Presented at the International Conference on Engineering Education Philippines (ICEE-PHIL) 2022
December 09-10, 2022

Chemical Engineering Laboratory Skills Training: Bridging the Gap between Remote Learning and Face-to-Face Industry Immersion

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Highlights

- Two-week training enhanced students' laboratory skills in preparation for industry immersion
- Students' positive response towards the laboratory skills training
- Positive feedback from industry on student performance during the industry immersion

Abstract

The Bachelor of Science in Chemical Engineering (BS ChE) of the University of the Philippines Visayas-School of Technology (UPV-SOTECH) traditionally sends incoming fourth-year students to manufacturing companies to render 240 hours of industry internship where they personally experience chemical engineering at work by being exposed to current tools, applications, and industrial processes. However, with the onset of the COVID-19 pandemic, teaching and learning have shifted to remote and virtual mode which limited the learning opportunities and obtained skill set of students. Particularly, the students referred to in this paper have limited to no experience in handling laboratory apparatus and glasswares, conducting laboratory experiments, and operating chemical engineering machineries and equipment. Once deployed to their respective companies, problems due to unprepared students may arise for both parties. To bridge the gap between remote learning and face-to-face industry immersion, a 40-hour chemical engineering laboratory skills training was conducted for these students. During the training, different laboratory exercises and modules were developed and performed, and lectures and workshops were conducted. These activities aimed for the students to gain necessary knowledge and practical skills prior to their internship. Validated assessment tools based on the Kirkpatrick Model were used to determine the training impact towards student performance. Based on the positive feedback from the students on the training program, they were successfully equipped with the necessary skills to perform excellently in their industry immersion. The feedback of the trainers for the students also showed that the performance of students was very satisfactory based on their written outputs and laboratory performance. Moreover, the highly-scored evaluation forms of the industry supervisors showed that student interns were well-equipped, knowledgeable, and well-prepared based on their satisfactory internship performance. Pearson correlation ($r=0.77$, $p<0.01$) shows a significantly strong positive correlation between the student's performance in the training and in the industry immersion.

Key Words: Laboratory skills training; chemical engineering; industry immersion; skills bridging for remote learning

1. Introduction

Instruction is the focus of every academic institution. However, for engineering courses, this is not comprehensive and complete without the hands-on application of concepts to actual operations or demonstrations (Hebron, 2020). Industry immersion and training play a crucial role in preparing engineering students to be future professionals. According to Coyle et al. (2007), good engineering practice is developed through the application of existing knowledge to industrial setup giving outcomes that will lead to knowledge refinement. Studies have also shown that students who underwent industry immersion and on-the-job training programs gained higher levels of self-esteem, practical knowledge and ability to solve industrial problems, multidisciplinary skills, and increased job prospects (Hebron, 2020).

In 2016, the BS ChE of UPV-SOTECH recognized the significance of industry immersion in producing globally-competitive professionals and instituted a course centered on industry practice in a chemical plant involving any unit operations, pollution control, and abatement processes. ChE 195 (Practicum) is a 5-unit course that aims to provide an avenue for students to (1) apply theories learned in the university to the actual practical solutions to industrial problems, (2) explain plant operations and processes, and operational techniques used, (3) demonstrate responsible attitude and self-motivation by systematically handling tasks in activities relevant to Chemical Engineering, and (4) demonstrate good human relations by practicing cooperative teamwork, good communication skills, and responsible work ethics.

Since the institution of the course, students are sent to companies to render 240 hours of industry immersion where they experience chemical engineering at work. They are also exposed to the current application of tools and techniques at work. With the onset of the COVID-19 pandemic, however, teaching and learning have shifted to remote and virtual modes. Instead of sending students to different industries, a home-based on-the-job training was successfully carried out which provided an alternative avenue for the application of chemical engineering principles. Even though this approach worked well for knowledge building through delivering content, it had limitations in establishing the students' practical laboratory and hands-on chemical engineering skills. Furthermore, students generally prefer classroom based qualitative learning in which they can actually perform experiments (Borrego et al., 2013).

Currently, as the number of COVID-19 cases goes down and the restrictions ease up, it is timely to revert to an industry immersion setup to expose the students to actual operations in chemical process industries. These students who will be undertaking industry internships have already taken chemical engineering laboratory courses, however, were limited to home-based and video-recorded experiments. The remote delivery of laboratory experiments can be efficiently devised to achieve most of the relevant skills except certain elements of hands-on practical exercises (Gamage et al., 2020; Gravier et al., 2007). Therefore, the curriculum should be constructed to include adjustments in students' learning trajectories mainly the inclusion of heuristic laboratory experience (Daniel, 2020) because sending them to partner industries without actual and applied knowledge can be a disadvantage to both parties. To address this, before the industry immersion, laboratory skills training was conducted. The training was a targeted preparatory course that allowed students to handle firsthand basic equipment and laboratory apparatus, as well as to perform laboratory tests and experiments. The skills learned from this training were necessary to bridge the gap between the theoretical knowledge from previous remote classes and the requirements of a face-to-face industry immersion.

The laboratory skills training aimed to (1) equip the students with practical and analytical laboratory skills needed for ChE 195 (Practicum), (2) provide exercises that will supplement the missed laboratory skills training on various chemical engineering laboratory courses taken by the students during remote classes, and (3) enhance the students' lifelong learning experience on various unit operations and processes essential for industry immersion.

2. Methods

The implementation of the Chemical Engineering Laboratory Skills Training involved several steps from preparation up to the training proper and assessment. The steps are detailed in the subsections below.

2.1 Preparations

The lab skills training is considered as an Academic Program Improvement (API) project since it is not part of the regular BS ChE curriculum of SOTECH-UPV. Due to its nature, a proposal was first secured and submitted to secure funding and support from the University. After the approval of the proposal, training modules and laboratory manuals were developed. The materials and equipment needed for the experiments and training activities were then procured and set-up. Prior to the training, a consultation with students and parents was conducted to discuss the objectives of the lab skills training, including the potential benefits and risks. The students were then required to secure medical insurance and submit an oath of undertaking and waiver affirming that they understood the guidelines set by the university for face-to-face activities.

2.2 Orientation of students

The forty-six (46) students of ChE 195 were divided into groups with four (4) students each. A training orientation detailing the schedule of experiments and expected outputs was then conducted. They also underwent a laboratory orientation introducing them to: (1) concepts and demonstration of proper usage of common laboratory glasswares and apparatus; (2) good laboratory practices.

2.3 Laboratory skills training

The training modules were designed to provide the students with a holistic and integrated laboratory skill set development in preparation for their Practicum. The laboratory skills training modules were divided into three categories: (1) General Experiments; (2) Specialized Experiments; (3) Lecture/Workshop Series. General experiments are short experiments and long experiments focused on acquiring basic laboratory skills and introduction to common unit operations. Specialized experiments were designed to apply basic laboratory skills and chemical engineering principles to lab-scale operations commonly found in industries. These experiments are then supplemented by a lecture series about common equipment and practices in the industry. The list of experiments and lectures for the training is shown in Table 1.

Table 1. List of Experiments, Lectures, and Workshops.

Short Experiments	**Long Experiments**	**Specialized Experiments**	**Lectures and Workshops**
1. Calibration of flow meters and Bernoulli's principle demonstration 2. Titration and gravimetric analysis 3. Reynold's theorem demonstration and flow over weirs 4. Design of packed column	1. Shell-and-tube heat exchangers 2. Friction losses in pipes and fittings 3. Drying at constant drying conditions 4. Size reduction and sieving	1. Food and fuel calorimetry 2. Fermentation and distillation 3. Water quality analysis	1. Valves and fittings 2. Piping and instrumentation diagram 3. Process control equipment 4. Gender sensitivity and Anti-sexual harassment orientation

2.4. Assessment

The assessment tools used were: (1) evaluation of the training program by the student trainees (2) evaluation of students' performance in the training by the program trainers; and (3) evaluation of the students' performance in the internship by the industry. This is based on the widely used Kirkpatrick Model which measures four levels of training evaluation namely: (1) reaction; (2) learning; (3) behavior; (4) results (Moldovan, 2016).

First, the trainees' reactions were measured through the evaluation of the training program by the student trainees and accomplished anonymously through Google Forms. This is a self-rated questionnaire using Likert Four-Point Scale (1= strongly disagree, 2= disagree, 3= agree, 4= strongly disagree) with questions adopted from the previously validated assessment tool of Hajjar and Alkhanaizi (2018). Their study obtained an overall Cronbach's alpha of >0.9 pertaining to acceptable reliability.

The trainees' learnings were measured by evaluating students' performance in the training by the program trainers through: (1) written laboratory reports; (2) laboratory performance; (3) attendance. The written laboratory reports were printed forms where students filled up their results from the experiment, discussed their findings and data analysis. For the laboratory performance, trainees were assessed by the trainers based on their ability to follow standard laboratory and experimental procedures and protocols, proper equipment handling, and contributions to the group. These outputs were scored based on the trainees' degree of attainment of the internally peer-reviewed course objectives of the training program.

Lastly, the behavior and results were measured by evaluating the students' performance in the internship by the industry. The evaluation form incorporated questions derived from the different criteria of the Accreditation Board for Engineering and Technology (ABET) and ASEAN University Network-Quality Assurance (AUN-QA) such as engineering competence, communication skills, lifelong learning, and team competence using a Likert Three-Point Scale (1= satisfactory, 2= adequate, 3= unsatisfactory).

3. Results and discussion

3.1 Evaluation of the training program by the student trainees

The feedback on the training content is shown in Figures 1 and 2. Figure 1 shows that the majority of the students strongly agreed that the three objectives of the training were attained. This implies that from the students' perspective, the training has helped them with the face-to-face industry immersion.

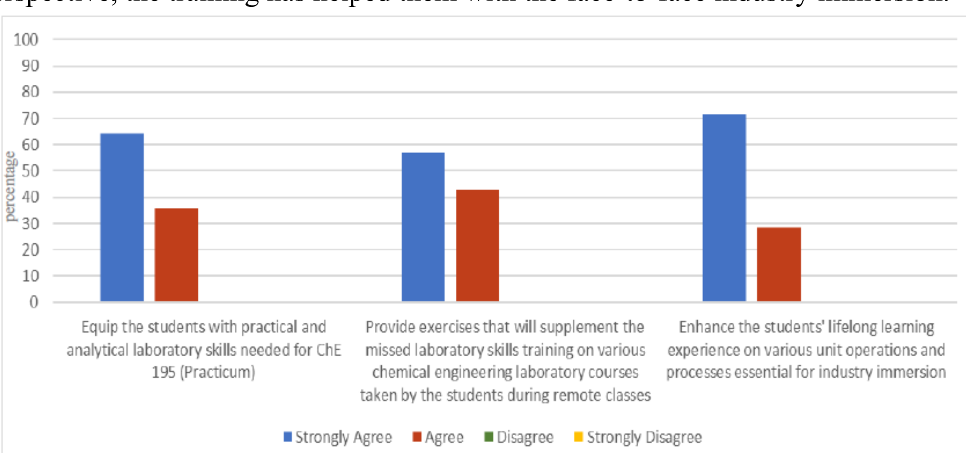

Figure 1. Attainment of the training objectives.

As shown in Figure 2, almost all students strongly agreed that the topics and experiments conducted were relevant and objectives were clearly defined. Also, most said that the training was organized and easy to follow through the materials distributed.

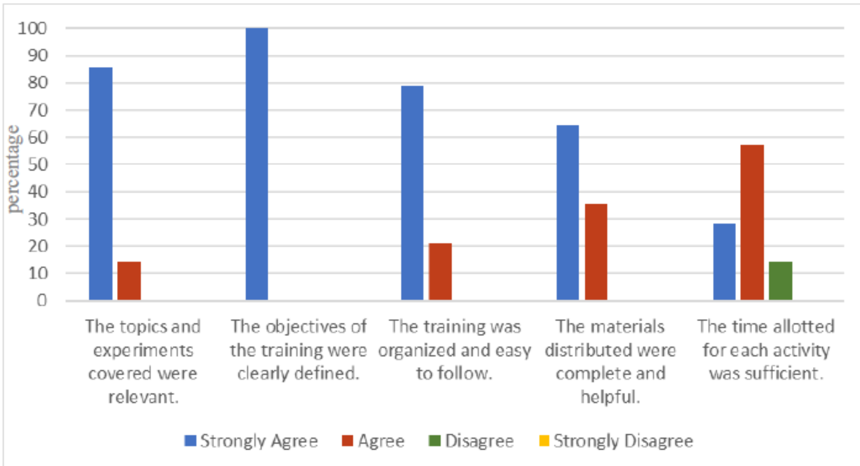

Figure 2. Assessment of the training implementation.

The students were also able to give strong points about the training program content through comments such as below:

> *"The program includes equipment for **small-scale experiments** that we were able to **use and apply in the large-scale operations of our assigned companies**. The program gives opportunities for us to **familiarize the use of the equipment which prepares us for our practicum**."*

> *"Our **lacking lab skills were supplemented** throughout the entire duration of the training program. The **rotation format is well-executed** and students were able to **develop interactive communication skills** under the effective supervision of professors, the soft skills needed in the industry."*

Furthermore, the trainees suggested including future activities that would enable them to use essential engineering software such as MATLAB, MS Excel, etc.

With regards to the effectiveness of the trainers, Figure 3 shows the assessment of the program trainers.

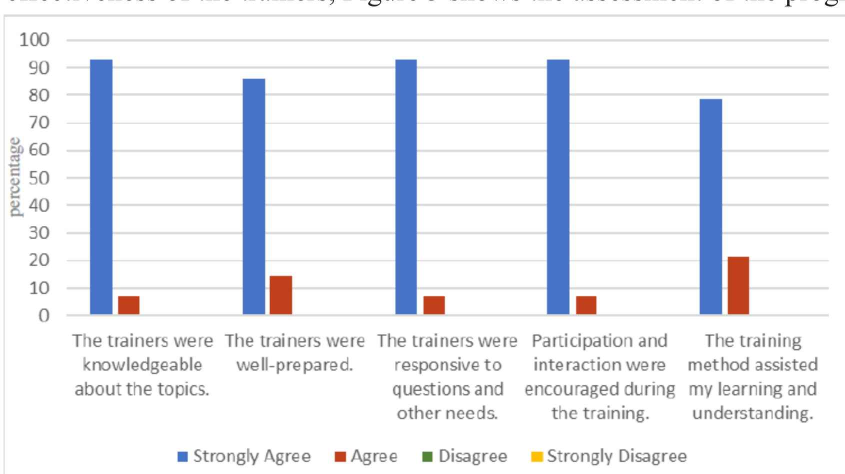

Figure 3. Assessment of the program trainers.

Figure 3 shows that the majority of the trainees strongly agreed that the trainers were knowledgeable about the topics, were well-prepared, and were responsive to questions and other students' needs. The assignment of experiments for each faculty was based on the level of topic mastery. Usually, the faculty was assigned to the experiment in which he/she taught the equivalent lecture course. This enabled him/her to supervise the students effectively and to maximize the sharing capability.

Furthermore, it can be seen that the training method used by each trainer was effective for students and that participation and interaction during the training were encouraged. This enabled them to work with their group and collaborate with each other.

Some of the strong points given in the feedback form regarding the trainers were enumerated below.

> *"**Considerate and experienced**. They are very **much willing to assist** the students and ensure that no one gets left behind while still **empowering us to solve problems on our own** and thus help the **students learn more about the topic naturally**."*

> *"The strongest point is that our facilitators **demonstrated how to operate the equipment thoroughly** and **made us feel accommodated when we ask questions**. I liked the instructors and how they **balanced the lecture with the experimental aspect**."*

3.2 Evaluation of the students' performance in the training by the program trainers

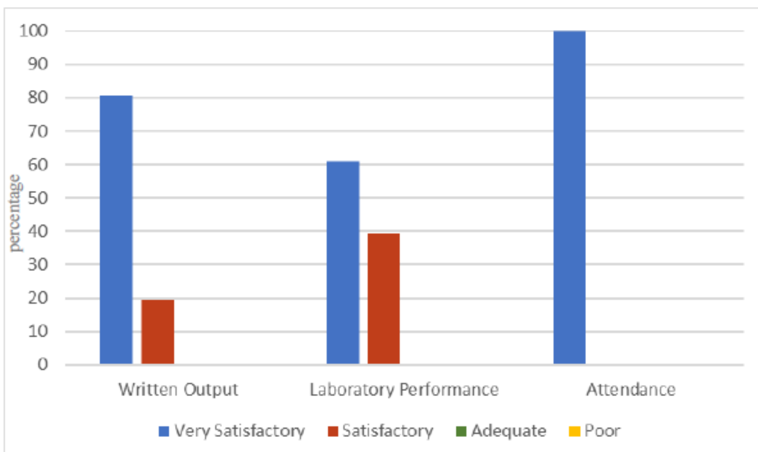

Figure 4. Student's performance in the training.

Figure 4 shows that 80% of the students had very satisfactory written outputs while the rest obtained satisfactory ratings. This shows that the calculations, interpretation, and analysis of the gathered data, and conclusions and recommendations of the students for the experiments were generally excellent.

Meanwhile, 60% demonstrated very satisfactory laboratory performance. Although relatively lower than their written output ratings, this is expected and understandable as this was the first time for most of the students in handling different complex equipment and apparatus. Despite this, the students learned crucial lessons and experiences in troubleshooting and rectifying errors that may be encountered in a manufacturing plant.

3.3 Evaluation of the students' performance in the internship by the industry

Figure 5 shows the knowledge of trainees on plant operations. This shows a high percentage of trainees who are able to explain the details of the processes and to describe the function of equipment used in the plant operations. It can be also seen that the majority of the trainees follow policy and procedures and are able to carry out assigned tasks independently. In terms of the ability to calibrate, use, and read various testing equipment required for plant operations, all trainees gained the satisfactory skills required in the industry. Further, 90% have satisfactory skills to operate equipment in a safe manner. The activities prepared for the training were devised to introduce to students the laboratory equipment, explain the concept involved, and train them in handling, and operating basic laboratory equipment and devices.

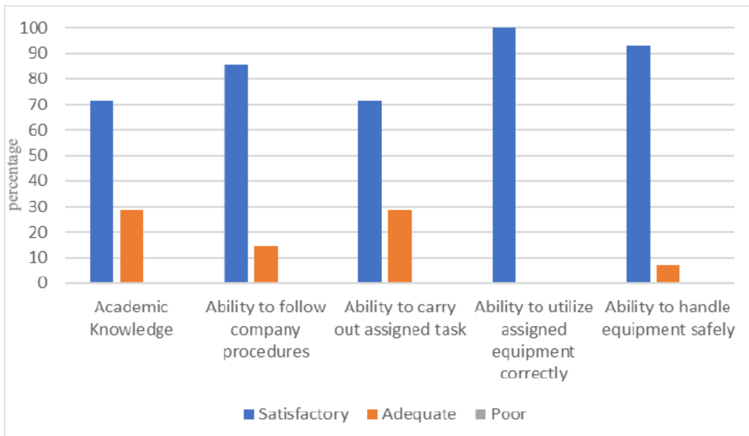

Figure 5. Knowledge of plant operations and processes.

Figure 6 shows that majority of the trainees have satisfactory human relations. During the lab skills training, this was one of the soft skills emphasized allowing the students to work in groups with randomly chosen members while being under supervision.

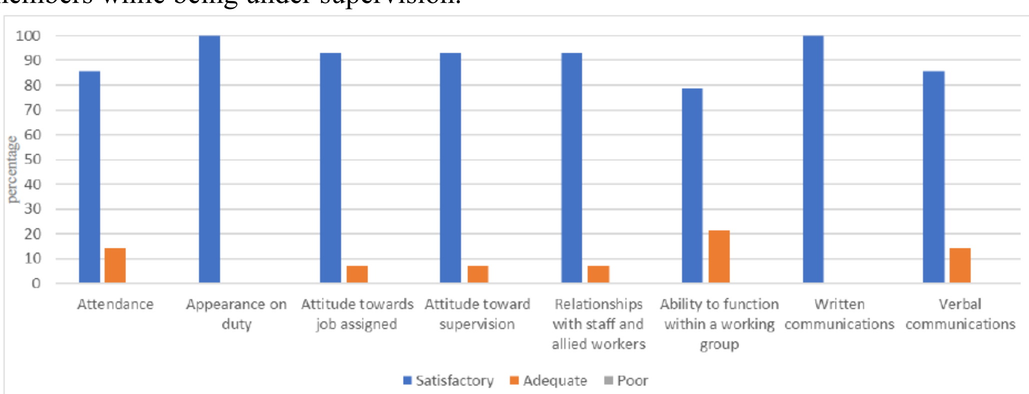

Figure 6. Human relations in industrial operations.

3.4 Correlation between the students' performance in the lab skills training and in the industry immersion

The data analysis revealed that the performance of the students in the training has a significantly strong positive relationship with the student's performance in the face-to face industry immersion as supported by Pearson correlation coefficient ($r = 0.77$, $p<0.01$).

4. Conclusions

The training program was successful in providing analytical laboratory skills and exercises that supplemented the missed laboratory skills during remote classes, and in enhancing the students' lifelong learning experience on various unit operations and processes. Ultimately, it also has bridged the gap between remote learning and face-to-face industry immersion. This was evident in the positive feedback from the students on the training program, the assessment of the trainers on the students, and the high rating evaluation of the industry. A significantly strong positive relationship was found between the students' training performance and students' industry performance. This study highly recommends the implementation of laboratory skills training for other chemical engineering batches that have undergone remote and online laboratory classes while incorporating the suggestions for improvement.

Acknowledgement

The authors would like to express their gratitude to the University of the Philippines Visayas for funding the training, to Dr. Dennis C. Ong and Engr. Francis Eric P. Almaquer for the mentorship and support, to Engr. Paul Arean S. Sanapo, Engr. Joyjane L. Borres, and Engr. James Darryl E. Peñas for serving as additional trainers, and to BS ChE students who participated actively in the Laboratory Skills Training.

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