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 (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 controlled 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 (presented below), requiring a more thorough understanding of the material in order to successfully complete the experiment.5

3. DESIGN OF IGLM EXPERIMENTS

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

4. RESEARCH METHODS

5. RESULTS

Table: 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 Impact 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 attempts. | • 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 begin to increase, accepting the instructor’s role of 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 |

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 engagement by representing 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 influenceability, contemplability, and displayability of 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 instructors are able to 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 further to 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.