Bioinspired Design Instruction Methods: A Quality Improvement Study

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Abstract

This quality improvement study investigates how functional decomposition instruction influences the quality, quantity, variety, and novelty of bioinspired engineering design solutions among undergraduate students. The study aims to validate the effectiveness of functional decomposition for enhancing engineering education. This study is inspired by the belief that bioinspired design principles can make a system more resilient and innovative when used in conjunction with functional decomposition. Despite the widespread application of bioinspired design, the advantages of specifically using functional decomposition have not fully been explored. By conducting a controlled experiment with undergraduate participants from the College of Engineering at Embry-Riddle Aeronautical University, this study compares the outcomes of students trained exclusively in bioinspired design against those who received additional instruction in functional decomposition. Both groups were presented with the same engineering design challenge to assess the impact of functional decomposition on the innovativeness and quality of their solutions. Results showed a significant increase in solution quantity for students receiving functional decomposition instruction but no significant differences in quality, variety, or novelty. This suggests functional decomposition may enhance productivity but not necessarily the innovativeness of bioinspired design solutions, highlighting the need for further research and refined instructional methods in engineering education.

Research Question

How does functional decomposition instruction impact the quality, quantity, variety, and novelty of bioinspired engineering design solutions among undergraduate engineering students, and what does this imply for the future of engineering education and the integration of bioinspired design principles?

Purpose

- To assess how functional decomposition instruction affects the outcomes of bioinspired engineering design projects among undergraduates, focusing on solution quality, quantity, variety, and novelty.
- To explore the integration of bioinspired design with functional decomposition, aiming to enhance system resilience, innovation, and the effectiveness of engineering education.
- To fill the research gap on the specific benefits of functional decomposition in bioinspired design through a controlled experiment, guiding future instructional methods in engineering education.

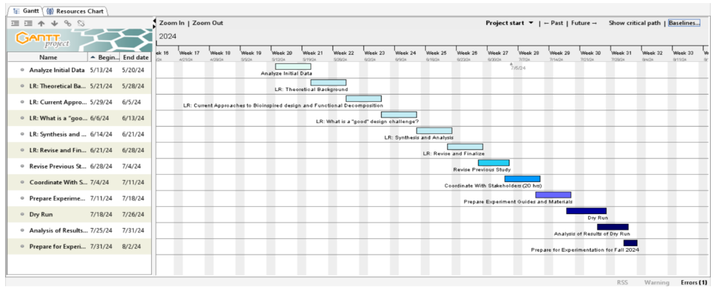

Figure 1: Current Progress Timeline

Hypothesis

Instruction in functional decomposition, when integrated with bioinspired design principles, will significantly improve the quality, quantity, variety, and novelty of engineering design solutions produced by undergraduate students.

Biologically Inspired Design-for-Resilience Lab

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Design Challenge Example

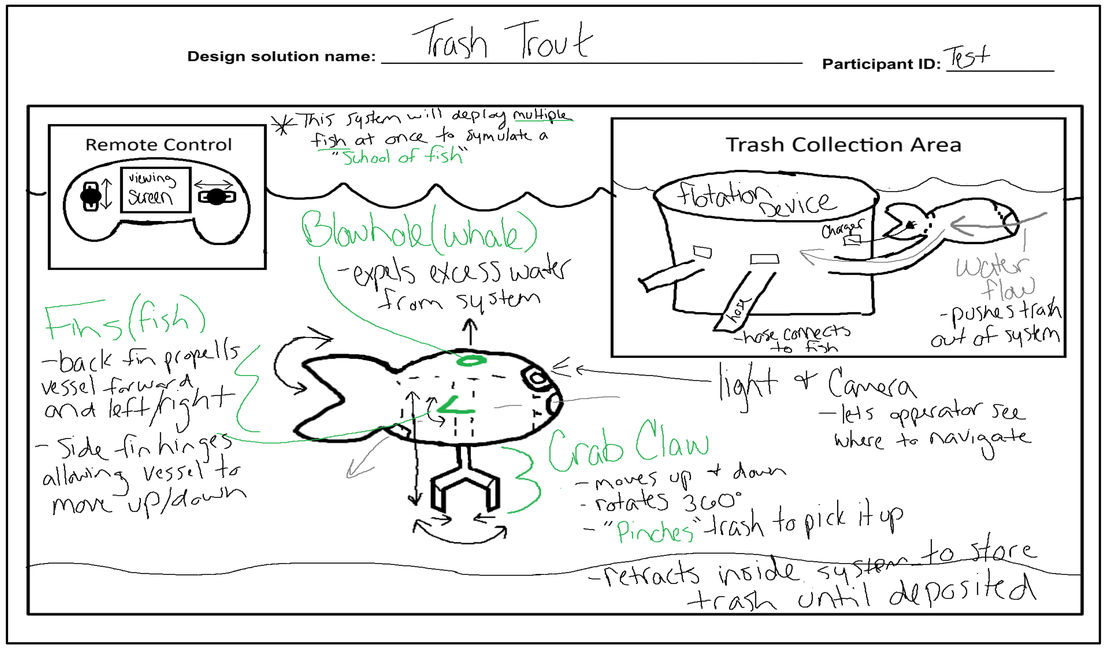

Figure II: Design Solution Example

Results

- Quality Unaffected by Additional Instruction: No significant difference in design quality between students taught with both bioinspired and analogical transfer videos and those taught with only bioinspired design.
- Higher Solution Quantity with Bioinspired Design Alone: Students exposed only to bioinspired design produced more solutions, indicating functional decomposition instruction doesn't increase solution quantity.
- No Difference in Variety and Novelty: Adding functional decomposition instruction doesn't significantly impact the diversity or innovation of design solutions.
- Students Familiar with Bioinspired Design: Majority were already familiar with bioinspired design, less so with analogical transfer and functional decomposition.

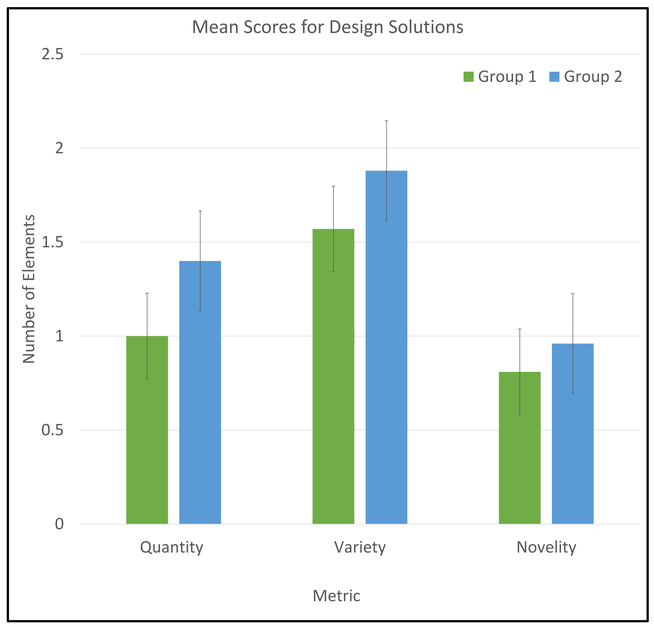

Figure III: Mean Scores for Design Solutions

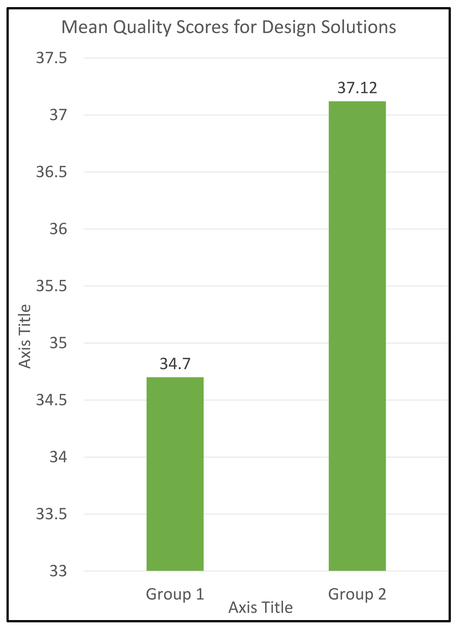

Figure IV: Mean of Quality Scores for Design Solutions

Design Challenge

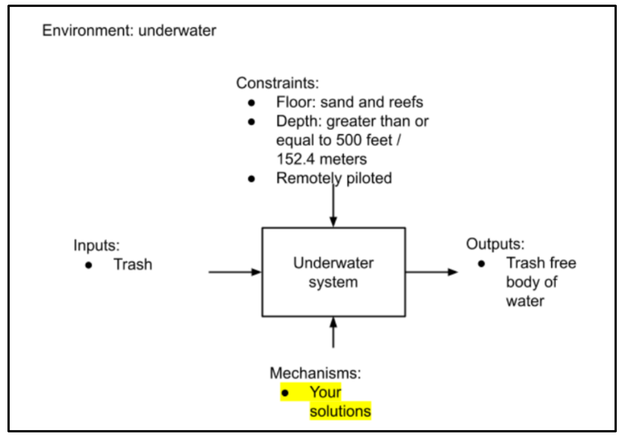

Figure V: Constraints and Requirements of Design Challenge

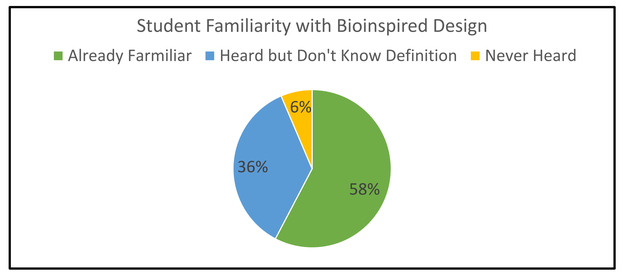

Figure VI: Student Familiarity with Bioinspired Design

Conclusion

- Limited Impact on Quality and Innovation: Functional decomposition instruction does not significantly enhance the quality, variety, or novelty of bioinspired engineering design solutions, suggesting its impact is neutral in fostering innovative design qualities among undergraduate engineering students.
- Positive Influence on Solution Quantity: While functional decomposition instruction does not increase the diversity or innovativeness of solutions, it is associated with a higher quantity of solutions, indicating its potential to encourage a more prolific exploration of design possibilities.
- Implications for Engineering Education: The findings imply that while functional decomposition is valuable for increasing the number of design solutions students can generate, it should be complemented with other instructional strategies that more directly foster quality, variety, and novelty in bioinspired design.

Future Work

- Study Review: The initial study will undergo a thorough review to refine methodologies and objectives based on feedback and outcomes.
- Defining "Good" Design Problem: Research will be conducted to establish criteria for what constitutes a "good" design problem, focusing on elements that enhance creativity and learning in engineering.
- Dry Run Implementation: A dry run of the revised study will be carried out to test the feasibility and effectiveness of the new methodologies and design problems.
- Collaboration Efforts: Coordination with other institutions, specifically Embry-Riddle Aeronautical University and Florida Polytechnic Institute, will be initiated to foster collaborative research and share insights.
- Extended Research: Further research will be conducted to explore additional aspects of bioinspired design and functional decomposition, aiming to deepen the understanding and application in engineering education.

Citations