Outcomes of Laboratory Experimentation in the Chemical Engineering Curriculum

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Abstract - Laboratory instruction has been a long standing component of the chemical engineering curriculum. Along with a sound theoretical foundation, firsthand experience in the field forms a wholesome educational experience since instruction in a laboratory entails a cognitive approach.For a student to develop a complete understanding, it is essential that concepts are made tangible. Experimentation improves the problem solving skills, critical thinking and investigative skills of students. Its most vital importance, however, lies in the fact that it provides the student with an in depth understanding of the subject, while making it an enjoyable learning experience.

Index Terms: Chemical engineering, undergraduate, laboratory, guidelines, cognitive, practical, analysis, safety.

1.0 Introduction

Chemical engineers apply the principles of Chemistry, Biology, Mathematics and Physics to devise processes and systems for manufacture. Truly, it is a branch with wide reaching applications. In consideration of this, laboratory instruction becomes an essential feature of the undergraduate curriculum, where the students are educated on techniques that are already employed in the industry or in research laboratories. The expected outcome of a laboratory course is to enable the student to connect the theories to practise. What is taught in the lab can be considered as general guidelines for the engineer's reference when he tailors new techniques and unique processes for production.

Laboratory instruction has been a long standing component of the chemical engineering curriculum. Over time, the methodologies used to impart this education have been varied. Yet, the laboratory experience has held its significance in the overall development of a chemical engineer. This paper reflects on the objectives of its inclusion and the outcomes, taking into consideration the perspectives of both the instructor and the student.

Engineering is a field where the students are entitled to a practical experience of anything that they learn.

This field is application-based. The industry requires not just 'educated' individuals, but 'trained' ones. The experimental approach is designed to cater to this requirement. Starting from data analysis to working ethics, students build up a personality suitable for the industry. Students are taught to experiment, observe, analyse and report. Laboratories often include real-time problem solving, creative design of processes and their subsequent optimisation. Students benefit from collaborative learning, and understand the importance of safety in a chemical engineer's working environment. As a whole, instruction in a laboratory entails a cognitive approach.

Along with a sound theoretical foundation, firsthand experience in the field forms a wholesome educational experience. The laboratory brings out the competency of a student in the curriculum thus making its inclusion pivotal in engineering education. Any laboratory program must be able to satisfy each of its objectives in order to be effective.

2.0 The Objectives

2.1 Practical Experience

Regular class lectures involve explanation of theoretical concepts to students. For a student to develop a complete understanding, it is essential that the concept is made tangible. This is where experimentation plays a major role. Over years, studies have shown that experimentation improves the problem solving skills, critical thinking and investigative skills of students. Apart from this, another benefit of significance is that students do not just use their minds to comprehend fresh concepts. The senses of vision, touch, smell and hearing often significantly contribute to the learning experience. This stimulates analytical thought flow and imprints the experience in the student's mind. The laboratory component included in the chemical engineering curriculum generally involves the use of chemicals and equipment that have been reduced to a lab scale. As a result, theories are given physical meaning and students gain hands-on experience before stepping into the industry.

Practical experience is also important for the budding researcher. Undergraduate students seldom get exposure to a full fledged research laboratory and thus rarely understand the correct procedures and the importance of good laboratory practice. However, in a laboratory course associated with a subject, they get to operate analytical instruments that are used in such laboratories while learning about organized research methodology.

2.2 Data and Error Analysis

Data is recorded and tabulated during any experimental procedure. Analysis of this data helps verify or validate theories learned in lectures. Various calculations and manipulations are performed on the observed values as and when is required. For example, given the prior knowledge of laws and theories learned in classes, the student can observe firsthand the deviations of real life processes from ideal behaviour. He learns to predict data trends and hence identify any errors in observation. Such graphical methods help better understand the process and also the working of some equipment.

On the other hand, error analysis gives insight into experimental parameters that may not have been taken into consideration during calculations that might have resulted in abnormal trends. Experimental data also gives information about the state of the system, enabling the student to learn about the effect of different parameters on the state. Inferring results from the experimental data makes for development of critical thinking. Data and error analysis thus helps the student develop organizational and manipulative skills.

2.3 Safety and Responsibility

The importance of safety in the lab as well as the industry cannot be emphasised enough. Especially in the case of a chemical engineer, it would in fact be appropriate to say that safety comes first. A responsible engineer understands that thorough safety considerations are mandatory at each and every stage of operation. Working with equipment in the lab during the course of study instils students with this fundamental quality.

When experimenting in a laboratory, a student is invariably taught the safety measures. This is an invaluable lesson for any engineering student. It is essential for him to understand the consequences of carelessness. This instils a sense of responsibility. The student learns that taking precautionary measures forms one of the most important considerations that one makes when experimenting. Maintenance and careful handling of apparatus, strict adherence to procedure, and the use of protective gear when performing experiments are pivotal in inculcating safety awareness. This learning expands to the industrial scale when equipment is handled by responsible engineers.

2.4 Scaling Up of the Experimental Set up

Laboratory experiments in the chemical engineering curriculum are done to understand processes on a small scale, where modifications to the apparatus and procedure can be implemented easily. While studying processes in the laboratory scale, the student also learns the theory of design and operating conditions in the industrial scale, such as large processing volumes and geometry of equipment, that are exclusive to such large scales. He understands how satisfactory results can then be translated to a macroscopic industrial scale. This is done by establishing analogies between the experimental set up and the industrial equipment– a few of which are geometric, dynamic, thermal and kinetic analogies. The student thus learns to correlate the process considerations in both scales –an important ability for a practicing chemical engineer.

2.5 Understanding Laboratory Equipment

It is necessary for the student to understand how the experimental setup functions. He may then explore the different methods that can be used as an alternative, based on similar operating variables. Experimental setups show the process parameters that are unique to small scale equipment, which are generally ignored in the industrial scale. It becomes easy to develop a simplified model after understanding the experimental apparatus and thus the student can simulate various operating conditions in a virtual lab environment – a vital tool in today's increasingly computerised industrial ecosystem. Using the power of simulation software, he can learn how it is possible to develop novel process pathways, decrease emissions and improve efficiencies, to list a few. Complexities can then be introduced into the simplified model to further his understanding of the process equipment.

2.6 Overall Development

Laboratory experimentation relates science (from the textbook) with technology (in the lab). The all-round laboratory experience kindles the spirit of scientific inquiry in students. It is a medium for collaborative interdisciplinary learning and decision making. Students learn to take calculated risks while foreseeing the possible outcomes. Lab work usually involves working in teams. More often than not, students begin to realise that teamwork is not the mere distribution of labour. Organisation of thought, structured planning, combating problems effectively and obtaining the desired result are essentials to successful teamwork in a lab. Here, experimentation teaches students to play their strengths and assume appropriate roles in a team set up. Apart from the major contribution it makes to a student's cognitive abilities, experimentation teaches students to persevere and learn from their mistakes. Its most vital importance, however, lies in the fact that it provides the student with an in depth understanding of the subject, while making it an enjoyable learning experience.

3.0 Conclusion

The benefits of including laboratory coursework in a subject study program outweigh any negative aspects that question its relevance and practicality. It carries importance with respect to academia and also helps undergraduate students develop soft skills that can be useful in their future careers. Their impact on learning cannot be underestimated and thus the coursework must be designed in such a way as to promote students to think and question, not just try to obtain results. Lab experiments must complement class lectures to reinforce new and old concepts to achieve this.

4.0 Resources

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