Curriculum Redesign of a Transfer Science Laboratory Course Through Application of an Inquiry-guided Laboratory Manual

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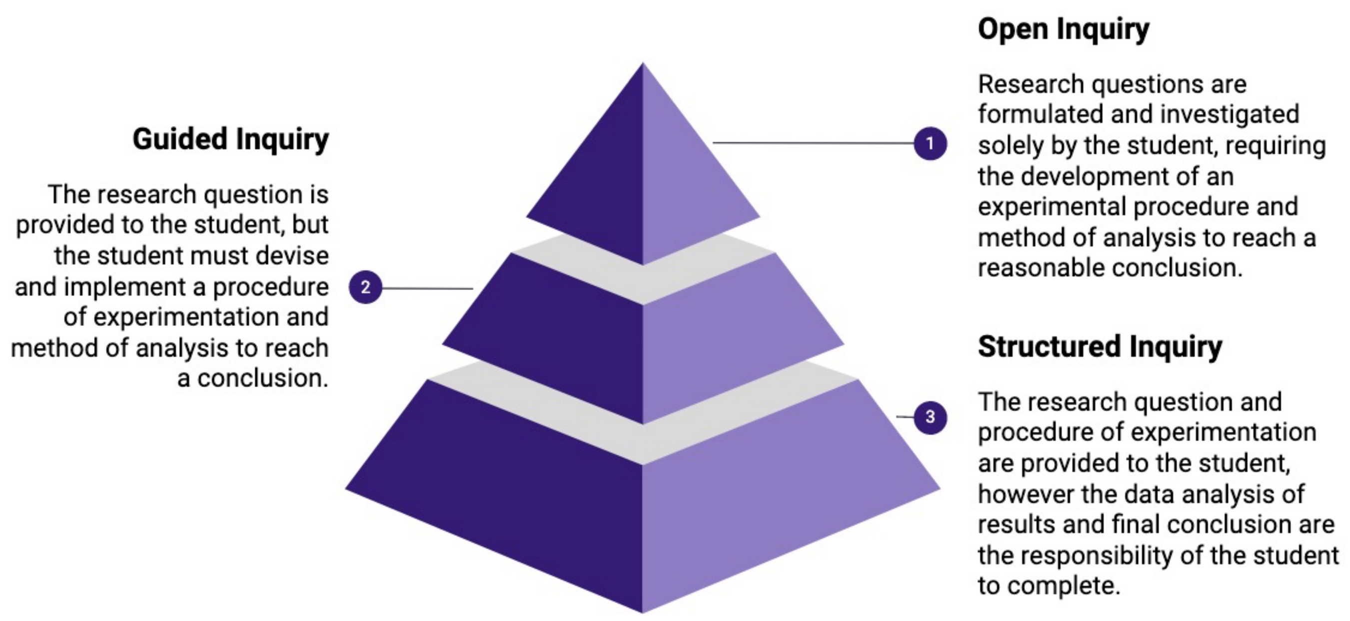
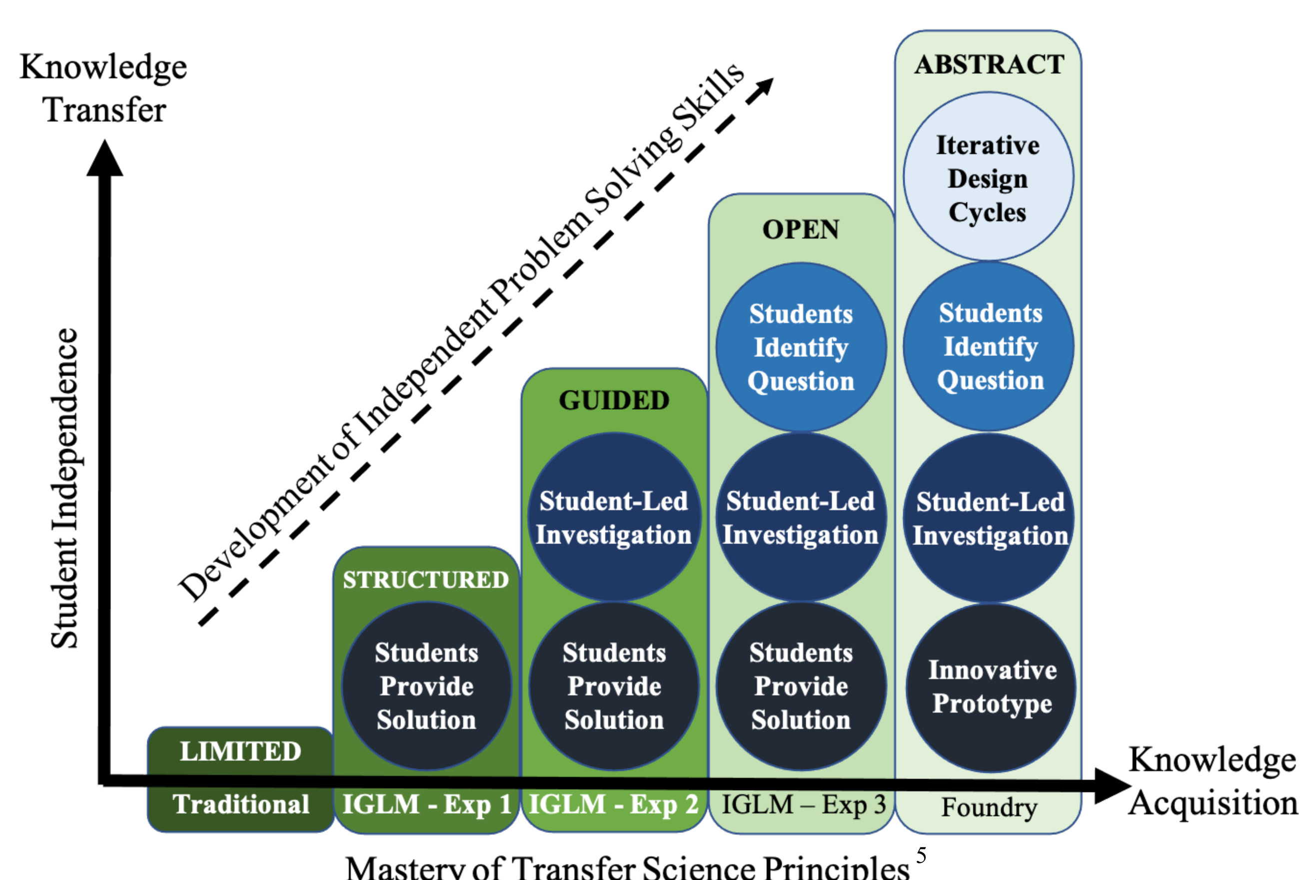
1. OVERVIEW & SCOPE

The purpose of this contribution is to convey preliminary results involving the curriculum redesign of a chemical engineering laboratory course through the novel application of the Inquiry-guided Laboratory Manual (IGLM). The context of this curriculum redesign involves a heat transfer laboratory course, which is the first of the transfer science course series offered by the Department of Chemical Engineering at Tennessee Tech. The pedagogy of the IGLM is anchored in the innovation-driven learning strategies of the Renaissance Foundry (herein the Foundry) and follows a scaffolding approach for inquiry-guided learning that seeks to provide students with learning experiences related to creativity and problem solving.[1] The constructivist framework of this inductive study ensures that the preliminary results and themes will be representative of the data from which they emerge and will be further discussed within the study. Additionally, this contribution addresses the need for continued research-based discussions on the curriculum design of engineering laboratories and data-driven conversation on how to provide holistic learning experiences for engineering students.

2. IGLM LEARNING FRAMEWORK



The design of experiments in the IGLM implements a **scaffolding approach to inquiry-guided learning** (*presented above*) in order to systematically increase student independence as the semester progresses.[2,3] The IGLM is framed in a context of the Foundry model, resulting in learning experiences that enable students to better identify relevant resources and information prior to engaging in inquiry-based activities.[4] **Each subsequent experiment increases the level of student independence in the lab** (*pressented below*), requiring a more thorough understanding of the material in order to successfully complete the experiment.[5]



3. DESIGN OF IGLM EXPERIMENTS[6]

IGLM Element	Structured Inquiry	Guided Inquiry	Open Inquiry	Abstract Inquiry
Experiment Learning Objective	Clearly stated with descriptive procedural elements and expectations	Clearly stated without descriptive procedural elements	Overview of transfer science principles involved for students to identify and explore a research question	Prototype of Innovative Technology using Renaissance Foundry Model (Arce et al., 2015)
Conceptual Model	Detailed model with descriptive comments	Descriptive model without comments	Generic non-descriptive model	
Setup & Procedure	Procedures provided with guidance for material and instrumentation setup	Materials and instrumentation provided without specific, defined procedures	Student-directed inquiry with instructor available as an informational resource	
Post-Lab Report	Structured report with comparative analysis	Report describes methodology, discussion of results, and comparative analysis	Report defines objective, methodology, discussion of results, and comparative analysis	

4. RESEARCH METHODS

Research Question	How does the application of the IGLM in a transfer science laboratory course influence student activities related to preparation prior to experimentation?
Setting & Population	• The setting of the study took place in a chemical engineering laboratory course that was paired with an instructional course, listed as ChE 3111: Trans Sci I: Cond, Raditn, Diff. • The research population was comprised of approximately 50 students that were registered for the ChE 3111 laboratory course during the 2019 Fall semester.
Data Collection	• Ethical Considerations: Data was collected as part of a larger IRB approved study. • Data source: Individual, student reflections that were required as part of the normal coursework of the ChE 3111 laboratory course. • Student Reflections: Written by students after completing each of the three lab experiments
Analytical Strategy	• Constructivist framework is paired with an inductive approach that applies a thematic analysis with coding strategies as per Saldaña[7] for open coding, sub-coding, and simultaneous coding. • Method ensures that the preliminary results and themes will be representative of the data from which they emerge, being highly pertinent to the research question.[7, 8]
Reflexivity & Subjectivity	• Reflexivity – Assumptions regarding engineering background were acknowledged while coding and measures were taken to self-monitor throughout.[9] • Subjectivity – Intrinsic incentive to enhance ENGE programs from viewpoint of potential future curriculum redesign.[9]
Trustworthiness	• Measurers were taken to ensure that all aspects of trustworthiness were addressed for credibility, transferability, confirmability, dependability.[9] • Methods and approaches taken - Peer debriefing, referential adequacy [9]

5. RESULTS

Theme	Description	Categories
Mutualism of Clarity and Attitude	The degree of clarity or understanding held by the student regarding the lab experiment's procedures and/or objectives has an impact on the attitudes and feelings that students express towards the experiment, which in turn mutually affects their motivation to seek clarity and address misconceptions.	• Unknown or Unexpected Actions Negatively Impact Attitude • Unclear Purpose/Instructions Negatively Impacts Attitude • Recognize Benefits of Positive Attitude While Seeking Clarity
Exploring Mistakes and Moving Forward	Students recognize that failure to accomplish their goal can still provide opportunities to explore and identify their mistakes, so as they move forward, the same mistake or error does not happen again during their repeat attempt or future experiments.	• Learning From Mistakes • Thoughts & Actions for Future Improvement
Role of Preparation in Lab Experiences	After experiencing failure and/or frustration, students recognize that they have the responsibility for being prepared prior to entering the lab and that self-motivated action to prepare can improve their understanding on how to complete the lab and efficiency of time spent doing so, thus improving their experience in the lab.	• Preparation - Confidence, Positive Experience • Lack of Preparation - Setup/Procedure Errors, Negative Experience • Lack of Preparation - Time Wasted • Preparation - Successful Experiment
Shifting Towards Independent Inquiry	As the semester progresses, students' perceptions of independence during inquiry begins to shift, accepting the instructor's role as an informational resource and taking action to work collaboratively to finish task.	• Students Find Independence Challenging • Independence Improved Learning • Ask Questions and Find Resources to Improve Understanding • Team Collaboration Necessary for Success

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6. DISCUSSION & CONCLUSIONS

How does the application of the IGLM in a transfer science laboratory course influence student activities related to preparation prior to experimentation?

The major themes of *Mutualism of Clarity & Attitude* and *Role of Preparation in Lab Experiences* provide insight into student perspectives regarding how they experience frustration or success in the laboratory while conducting the IGLM's experiments.

- Students are more likely to apply themselves towards understanding the principles and objectives of the lab when they are completing the course's prelab activities.
- Students are more likely to successfully complete the experiment by improving their clarity for what should occur during the experiment.
- The relationship between students' experiences and attitudes in the lab may be linked to the influence provided by the IGLM for directing their efforts to prepare
- By guiding students actions with specific prelab activities that task students to research and identify relevant principles and concepts, they are better equipped to consider and plan-out a course of action experimentation.

The major themes presented as *Exploring Mistakes and Moving Forward* and *Shifting Towards Independent Inquiry* are important for improving our understanding of how students react and learn from their mistakes or failures in the laboratory and how that influences their future efforts to succeed.

- By increasing the level of independence that students experience in the lab, their opportunity for failure is also increased.
- By the instructor promoting an environment that does not punish failure, but encourages students to understand why something failed, students are more likely to learn how to better ask direct questions and improve skills of inquiry.
- Furthermore, such inquiry skill sets can be applied during activities of
- Students practice inquiry as they seek to target relevant information during prelab activities and are thus better able determine appropriate procedures for experimentation at greater levels of independence.

In conclusion, the themes generated and presented herein present a unique perspective into students' actions and attitudes towards preparing for experiment in a chemical engineering laboratory. Moving forward, the data involved in this study is a preliminary subset of a much larger collection of data that will be explored to further understand and develop such learning experiences for engineering students. The findings that have been presented will be of considerable use in future editions of the IGLM, as well as for other curriculum design efforts.