CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study demonstrates that the integration of the STEM learning model with the Engineering Design Process (EDP) plays a significant role in fostering students' active participation in wind turbine projects. This approach not only enhances students' project completion skills but also supports the growth of renewable energy awareness and critical thinking abilities, although the direct relationship between project outcomes and these two aspects remains statistically insignificant.

The application of the STEM model integrated with the Engineering Design Process (EDP) proved effective in significantly increasing students' awareness of renewable energy. The Wilcoxon Signed Ranks Test showed highly significant improvements in the experimental group ($p = .000$) compared to the control group ($p = .021$), while the Mann–Whitney U test revealed no significant pre-test differences ($p = .805$) but a significant post-test difference ($p = .015$) favoring the experimental group. N-Gain analysis also confirmed a significant difference ($p = .008$) with a small effect size ($r = .125$). The largest improvements were in Awareness & Knowledge, Environmental Impact, and Attitudes & Opinions indicators, each with p-value = .000. Although Policy & Investment ($p = .456$) and Education & Social Responsibility ($p = .002$) did not show significant post-test differences ($p = .622$; $p = .367$), both still achieved positive gains ($r = .193$ and $r = .127$), indicating the model's potential to enhance all awareness indicators with further refinement.

The STEM-EDP model was also highly effective in improving students' critical thinking skills. The Paired Sample t-test showed very significant gains in both the experimental group ($p = .000$) and the control group ($p = .000$). However, the Independent Sample t-test revealed no significant difference in pre-test scores (p = .721) but a very significant difference in post-test scores (p = .000) favoring the experimental group. N-Gain analysis confirmed this with a large effect size (p = .000; η^2 = .412). At the indicator level, the highest gains in the experimental class occurred in Inferring/making and evaluating statements, Providing further explanation/identifying assumptions, and Developing basic skills/observing indicators. Post-test results showed highly significant differences (p = .000) in Strategies and tactics/determine the actions, Developing basic skills/observing, Inferring/making and evaluating the statements, confirming the model's strong impact on enhancing observation, strategic thinking, and evaluative reasoning skills.

In terms of project performance, students in the experimental group outperformed those in the control group, as evidenced by significantly higher performance scores. This improvement was largely supported by key EDP stages such as identifying the need or problem, researching the need or problem, drawing/sketching possible ideas/solutions for the problem, selecting the best possible solutions, constructing a prototype, testing the prototype, redesigning, and communicating the solution, all of which showed significant correlations with performance outcomes. Additionally, no significant correlations were found between project performance and either renewable energy awareness or critical thinking skills, indicating that high performance in completing projects does not automatically reflect gains in these areas.

These findings highlight that integrating the STEM model with the Engineering Design Process has proven to be an effective way to improve students' awareness of renewable energy, critical thinking skills, and project performance in wind turbine projects. Significant progress was seen in key indicators of awareness and critical thinking, supported by strong project outcomes driven by important EDP stages. Although the correlation between student performance and the other two variables was not statistically significant, the findings show the model's potential to develop both cognitive and practical skills. Future applications should focus on enhancing reflection, time management, and value-based learning to ensure performance gains are matched with deeper understanding and lasting awareness.

5.2 Recommendation

Based on the findings, it is recommended to combine the EDP stages with STEM phases, such as problem identification, research, ideation, selecting the best solution, prototype construction, testing, redesigning, and communication, to enhance the impact of EDP. During the redesign stage, it is recommended to make improvements directly to the prototype because this can produce concrete solutions and real improvements rather than just an evaluation that only identifies problems without providing solutions. It is also recommended to develop a practical STEM-EDP guide with clear steps and assessment rubrics for broader application.