AND DR OO/IRSPBL 2025/RPresult.csv"
df = pd.read_csv(file_path)  # Corrected: Use read_csv instead of read_excel

# Extract the paired samples
before = df['before']
after = df['after']

# Calculate the paired t-test
t_stat, p_value = ttest_rel(before, after)

# Print results
print(f"  Paired t-Test Results")
print(f"   - t-statistic: {t_stat:.4f}")
print(f"   - p-value: {p_value:.4f}")

# Interpretation
alpha = 0.05  # Significance level
if p_value < alpha:
   print("Reject the null hypothesis: There is a significant difference.")
else:
   print("Fail to reject the null hypothesis: No significant difference.")

#  ◇  Visualization 1: Before vs After Scatter Plot with Lines
plt.figure(figsize=(8, 5))
plt.plot(before, after, 'o', color='blue', alpha=0.6, label="Before vs. After")
plt.plot([min(before), max(before)], [min(before), max(before)], 'r--', label="No Change Line")
plt.xlabel("Before Scores")
plt.ylabel("After Scores")
plt.title("Before vs. After Paired t-Test Visualization")
plt.legend()
```

```
plt.grid(True)
plt.show()
```

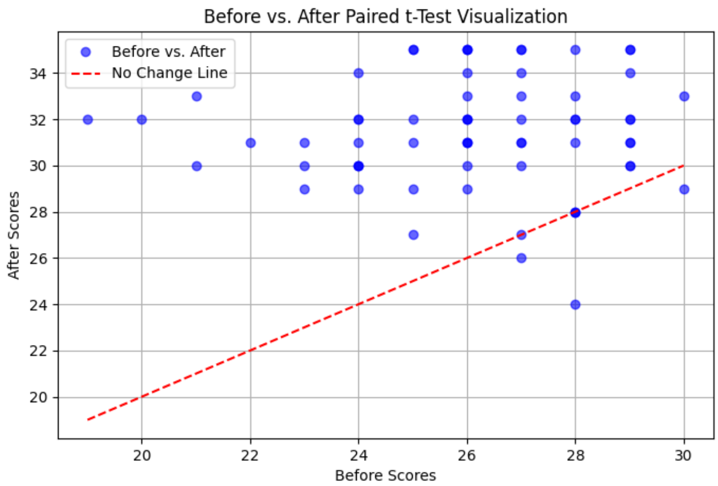


Figure 6: Visualization of the paired t-test result from Python

Before vs After Scatter Plot (with Line of No Change)

- Each **dot** represents a participant's **before and after score**.
- The **red dashed line** shows where scores would be **if there were no change**.

First Principle (Microsoft Excel)

Microsoft Excel does not directly return the t-statistic value in the T.TEST function. It was computed manually using the formula: =AVERAGE (A2:A66) / (STDEV.P(B2:B66) / SQRT (COUNT (B2:B66))) Where A2:A66 and B2:B66 represent the paired sample columns.

Data Cleaning

Table 5: Treatment and Control Courses

Year	Course	Categorization	Description
2022	Applied Thermo I	Treatment	Taught by Author 3 Reflection-in-action implemented
2023	Applied Thermo II	Treatment	Taught by Author 3 Reflection-in-action, reflection-on-action, reflection-for-action implemented
	Mechanical Engineering II Machine Design II Heat and Mass Transfer Advanced Mechanics of Materials Engineering Materials Selection & Economics Technology Policy and Development Laboratory Practical Numerical Methods Technical Communication Economics for Engineers	Control	Taught by peer instructors, RP not implemented

Table 6: Survey Items

Item	**Item Description**	**New Variable Name**	**Code**
Common to Surveys I and II			
Comfort expressing opinions	How comfortable did you feel expressing your opinions or asking questions in this course?	Opinion_Expressed	1 = “Not at all” 2 = “Slightly” 3 = “Moderately” 4 = “Very” 5 = “Extremely”
Organization of learning materials	How organized were the learning materials?	Learning_Materials_ Organized	
Improving understanding (IU)			
…Tutorials	…tutorials in improving…. course material?	IU_Tutorials	1 = “Not applicable” 2 = “No impact whatsoever” 3 = “Useful” 4 = “Extremely useful”
…Class Activities	…class activities in improving …course material?	IU_ClassActivites	
Feedback Clarity	How well did this instructor provide clear, constructive feedback?	FeedbackClarity	1 = “Not applicable” 2 = “Not well” 3 = “Slightly well”

			4 = “Extremely well”
Ranking of pedagogical activities	Rank these teaching practices in order of how useful they were to your learning experience (Rearrange starting from the most useful to the least useful) …Lectures, Tutorials, Class Activities		
Improvements	What are some teaching practices that this instructor could improve on?		
	What are some teaching practices that this instructor should retain?		
Unique to Survey I			
Group assignments	How useful were the …group assignments in improving your understanding of the course material?	IU_GA	
Unique to Survey II			
Lectures	How useful were the lectures in improving your understanding of the course materials?	IU_L	1 = “Not applicable” 2 = “No impact whatsoever” 3 = “Useful” 4 = “Extremely useful”
Online Assessments	How useful were the online tests in assessing your understanding of the course materials?		1 = “Not applicable” 2 = “No impact whatsoever” 3 = “Useful” 4 = “Extremely useful”
Best Course Learning Experience	This semester, in which course did you have your best learning experience?		
	Please provide two or three reasons why you chose this course as the one in which you had the best learning experience this semester.		
	Did this instructor teach you *Applied Thermodynamics* last semester?		
	Based on the feedback you gave last semester; how would you rate the teaching practice this semester?		1 = “Better” 2 = “No impact whatsoever” 3 = “Worse”

Notes:

Table 7a and 7b. Parent Categories for Student Learning Experience

	Variable name	Parent category
Survey 1	1. Opinion Expressed (Q1) 2. Leaning Materials Organized (Q2) 3. Feedback Clarity (Q6)	Student Experience
	1. IU_GroupAssessment (Q3) 2. IU_Tutorials (Q4) 3. IU_ClassActivities (Q5)	Student Engagement

	Variable name	Parent category
Survey 2	1. Opinion Expressed (Q1) 2. Leaning Materials Organized (Q2) 3. Feedback Clarity (Q6)	Student Experience
	1. Lectures Improve Understanding **2.** IU_Lectures **3.** IU_Tutorials **4.** IU_ClassActivities	Student Engagement

Density Plot

A visual representation of the density distribution plot of the pre-intervention (Before) vs post-intervention (After) Data is presented in Figure 7.

Figure 7: Visualization of Density Distribution Plot of Pre-intervention (Before) vs Post-intervention (After) Data

The density distribution plot illustrates the spread of the "before" and "after" scores, helping us to observe any overlap or shift in scores following the intervention. Next, we present a box plot of the students' pre- and post-intervention scores (figure 5), which displays the mean scores for both pre- and post-intervention and includes error bars to represent the standard deviation from the mean.

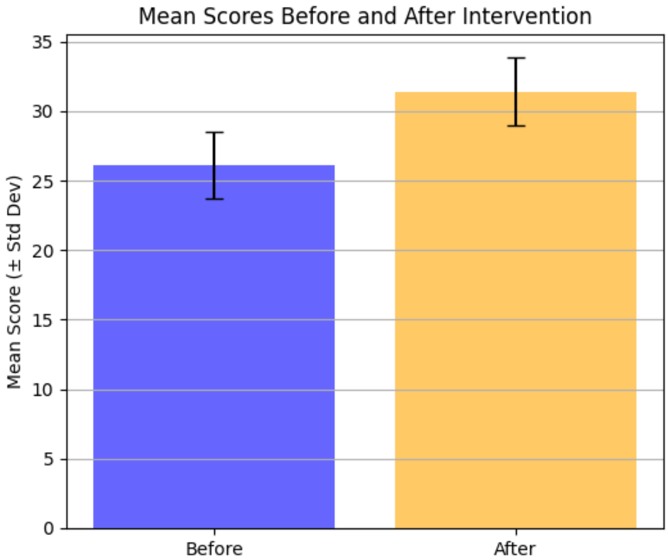


Figure 8: Box plot of Mean Scores Before and After Intervention

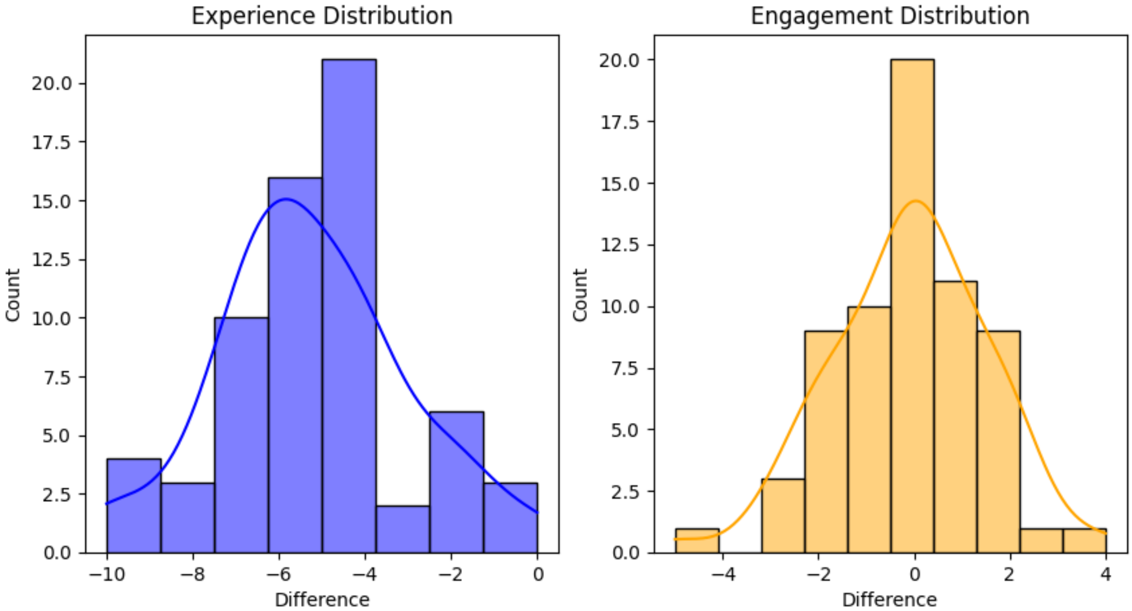


Figure 9: Normality Checks for the student engagement and student Experience groups.

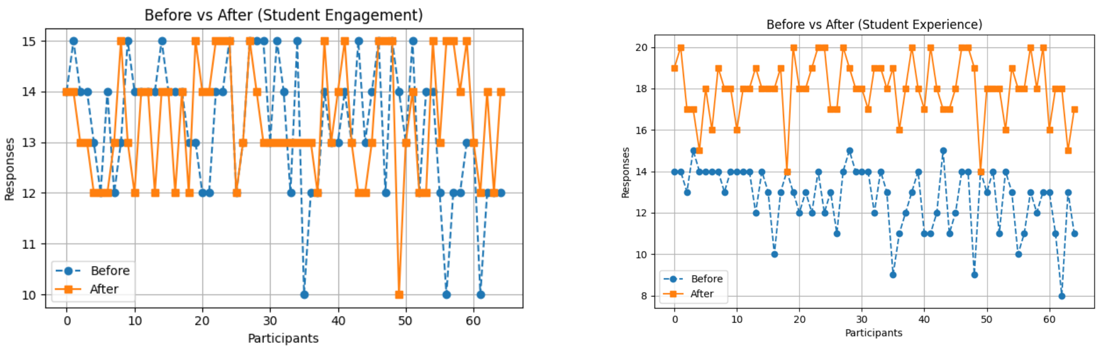


Figure 10: The Visualization of the Wilcoxon signed ranked test on the Student Experience and Engagement