SKILL-ELABS IMPACT EVALUATION REPORT

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INTRODUCTION

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1.Introduction

The Ministry of Skill Development and Entrepreneurship (MSDE), in collaboration with the Directorate General of Training (DGT) and the National Instructional Media Institute (NIMI), is leading a pioneering initiative to create "Skill-eLabs" for vocational education. Implemented by Amrita Vishwa Vidyapeetham, this project aims to transition vocational education and training (VET) into the digital realm, enhancing resilience, accessibility, and quality, especially in response to challenges like the COVID-19 pandemic and the increasing presence of online and digital aspects of trade-businesses. As part of the initiative, Skill e-Labs packages were developed that provide immersive and interactive learning through videos, 3D simulations, virtual and augmented reality, and comprehensive assessments (in English and Hindi languages) for the Solar Technician and Electronic Mechanic trades.

After a successful development and review process by experts and stakeholders, a pilot phase was conducted in two National Skill Training Institutes (NSTI) and two Government Industrial Training Institutes (ITI) across India, involving 160 students and 18 instructors. The pilot evaluated the usability of the skill-eLab package, assessed the potential for scaling the initiative across other ITIs/NSTIs, and determined its effects on skill acquisition, retention, and learner confidence. Two teams of researchers and deployment engineers from AMMACHI Labs, Amrita Vishwa Vidyapeetham conducted the Skill-eLabs pilot across four locations. Each team covered two institutions sequentially, providing training, data collection, and mentorship for both students and instructors at each site.

The Skill-eLabs pilot study demonstrated significant positive outcomes across both student performance and instructor experiences. Students who used Skill-eLabs showed improved overall performance, enhanced practical skills, and increased adherence to safety protocols compared to the control group. Notably, when control group students later received Skill-eLabs training, the performance gap disappeared, highlighting the effectiveness of the digital learning tools. Instructors reported a substantial increase in their confidence to integrate technology into teaching, with median levels rising from 5.0 to 9.0 (out of 10) after the intervention. Both 3D simulations and AR/VR technologies were highly rated by instructors and students for enhancing learning engagement and practical skill development. While some technical challenges were noted, there was unanimous consensus among instructors recommending the Skill-eLabs package for future trainees, citing its ability to combine theory with hands-on training and boost employability.

Ultimately, we can say that the pilot results suggest that the Skill-eLabs training approach is a successful way to enhance vocational education and training by improving practical skills, increasing student engagement, boosting instructor confidence in technology integration, and better preparing trainees for real-world job scenarios. MSDE should strongly consider scaling up this approach to all NSTIs, ITIs, and similar institutions to modernize and strengthen India's vocational education system, thereby improving employability and supporting the country's skilled workforce development goals.

This report provides the detailed impact evaluation results, and recommendations based on the implementation of the skill-eLabs package at NSTI Dehradun, NSTI Mumbai, Govt. ITI Jhajjar, Haryana and Govt. ITI Bicholim, Goa conducted from 10-June-2024 to 4-July-2024.

1.1 Background of the Project: The Ministry of Skill Development and Entrepreneurship (MSDE), through the Directorate General of Training (DGT) and the National Instructional Media Institute (NIMI), in collaboration with industry partners, has developed high-quality e-content for Vocational Education and Training (VET) that is now available on its platforms. To ensure VET remains effective in an online environment, it is essential to upgrade the modes of practice and other pedagogies. Transitioning VET workshops to a digital format is a critical step forward, not only for social resilience (especially in the wake of COVID-19) but also for scaling quality education to enhance access and coverage across India.

To achieve the vision of providing quality e-content and simulation-based learning to all students (including those in secondary schools, ITIs, PMKVYs, and JSS), the concept of "Skill-eLabs" was introduced. These Skill-eLabs feature high-quality e-content and simulation-based learning, allowing students to experience real-world work environments, perform skills, learn through experience, safely operate complex or costly equipment, and understand safety protocols in an immersive setting. Skill-eLabs is unique, as it enables students to practice skills virtually in an engaging and gamified environment, as opposed to traditional e-content that mainly includes instructional videos, textual information, and quizzes. This approach aims to motivate students and enhance their engagement with various skills, ultimately improving their performance, including that of low-achieving students.

As part of the project, a portfolio of Skill e-Labs (virtual workshops or laboratories) was developed and hosted on the AMPLE platform. Access to the Skill e-Labs was enabled on computers (Virtual Reality, 3D simulations, videos, assessments) and smartphones (Augmented Reality, videos, assessments) in both English and Hindi languages.

The implementation of Skill-eLabs included a comprehensive "Train the Trainer" program designed to familiarize instructors with the new learning technologies and equip them to integrate these tools into their classrooms. During the pilot phase, instructors actively participated by observing mentor-led training sessions and supporting students, gaining hands-on experience with the Skill-eLabs package. Additionally, instructors provided valuable feedback through pre- and post-surveys, offering insights on the effectiveness of the package from an educator's perspective.

1.2 Selection of Trades and Practical Exercises: The selection of the two trades for developing the Skill e-Lab components (i.e., Solar Technician and Electronic Mechanic) was based on the availability of infrastructure in all the institutions under DGT and NIMI, the presence of expert instructors, and industry demands. DGT and NIMI experts provided systematic guidance in selecting these trades and the best-suited skill exercises for the entire curriculum. The priorities were set considering the exercises' complexities, equipment and components' availability, and job-specific requirements.

1.3 Skill-eLabs: Key Design Considerations: The following key considerations were integral to the design of Skill-eLabs:

- **Curriculum Alignment:** Ensuring that the content closely follows the official curriculum for ITIs/NSTIs to provide relevant and structured learning experiences.
- **Real-World Scenarios:** Incorporating practical, real-world situations to enhance the applicability of learned skills in actual vocational settings.
- **Safety Protocols:** Embedding safety guidelines and best practices to promote safe learning environments, especially in high-risk trades.
- **Engagement Features:** Integrating interactive elements, and immersive experiences, to keep students actively engaged.
- **Feedback Mechanism:** Providing real-time feedback to learners, enabling continuous improvement and reinforcing key concepts.
- **3D Environment:** Creating visually rich, 3D simulations that replicate real-world tools and processes, enhancing understanding through virtual practice.

These design considerations were essential to create an immersive, interactive, and effective learning experience that not only builds practical skills but also improves student retention, confidence, and safety awareness.

1.4 Skill-eLabs Components: The allocation of the mentioned skill lab components for the two job roles is illustrated in the following table:

Skill Lab Component	Solar Technician	Electronics Mechanic
Demonstration Videos	3 Videos	3 Videos
3D Simulation Exercises	3 Simulated Exercises	3 Simulated Exercises
Augmented Reality	1 AR	1 AR
Virtual Reality	1 VR	-
Assessment	Yes	Yes

Table 1: Skill-eLab Components for each trade

The Electronics Mechanic skill-eLabs package includes 3D simulations, augmented reality (AR), and interactive assessments, but does not feature a virtual reality (VR) module. This composition aligns with the original project scope and the specific learning objectives of the Electronics Mechanic curriculum.

1.5 Selected Exercises: The Skill-eLabs packages were developed for the following exercises.

Solar Technician trade modules				
S.No	Skill-eLabs Module	Year	Exercise number	Exercise name
1	Module	Year 1	79	To construct a home lighting system using solar panel
2	Module 2	Year 1	175	To assemble, install and commission of solar water pump
3	Module 3	Year 1	107	To construct a 1KW Solar PCU to 1 KW Solar panel installation

Table 2: Selected exercises for solar technician trade modules.

Electronics Mechanic trade modules				
S.No	Skill-eLabs Module	Year	Exercise number	Exercise name
1	Module 1	Year 2	296	Identify components & different sections of LCD and LED TV
2		Year 2	297	Identify components & different sections of LCD and LED TV
3		Year 2	299	Dismantle the given LCD/LED TV to find faults with input stages through connectors
4		Year 2	300	Detect defects in an LED/LCD TV receiver given to you. Rectify the fault.
5	Module 2 and Module 3	Year 2	301	Troubleshoot the faults in the given LED/LCD TV receiver- Locate and rectify the faults.
6		Year 2	302	Test LED/LCD TV after troubleshooting the defects.

Table 3: Selected exercises for electronic mechanic trade modules.

1.6 Purpose of the Evaluation: This evaluation aims to ensure that Skill-eLabs effectively meets the educational and practical needs of students in ITIs and NSTIs. It focused on assessing the usability and effectiveness of the Skill-eLabs package, identifying areas for improvement, and providing recommendations for scaling the development, implementation, and adoption of Skill-eLabs across ITIs and NSTIs.

2. Objectives

The objectives of the pilot study are as follows:

- **To assess skill acquisition** among Skill-eLabs participants by comparing their performance to a control group, and evaluating their proficiency in completing tasks during both simulated and traditional practical assessments.
- **To evaluate retention and recall abilities** by measuring participants' capacity to retain information and apply it practically after the training.
- **To investigate participants' perceived confidence** by assessing changes in their self-perceived abilities and confidence levels before and after Skill-eLabs training.

In addition to the above objectives, the study will also perform the following:

- To explore whether Skill-eLabs training can help all students, especially lower-achieving students in ITIs improve their learning outcomes and approach the performance levels of higher-achieving students from NSTIs**.**
- To explore how the Skill-eLabs package influences instructors' confidence in using technology and their perceptions of its ease of integration into vocational training.
- **Recommendations for Expansion:** The study will provide insights and suggestions for effectively scaling up the development of Skill-eLabs across ITIs and NSTIs.
- **Recommend Implementation and Adoption Strategies:** The report will outline suggestions for the successful implementation and adoption of Skill-eLabs.

3. Methodology

This section describes the participant's details, study design, ITI/NSTI locations, data collection, and data analysis in detail. It also describes how the pilot study was conducted in each institution in a general way.

3.1 Participants: In each institution, 20 student trainees were selected from the Solar Technician trade, and another 20 students were selected from the Electronic Mechanic trade. Overall, 40 students were selected from each institution, totaling 160 students from all four institutions. The participants for the Solar Technician trade were directly selected from that trade, and to complete the 20 slots, the remaining students were randomly selected from the Electrician or Wireman trades based on availability. For the Electronic Mechanic trade, 20 student trainees were randomly selected from a pool of 40 students in each institution. All the students signed a consent form before taking part in the pilot study.

3.2 Study Design: In this pilot study, a mixed methods approach was used to ensure a comprehensive understanding of the participants' experiences and the effectiveness of the technology. In the qualitative, exploratory part of the study, we gained insights that will help refine the technology and improve implementation strategies for future use. Since this technology had not been tested with the target audience, the study aimed to collect qualitative data through open-ended participant feedback to identify emerging themes. Separate sets of open-ended questions were tailored for the participants in the experimental and control groups to capture their distinct experiences and feedback.

In the quantitative part of the study, a pre-survey assessment was done. It assessed the participants':

- Prior work experience
- Experience with technology-enhanced learning
- Familiarity with safety PPE
- Motivation for choosing their respective trade
- Basic demographic variables

Further, we assessed instructor ratings of the participants' practical skills once the training was completed. We then used the instructor ratings as an outcome measure for an impact evaluation study.

Post-test-only control group design: To reduce costs and eliminate potential test-retest effects, a post-test-only control group design was opted. This was in recognition that the instructors might have rated the participants' practical skills differently the second time because they became more proficient in evaluating the students' skills.

Control and Experimental Groups: Altogether 40 participants comprised the experimental and 40 the control group for each of the two training courses (Solar Technician and Electronic Mechanic), with a total of 160 participants. To reduce the effects of confounding variables (such as pre-existing knowledge and skills) and ensure adequate internal validity, participants were randomly assigned to the experimental and control groups.

Procedure of Research Study:

- **Initial Phase:** In the experimental group, participants received training through the Skill-eLabs package, and in the control group (in this initial phase), participants received traditional training from an instructor. After the participants in both the experimental and control groups had completed their respective training courses, instructors observed them demonstrate their skills during a practical exercise session and rated their skills. For the impact evaluation study, we only considered the instructors' ratings of the practical skills that the participants had acquired as per the curriculum of the first module of the training, as the instructors only taught the first module. We then compared the instructors' ratings between the experimental and control groups.

- **Subsequent Phase:** In a subsequent phase of the study, the participants from the control group who had received training from an instructor also received the same Skill-eLabs training package as those from the experimental group. After the participants completed the Skill-eLabs training, instructors again rated their practical skills. In this way, we were able to assess the effects of receiving training first from an instructor and then additionally through the Skills-eLabs package.

Data collection through AMPLE: Questions regarding the participants' subjective perceptions of their knowledge, skills, and confidence were embedded within the AMPLE platform that was used for the Skill-eLabs package and were asked before and after each module. Further, a quiz via multiple-choice questions was part of the Skill-eLabs package training. The participants' responses to these questions delivered further data to explore their learning processes.

Mentor Involvement:

Two teams of mentors—researchers and deployment engineers from AMMACHI Labs, Amrita Vishwa Vidyapeetham—were deployed to implement the pilot at four institutions. They played a critical role in instructor training, student familiarisation with the technology, and the data collection process, supporting participants during both the familiarisation and assessment phases. The teams ensured accurate data collection and provided assistance to participants who struggled to meet the assessment criteria. All collected data were organised into an online document, and data cleaning was completed to ensure the integrity and accuracy of the results.

3.3 Procedure of the Study and Data Collection

Phase 1: Recruitment of Participants and Random Assignment to the Experimental and Control Groups

Student trainees were selected from two National Skill Training Institutes—NSTI Dehradun and NSTI Mumbai—and two Government Industrial Training Institutes—Govt. ITI Jhajjar, Haryana, and Govt. ITI Bicholim, Goa. They were then randomly assigned to either an experimental group or a control group. (see table 1).

<table>
<tr><th></th><th colspan="2">NSTI Dehradun</th><th colspan="2">NSTI Mumbai</th><th colspan="2">Govt. ITI Jhajjar, Haryana</th><th colspan="2">Govt. ITI Bicholim, Goa</th></tr>
<tr><td>Solar Technician</td><td colspan="2">n = 20</td><td colspan="2">n = 20</td><td colspan="2">n = 20</td><td colspan="2">n = 20</td></tr>
<tr><td>Electronic Mechanic</td><td colspan="2">n = 20</td><td colspan="2">n = 20</td><td colspan="2">n = 20</td><td colspan="2">n = 20</td></tr>
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</table>

Solar Technician	n = 10	n = 10	n = 10	n = 10	n = 10	n = 10	n = 10	n = 10
Electronic Mechanic	n = 10	n = 10	n = 10	n = 10	n = 10	n = 10	n = 10	n = 10

Table 4. Selection of the Participants from Four Training Institutes and Random Assignment to the Experimental and Control Groups

Phase 2: Pre-Survey and Technology Familiarization

Before any training took place, we assessed the participants' prior work experience, experience with technology-enhanced learning, familiarity with safety PPE, motivation for choosing their respective trade, and age in a pre-survey. This was followed by an orientation session in which each trainee was acquainted with the Skill-eLabs program. To promote comprehensive understanding, Electronics Mechanic student trainees engaged in exercises from the Solar Technician trade and vice versa.

Phase 3: Post-Test-Only Control Group Study

Phase 3 a): Implementation of the Training

The two experimental groups (Solar Technician and Electronic Mechanic trainees) received the training via Skill-eLabs, and the two control groups (Solar Technician and Electronic Mechanic trainees) received the first-module training via traditional instructions from an instructor. Post-assessment, the control group then received the Skill-eLabs training and were again assessed to determine the impact of this new training method.

In the experimental group, participants commenced their training on the AMPLE online portal, logging in with credentials provided by Amrita. The Skill-eLabs package consisted of videos, 3D simulations, and assessments. Pre-module and post-module quantitative and qualitative questions were embedded within the AMPLE platform. Data, including simulation scores and other relevant metrics, were collected directly on the AMPLE platform. An assessment consisting of multiple-choice questions (MCQs) was embedded within the package. To ensure skill acquisition and retention, specific assessment criteria were established. Each participant was required to achieve certain performance benchmarks to progress through the training. To move forward, each participant needed to score six or higher out of 10 on the MCQ assessment. If a participant did not meet this threshold, they were required to repeat the Skill-eLabs package until they achieved the passing score. The number of attempts were tracked. To sustain motivation and provide additional support, if a participant failed to pass after two attempts, a mentor would offer targeted guidance on which areas to focus in the Skill-eLabs package during the third attempt to help improve their score and understanding. This guidance is aimed to address specific learning gaps, ensuring that all participants have a fair chance to succeed. The quiz was not intended as a formal evaluation but as a tool to reinforce theoretical knowledge and was an integral part of the training pedagogy. The goal was to support student learning by allowing them to master fundamental concepts at their own pace, similar to the approach used in MOOCs.

Phase 3 b): Post-Test to Measure the Outcome of the Training

Once the participants in the two experimental groups passed the MCQ assessment of the Skill-eLabs package, they proceeded to a practical exercise session, where they were evaluated by instructors who rated several key skills needed for one of the exercises: use of personal protective equipment (PPE), level of support needed to complete the practical exercises, practical demonstration of skills, and achievement of the learning outcomes for the exercise.

Participants in the two control groups also demonstrated their skills during a practical exercise session after they completed the training and their skills were rated by the instructors according to the same criteria.

Phase 4: Participant Feedback

The final stage involved gathering participant feedback, which included qualitative, open-ended questions about their overall experience with the training and suggestions for improvement, as well as quantitative self-report questions assessing the usability and effectiveness of the Skill-eLabs package. Some students provided written feedback, while others submitted voice recordings, enriching the depth of the qualitative data.

Figures 1 and 2 illustrate the study design for the experimental and control groups.

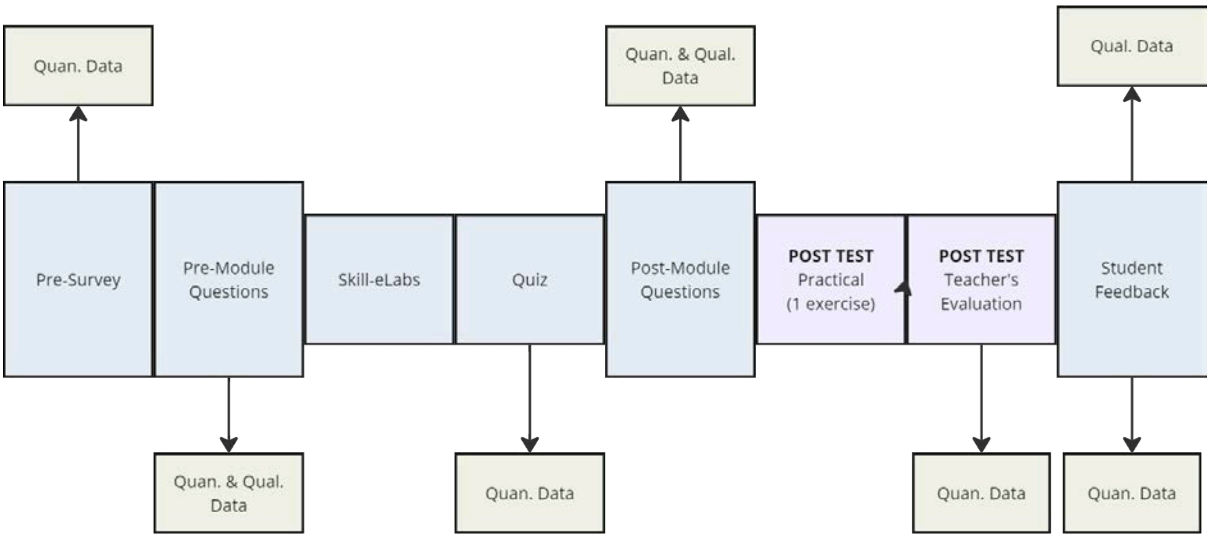


Figure 1: Experimental Group: Procedure of the Research Study

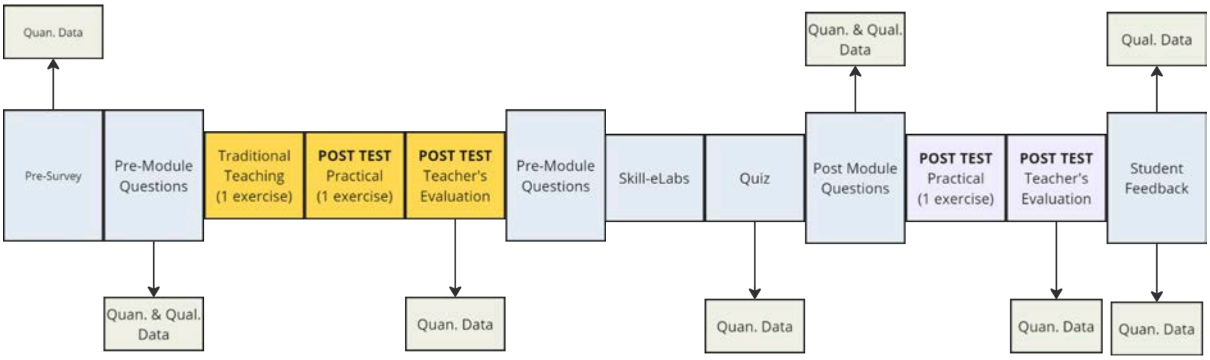


Figure 2: Control Group: Procedure of the Research Study

3.4 Implementation Schedule

A 10-day offline implementation was carried out across four institutions, with two deployment teams comprising 5 mentors (researchers and deployment engineers) from AMMACHI Labs, Amrita Vishwa Vidyapeetham. The first team commenced training at NSTI Mumbai, then continued at the Government Industrial Training Institute in Bicholim, Goa. Simultaneously, the second team conducted training at the Government Industrial Training Institute in Jhajjar, Haryana, before proceeding to NSTI Dehradun.

During the first 5 days, the focus was on training the Solar Technician trade trainees, followed by the Electronics Mechanic trade trainees in the remaining 5 days. On the first day, two mentors concentrated on training the vocational instructors in the use of 3D simulations, Augmented Reality (AR), and Virtual Reality (VR) simulations, ensuring they were equipped to support students effectively.

For the remainder of the program, the instructors also participated in the participants' training sessions, working closely with both the experimental and control groups. The instructors collaborated with the mentors, guiding the student trainees through the Skill-eLabs packages and traditional teaching methods, ensuring a comprehensive and hands-on learning experience for all involved.

Sl No	Institute	Deployment Team	Dates
1	NSTI Mumbai, Maharashtra	Deployment Team 1	10-June-2024 to 21-June-2024
2	Bicholim, Govt. Industrial Training Institute, Goa	Deployment Team 1	24-June-2024 to 4-July-2024
3	Govt. Industrial Training Institute, Jhajjar, Haryana	Deployment Team 2	10-June-2024 to 21-June-2024
4	NSTI Dehradun, Uttarakhand	Deployment Team 2	24-June-2024 to 4-July-2024

Table 5: Implementation schedules across centres.

SECTION B:

SOLAR TECHNICIAN: RESULTS AND ANALYSIS

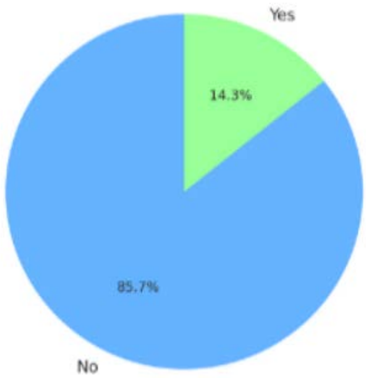
- Pre-Survey Results
- Improvement in Skill Acquisition and Knowledge
- Participant Feedback

Solar Technician

1. Pre-Survey Results

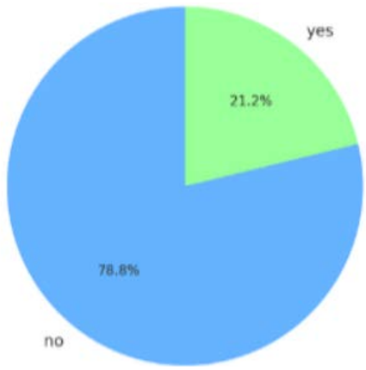
The participants for the Solar Technician trade were primarily selected from that trade. To fill the 20 remaining slots, students were randomly chosen from the Electrician or Wireman trades based on availability. The final cohort comprised 80 students, evenly divided into experimental (40) and control (40) groups. The majority of students were aged between 18 and 22 years, which aligns with the typical age range for vocational education. Notably, 81.8% of the students were first-generation learners, reflecting the diverse educational backgrounds within the cohort.

Prior work experience: A significant majority of the students (85.7%) reported having no prior work experience, indicating that many are likely transitioning directly from school or have limited exposure to the workforce. This lack of work experience may influence their approach to the training, potentially heightening the importance of acquiring practical skills for future employment.



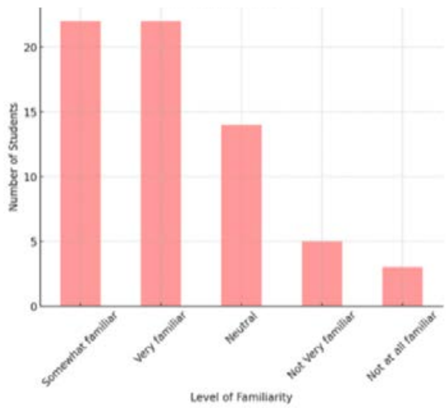
Prior work experience

Experience with technology-enhanced learning: The data also reveals that the majority of students (80.5%) lack prior experience with technology-enhanced learning. This is a critical factor, as it suggests that these students may require extra assistance or training to adapt to digital learning platforms, particularly when engaging with advanced learning technologies such as 3D simulations, augmented reality (AR), and virtual reality (VR).



Experience with technology enhanced learning

Familiarity with Safety PPE: The majority of students, 85.62%, exhibit a moderate to high level of familiarity with safety PPE. This suggests that most students have a reasonable understanding of how to handle protective equipment, an essential skill for working in the Solar Technician trade. However, 14.28% of the students report lower familiarity with PPE, indicating a need for additional training or support in this area to ensure comprehensive safety knowledge across the cohort.



Familiarity with Safety PPE

Motivation for Choosing the Solar Technician Trade: Objective for Selecting the Solar Technician Trade: When inquired about their rationale for choosing this trade, 42.42% of students indicated that their principal objective was to improve their employment opportunities. This indicates that career progression is a crucial factor in drawing students to the Solar Technician profession. Furthermore, 37.88% of the students demonstrated a sincere interest in the field, reflecting a harmonious motivation influenced by both enthusiasm and pragmatic factors. Additionally, 12.12% of the students choose the trade due to a passion for green energy, reflecting significant environmental motives among the cohort.

2 Improvement in Skill Acquisition and Knowledge

2.1 Statistical Comparison of Experimental and Control Groups

2.1.1 Highlights

Key findings

- **Significant improvement in Performance and Learning Outcomes:** Students who participated in the Skills-eLabs course demonstrated significantly higher overall performance and learning outcomes in practical tests compared to those in the control group.
- **Enhanced Autonomy:** The Skills-eLabs course effectively reduced the need for instructor assistance during practical exercises.
- **Improved Adherence to Safety Protocols:** Students who completed the Skills-eLabs course adhered more closely to safety protocols during practical exercises.

2.1.2 Detailed Statistical Analysis:

2.1.2.1 Pre-Intervention Baseline Data Comparison

During the pre-survey assessment, the following two key questions were asked and can be used to ensure that the experimental and control groups were similar in terms of their prior experience level:

1. *Do you have any prior experience with technology-based training, including video, 3D simulation, augmented reality (AR), virtual reality (VR), or similar methods? Responses were recorded as:*
   - *Yes*
   - *No*
2. *Please rate your familiarity with Personal Protective Equipment (PPE) on a scale from 1 to 5:*
   - *1 = Not familiar at all*
   - *2 = Not very familiar*
   - *3 = Neutral*
   - *4 = Somewhat familiar*
   - *5 = Very familiar*

Normality tests conducted on the responses to both questions indicated that the data distributions were non-normal. Consequently, non-parametric statistical methods were employed to compare the control and experimental groups.

For the Solar Technician course, a Chi-square test was conducted with 79 participants to examine differences in prior experience with technology-based training between the control and experimental groups. The proportion of participants who reported having no prior experience (80% in the experimental group and 79.5% in the control group) did not differ between the groups, X^2 (1, N = 79) = 0.003, p = .955.

Additionally, a Mann-Whitney U test was performed with 77 participants to assess differences in familiarity with PPE between the control and experimental groups. The results revealed a statistically significant difference in mean rank between the experimental group (31.71) and the control group (46.1), U=464, z=-2.944, p = .003. The median for the experimental group was 4.00 and the control group was 5.00.

2.1.2.2 Instructor Evaluation Measures Post Skill-eLabs Course

After participants completed the practical exercises for Solar Technician and Electronic Mechanics courses, an instructor from ITI/NSTI evaluated their performance during practical tasks. Participants were evaluated on their overall performance in practical tests and their achievement of the learning outcomes associated with specific exercises. The assessment was conducted using a Likert scale ranging from 1 to 5, with 1 representing "Poor" and 5 representing "Excellent." The following questions were posed:

> *Question 1: How would you rate the student's overall performance in the practical tests? (1 = Poor, 5 = Excellent)*

The practical evaluation was structured using a rubric, which was developed based on key performance criteria aligned with the DGT Assessment Criteria for *Professional Skills / Trade Practical.*

1. Technical skills in the use of tools
2. Accuracy achieved while undertaking work
3. Task completion efficiency (time taken to do the practicals)
4. Quality of work (neatness and consistency in the finish)

The average of the four criteria was calculated as the students performance in practical tests by the instructor.

> Question 2: *Has the student achieved the learning outcomes for the specific exercise? (1 = Poor, 5 = Excellent)*

To complement the practical evaluation, the learning outcomes achievement was rated based on the *Professional Knowledge* attained by the students.. This focused on the students' ability to understand, retain, and communicate theoretical concepts. Key evaluation areas included:

1. Understanding of key concepts
2. Comprehension of technical terminology
3. Accuracy in communicating concepts
4. Retention of information

Within each evaluation area, the instructors were given the opportunity to ask different questions in the evaluation process to check student's knowledge/skills. The average of the four criteria was calculated as the students' achievement of the learning outcomes for the specific exercise by the instructor.

An exploratory factor analysis was performed to examine the underlying structure of the responses. The results indicated that the two questions loaded onto a single factor, suggesting that they could be combined and analyzed as a unified construct. This factor represents a composite measure of students' overall performance and their attainment of the learning outcomes in the practical tests.

Refer Appendix C: Evaluation Questions and Rubrics for details

Question 3: How many times did the student require assistance or guidance from instructors to complete practical exercises?

Instructors also assessed the level of independence demonstrated by students during the completion of practical exercises. The assessment focused on the frequency with which students required assistance or guidance from instructors. The responses were recorded on a scale as follows:

- 0 times (1)
- 1-3 times (2)
- 4-6 times (3)
- More than 6 times (4)

Question 4: How many safety protocols did the student follow correctly during practical sessions, as per the checklist provided?

Finally, to measure student's attention to safety practices and their ability to apply the required safety standards consistently during practical tasks, instructors evaluated the extent to which students adhere to safety protocols during practical sessions using the scale below:

- 1 = None followed
- 2 = Some followed
- 3 = All followed

An Amrita mentor supervised this evaluation process, to ensure all the students went through a uniform evaluation process.

2.1.2.3 Instructor Evaluation Results

- An independent sample t-test was done to compare the student's overall performance and learning outcome in the practical tests in the experiment and control group. Experiment group students had statistically significantly higher performance (3.97 ± 0.794) than control group students (3.4 ± 1.45), $t(76) = 2.177$, $p = 0.033$.

- A Mann-Whitney U test was run on 76 participants to determine if there were differences in the number of times the student required assistance or guidance from instructors to complete practical exercises between control and experimental group. Median for the experiment group was 1.00 and the control group was 2.00. Mean rank for the experiment group (28.43) was significantly lower, $U=349$, $z=-4.375$, $p < .001$ than the control group (48.05).

- A Mann-Whitney U test was also run on 75 participants to assess whether there were differences in the adherence to safety protocols by students during practical exercises between the control and experimental groups. Median for the experiment group was 3.00 and the control group was 3.00. Mean rank for the experiment group (41.08) was significantly higher, U=589, z=-2.047, p = .041 than the control group (35).

2.2 Skill Acquisition of the Control Group after they Received an Additional Skill-eLabs Training

2.2.1 Highlights

Key Findings

- **Significant improvement in Performance and Learning Outcomes:** The Skill-eLabs course led to a statistically significant improvement in students' overall performance and mastery of learning outcomes.
- **Increased Independence:** The Skill-eLabs course effectively fostered student autonomy.
- **Improved Adherence to Safety Protocols:** The Skill-eLabs course also significantly increased students' adherence to safety protocols during practical exercises.

These findings suggest that differences between experiment and control group in independent task performance and adherence to safety protocols vanishes when the control group students also take the skill eLabs course.

2.2.2 Instructor Evaluation Results

After the control group participants went through the Skill-eLabs course:

- A paired samples t-test showed that a Skill-eLabs course elicited a statistically significant Improvement in students' overall performance and learning outcome (t(38)=-2.07, p = .045). The mean increased from 3.67 ± 1.562 prior to the Skill-eLabs course to 4.13 ± .978 after the Skill-eLabs course.
- A Wilcoxon signed-rank test showed that the Skill-eLabs course elicited a statistically significant decrease in students' requirement for assistance or guidance (Z = -4.344, p < .001). Prior to the skill eLabs course, the median for the number of assistance or guidance from instructors was 2(1-3 times). The median reduced to 1(0 times) after Skill-eLabs course.
- A Wilcoxon signed-rank test showed that the Skill-eLabs course elicited a statistically significant increase in the adherence to safety protocols by students during practical

exercises (Z = -2.585, p = .01). The median was 3 ("all followed") prior to the skill eLabs course and it was 3 ("all followed") after the Skill-eLabs course as well.

2.3 Comparison of NSTI and ITI Performance after Skill-eLabs Courses in Conceptual and Practical Skills

2.3.1 Highlights

Key Findings

- **Stronger Cognitive Performance among NSTI Students:** NSTI students demonstrated a significantly stronger grasp of the material assessed in both simulations and quizzes compared to ITI students. This suggests that NSTI students possess higher levels of understanding in these areas following the completion of the skill eLabs courses.

2.3.2 Improvement in Knowledge and Understanding (Performance in Quiz)

After completing the Skills-eLab course, student trainees participated in a multiple choice quiz to assess their knowledge levels. Each student completed three simulation exercises, and their simulation marks were recorded during the simulation exercise. Additionally, a formal quiz was administered at the end of each exercise. Students were permitted to make multiple attempts on the quiz to ensure they achieved a minimum score of 60%. The quiz was not intended as a formal evaluation but as a tool to reinforce theoretical knowledge and was an integral part of the training pedagogy. The goal is to support student learning by allowing them to master fundamental concepts at their own pace, similar to the approach used in MOOCs. Only after demonstrating a certain level of proficiency with the content could a student progress to the practical assessment.

In the first attempt of the quiz, nearly one-third of the ITI students did not pass. The table below shows the number of students who passed or failed each quiz attempt for both NSTI and ITI students:

	Quiz 1 (Pass)	Quiz 1 (Fail)	Quiz 2 (Pass)	Quiz 2 (Fail)	Quiz 3 (Pass)	Quiz 3 (Fail)
NSTI	37	3	31	9	31	9
ITI	27	12	23	16	28	11

Table 6: Quiz Pass and Fail comparison between NSTIs and ITIs in the first attempt.

A statistical comparison was made between the performance of NSTI and ITI students after both their first and final quiz attempts. It was observed that NSTI students consistently scored significantly higher than ITI students across all three simulation exercises and in the quiz. The results are presented below.

Comparison of simulation marks:

- Exercise 1: NSTI (78.68 ± 10.724), ITI (72.36 ± 9.745), $t(77) = -2.738$, $p = 0.008$
- Exercise 2: NSTI (85.65 ± 7.231), ITI (81.28 ± 7.993), $t(77) = -2.548$, $p = 0.013$
- Exercise 3: NSTI (86.15 ± 8.705), ITI (79.69 ± 7.392), $t(77) = -3.55$, $p < 0.001$

Comparison of first attempt of the quiz:

- Exercise 1: NSTI (7.7 ± 1.436), ITI (5.92 ± 2.018), $t(77) = -4.518$, $p < 0.001$
- Exercise 2: NSTI (6.98 ± 1.609), ITI (5.56 ± 1.635), $t(77) = -3.866$, $p < 0.001$
- Exercise 3: NSTI (6.63 ± 1.462), ITI (5.77 ± 1.842), $t(77) = -2.29$, $p = 0.025$

Comparison of final attempt of the quiz:

- Exercise 1: NSTI (7.93 ± 0.971), ITI (7.23 ± 1.327), $t(69.56) = -2.648$, $p = 0.01$
- Exercise 2: NSTI (7.55 ± 1.154), ITI (6.67 ± 1.009), $t(77) = -3.619$, $p < 0.001$
- Exercise 3: NSTI (7.25 ± 1.006), ITI (6.59 ± 1.019), $t(77) = -2.898$, $p = 0.005$

These findings indicate that NSTI students had a stronger grasp of the material and skills assessed in the simulations, suggesting a higher level of competency and understanding compared to their ITI counterparts following the completion of the skill-eLabs courses.

3 Participant Feedback

3.1 Impact of 3D Simulations

Key Insights from students' feedback from the three modules

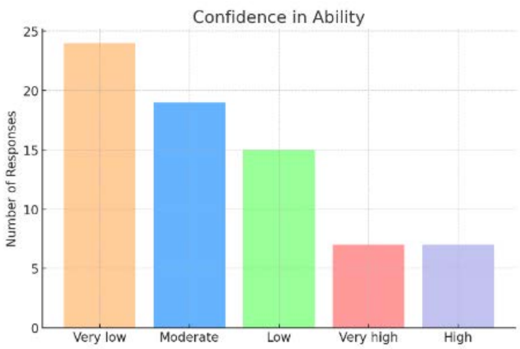
- **Boost in Confidence**: 68.5 to 87% of the students reported increased levels of confidence, with up to 61.54% of students feeling "very confident" after the simulations.

- **Improved Understanding**: Over 69% of students reported marked improvement in key concepts like solar panel placement and load calculation.
- **High Satisfaction**: More than 90% of students reported that the simulations are sufficient for their learning needs.
- **Real-World Readiness**: Most students felt prepared to apply their skills in real-world scenarios.

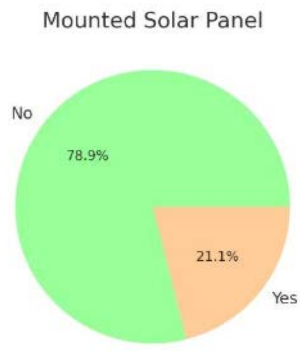
As part of the Skill-eLabs course and embedded within the package, the students were given a pretest before engaging with the Skill-eLabs package. The pre-module questions assessed their current self reported confidence levels and understanding of the exercise. After completing the 3D simulations and quiz, post module questions were administered, which evaluated their self reported understanding and confidence levels. In the solar module, there were three simulations, and the results are shared below.

3.1.1 Simulation 1: Solar DC Home Lighting System

The ***pre-module results*** provided valuable insights into the initial preparedness of the students before engaging with the simulation for installing a DC home lighting system. A majority of the students, 72.60%, reported having learned the relevant theory, while 27.40% had not. Additionally, the pre-test showed that 78.95% of students had never mounted a solar panel before, with only 21.05% having prior hands-on experience. When asked about their confidence in performing the tasks, 80.55% rated their confidence levels as very low, low, or moderate.

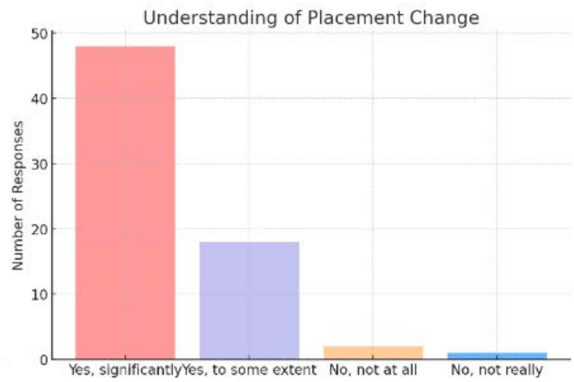


Confidence in ability

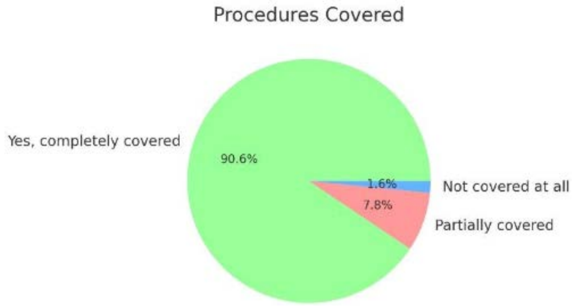


Mounted solar panel in real life

In contrast, the ***post-module results*** revealed a positive impact of the simulation on students' understanding and skills. After completing the simulation, 69.57% of students reported a significant improvement in their understanding of solar panel placement, with an additional 26.09% reporting some improvement. Only 4.35% reported no change, indicating the simulation was highly effective in enhancing comprehension of key concepts. Furthermore, 90.63% of students felt the procedures covered in the simulation were completely sufficient, demonstrating the simulation's ability to provide thorough and practical instruction.



Change in understanding of solar panel placement

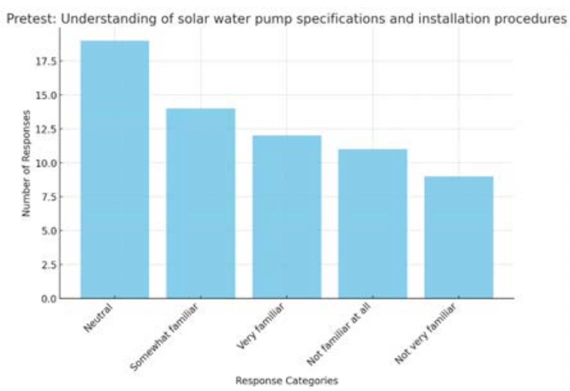


Procedures covered in the simulation

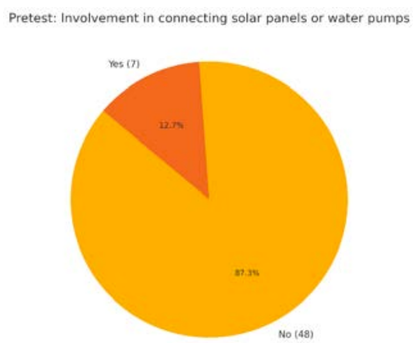
⭐ This suggests that the Skill-eLabs module had a positive impact on students' ability to grasp key concepts related to the installation and testing of solar home lighting systems.

3.1.2 Simulation 2: Solar Water Pump Installation

The ***pre-module results*** revealed a moderate baseline knowledge among students regarding solar water pump specifications and installation procedures. On a scale of 1 to 5, the majority of students (29.23%) rated their understanding as neutral, 21.54% felt somewhat familiar, and only 18.46% considered themselves very familiar. A significant portion, 16.92%, had no familiarity with the subject, while 13.85% had little familiarity. These results indicated that nearly half of the students had a neutral or somewhat familiar understanding, with only a small group feeling confident in their knowledge. Furthermore, 87.27% of students reported never having connected solar panels for water pumps before, underscoring the lack of hands-on experience among most participants. Only 12.73% had prior experience with these tasks, indicating that for the majority, the simulation would be their first practical exposure.

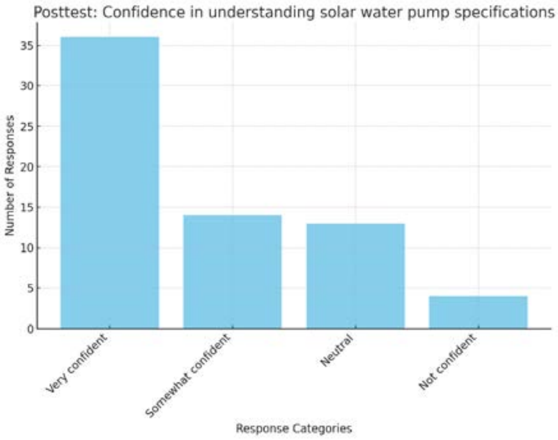


Understanding of Solar water pump procedures

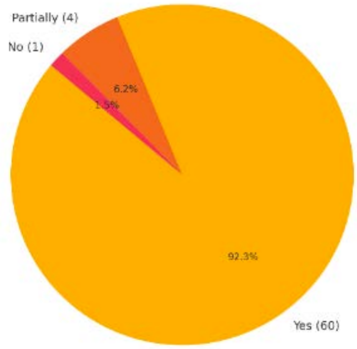


Involvement in connecting solar panels and water pump

The ***post-module results*** demonstrated a significant improvement in students' understanding and confidence after completing the simulation and tutorial videos. Nearly half of the students (49.32%) reported feeling very confident in their understanding of solar water pump specifications for agricultural work, a sharp increase from the pre-test. A further 19.18% felt somewhat confident, while 17.81% remained neutral. Only 5.48% reported not feeling confident after the simulation. Furthermore, when asked if they felt equipped to identify suitable locations for implementing a solar water pump, 92.31% of students responded positively, with only 6.15% feeling partially equipped and 1.54% feeling unequipped. These results suggest the simulation successfully translated theoretical knowledge into practical skills.



Confidence in understanding solar water pump specifications

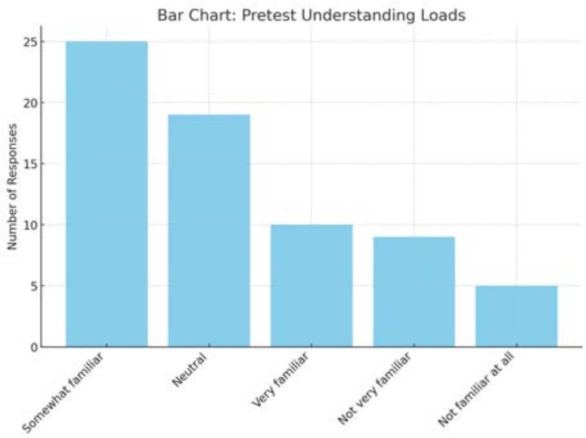


Equipped to identify suitable locations for implementing solar water pump

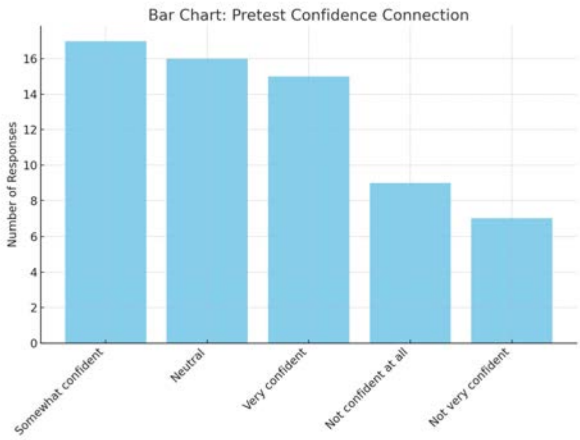
⭐ The results suggest that the Skill-eLabs module significantly improved participants' understanding of the specifications and installation procedures for solar water pumps.

3.1.3 Simulation 3: Solar Rooftop Installation

The ***pre-module results*** for Module 3 revealed varied levels of understanding and confidence in calculating loads for a solar energy system. Of the respondents, 36.76% rated themselves as "somewhat familiar" with the concept, while 27.94% remained neutral. A smaller portion (14.71%) felt "very familiar" with the process, but a notable percentage (20.59%) rated themselves as "not very familiar" or "not familiar at all." This distribution suggests that while a majority had a basic understanding of load calculation, many students lacked sufficient confidence in this essential aspect of solar system installation. Regarding safety measures, the pre-test showed a strong baseline knowledge, with 95.38% of students indicating familiarity with safety requirements for installing and operating solar energy systems. This high percentage suggests that safety protocols were well understood by most students, likely due to prior training or exposure to safety protocols in earlier simulations. Confidence in connecting solar components, however, was mixed: only 23.44% of students reported feeling "very confident," while 26.56% were "somewhat confident." Nearly half (49.44%) felt neutral or lacked confidence, with 14.06% stating they were "not confident at all" and 10.94% reporting they were "not very confident."

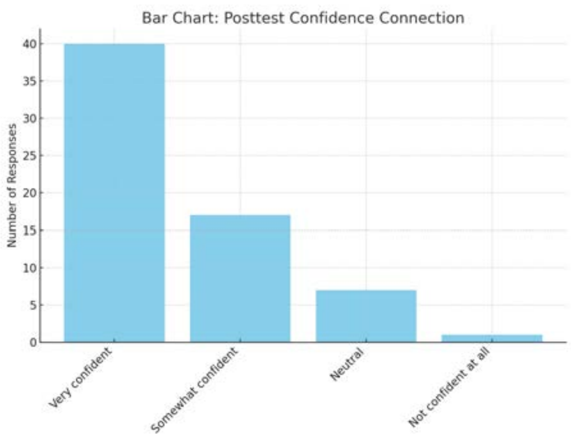


Familiarity in understanding load calculation

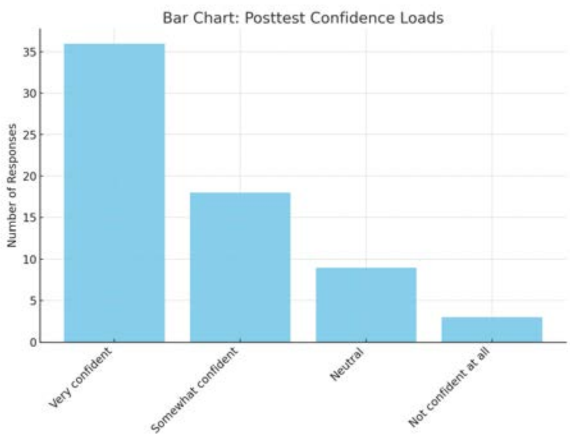


Confidence in connecting solar components

The ***post-module results*** revealed a notable increase in students' confidence across both focus areas. In terms of connecting solar components, 61.54% of students reported feeling "very confident," a significant increase from the pre-test. Additionally, 26.15% felt "somewhat confident," and only a small fraction (1.54%) remained "not confident at all." Similarly, confidence in calculating loads saw significant gains: 54.55% felt "very confident" in the post-test, compared to just 14.71% in the pre-module questions. Another 27.27% felt "somewhat confident," while the percentage of students who remained neutral or lacked confidence dropped to 18.19%, down from 41.18%. This increase in confidence demonstrates the effectiveness of the simulation in solidifying students' understanding of load calculations, a critical skill for ensuring the suitability of solar energy systems.



Confidence in connecting solar components



Confidence in load calculation

- **Change in confidence to connect the solar panel components:** The results of the paired t-test show the perceived progress in participants' confidence to connect the solar panel, PCU, battery, loads and other accessories for the 1KW system.

In addition to the t-test calculation a non-parametric test (Wilcoxon test) was performed to address statistical challenges attributed to the small sample size. Both statistical tests show the same results in significance.

Results show a statistically significant progress in the values of their confidence based on their prior understanding, after the Skill-eLabs module ($t = -6.204$, $p < .001$, $n = 60$). After the skill-eLabs module training ($M = 4.47$, $SD = 0.812$), participants reported significantly better confidence to connect the solar panel, pcu, battery, loads and other accessories for the 1kw system, than before the training ($M = 3.32$, $SD = 1.359$).

The results suggest that the Skill-eLabs module significantly increased participants' confidence in connecting solar panel components for a 1 KW system.

3.2 Impact of Augmented Reality Experience

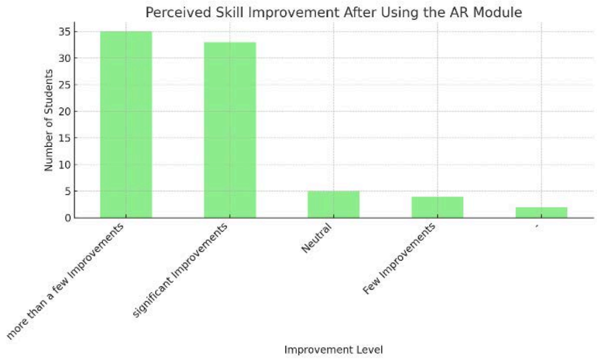
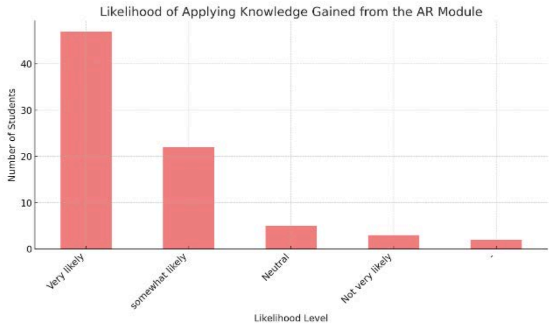
Key Insights from students' feedback

- **Skill Improvement**: 86.1% of students reported significant or moderate improvements in their skills.
- **Knowledge Application**: 87.7% reported improved confidence in remembering and applying the knowledge gained.
- **Key Themes from Qualitative Feedback**:
  - **Learning Enhancement**: Many Students reported enhanced understanding, in solar panel installation.
  - **Ease of Use**: Many students highlighted the user-friendly interface and interactive features.
  - **Practical Application**: Several students appreciated the real-world scenario simulations.
  - **Positive Feedback**: The majority of students described their learning experience as positive.

The Augmented Reality (AR) module was designed to train students on the optimal placement of solar panels, including determining the best angle and direction to maximize current generation. Additionally, the module aimed to help students understand the impact of environmental factors such as shade, obstacles, rain, and day/night cycles on solar energy production.

3.2.1 Quantitative Feedback on the AR Module

Following their interaction with the AR module, students were asked to respond to two quantitative questions to gauge their perceptions of the AR module's role in their learning process.

Question	Quantitative Evidence
Perceived Improvement in Skills: Students rated their perceived improvement in solar technician skills on a scale from 1 (minimal improvement) to 5 (significant improvement). The results suggest that a large proportion of students (86.1%) felt they experienced "Significant Improvements" or "More than a few Improvements."	 Perceived skill improvement after AR
Likelihood to Apply Knowledge: Students were also asked how likely they were to remember and apply the knowledge gained from the AR module when placing a solar panel, with ratings from 1 (unlikely) to 5 (very likely). The responses suggest that 87.7% of students felt "Very likely" or "Somewhat likely" to apply the knowledge gained.	 Likelihood of applying knowledge gained from AR

3.2.2 Qualitative Feedback on the AR Module

The qualitative assessment involved two questions aimed at exploring students' experiences with the AR module in more depth. The insights drawn from these thematic analyses are valuable but should be considered preliminary.

Learning New Skills or Reinforcing Existing Ones

The AR module was reported to significantly enhance students' understanding of solar panel installation, particularly in mastering the correct direction and positioning. Approximately 60% of participants highlighted these benefits, with around 35% focusing on new skill acquisition and 25% on reinforcing existing knowledge. The module's user-friendly interface and interactive elements were praised by about 40% of respondents, who found these features made learning smoother and more engaging. Additionally, 30% of students valued the practical application of skills, noting that the module effectively simulated real-world scenarios, which helped them better grasp hands-on tasks.

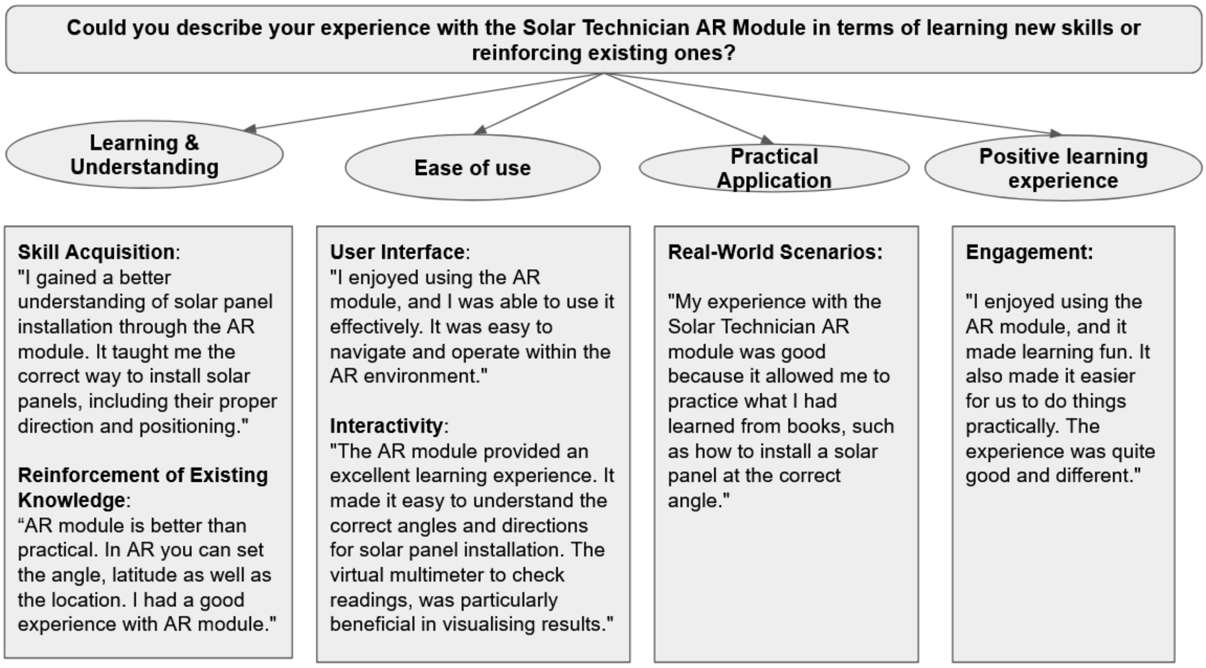


Figure 3: Thematic Analysis of Solar Technician Students' Responses to the Question: "Describe your Experience with the AR Module for Learning New Skills or Reinforcing Existing Skills."

Understanding and Retention Compared to Traditional Learning Methods

The AR module was perceived as a valuable tool for enhancing understanding and retention of solar technician concepts, with all participants (100%) noting improvements compared to traditional methods. A significant portion of students (70%) emphasized the module's interactive nature as key to better retention, while 60% appreciated the visual representation of concepts, which made complex ideas easier to understand. The ease of use and accessibility of the module were also highlighted by 87% of students, who found the interface user-friendly and the learning experience convenient. Furthermore, 77% of participants recognized the module's effectiveness in reinforcing practical skills through hands-on virtual experiences.

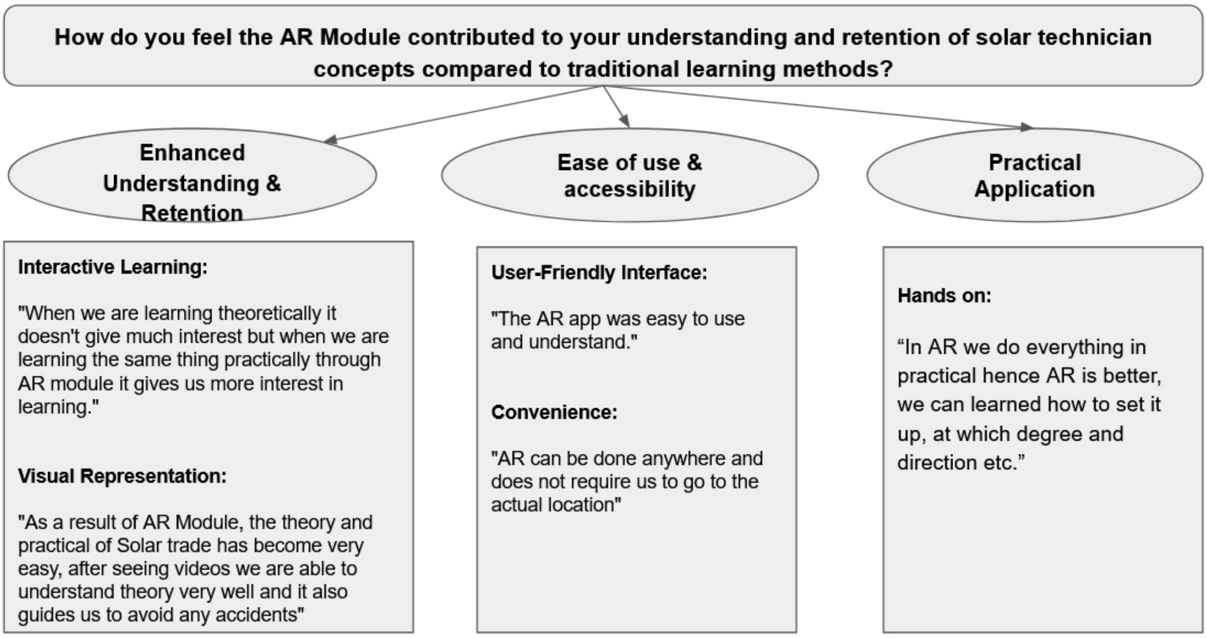


Figure 4: Thematic Analysis of Solar Technician Students' Responses on AR Module's Impact on Understanding and Retention Compared to Traditional Methods.

In summary, the AR module appears to be positively perceived by students, particularly in terms of its potential to enhance learning through skill acquisition, practical application, and retention of knowledge. The user-friendly interface and interactive elements were noted as significant contributors to this positive perception.

3.3 Impact of Virtual Reality Experience

Key Insights from students' feedback

- **High Usability**: 82.3% of students reported that the VR module is easy to use.
- **Effective Learning**: 85.4% of students reported that the VR module enhanced their learning compared to traditional methods.
- **Key Themes from Qualitative Feedback**:
  - **Realistic Simulation**: The VR environment closely mirrored real-world scenarios.
  - **Engaging Interactivity**: Interactive elements were vital for hands-on skill acquisition.
  - **User-Friendly Interface**: The interface was intuitive and easy to navigate.
  - **Improved Practical Skills**: The module enhanced practical understanding of procedures.
  - **Boosted Confidence**: Students reported increased confidence after using the VR module.

The Virtual Reality (VR) module was developed to offer students an immersive and realistic experience, focusing on the integration of all components necessary for rooftop solar installation, with particular attention to using safety PPE. Following the completion of videos, AR, and 3D simulations, students engaged with the VR module to further enhance their skills. Prior to this, all students participated in technology familiarisation training, which included comprehensive instruction on using VR, controllers, and navigating the virtual environment.

3.3.1 Quantitative Feedback on the VR Module

After interacting with the VR module, students provided self-reported ratings on two key aspects of their experience. These results offer preliminary insights on the experience.

<table>
<tr><th>Question</th><th>Quantitative Evidence</th></tr>
<tr><td>

Usability of the VR Module:
The majority of students (82.3%) rated the VR module as either "Very easy" or "Somewhat easy" to use, indicating a strong positive reception of the VR technology. Only a small percentage (3.2%) found the module difficult to use, while 14.5% remained neutral. These findings suggest that the VR module is generally well-designed and user-friendly.

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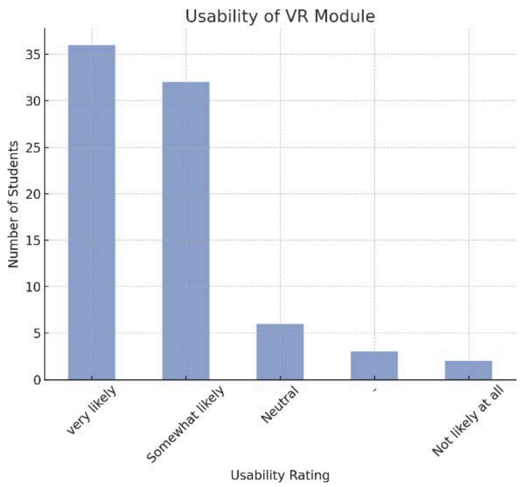

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Effectiveness Compared to Traditional Methods:
An overwhelming majority (85.4%) of respondents either "Strongly Agreed" or "Agreed" that the VR module offered a more effective learning experience than traditional methods. Only 3.2% disagreed, while 11.3% remained neutral. These self-reported responses suggest that students perceive the VR module as an enhancement over traditional learning methods.

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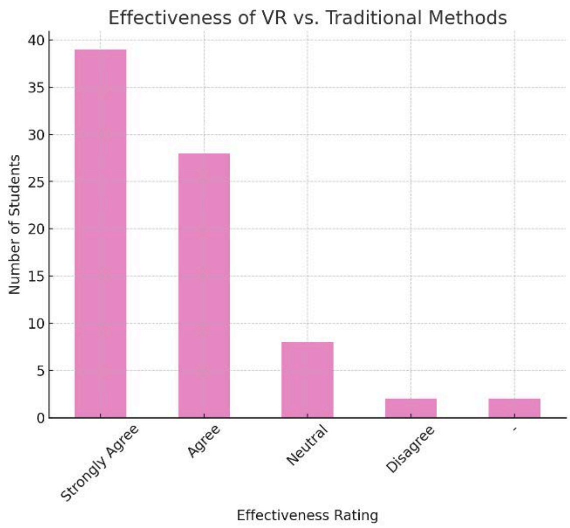

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Overall, these preliminary findings suggest that students generally view the VR module as effective and user-friendly.

3.3.2 Qualitative Feedback on the VR Module

The qualitative assessment included two questions designed to delve deeper into students' experiences with the VR module. While the insights gained from the thematic analysis are valuable, they should be viewed as preliminary findings.

User-Friendly and Intuitive Aspects for Skill Acquisition

The VR module was perceived as a valuable tool for skill acquisition, with 30% of students highlighting realistic simulation as crucial for understanding real-world applications. Additionally, 35% of students found the interactive elements, such as hands-on activities and immediate feedback, to be highly engaging and essential for learning. The user interface was described as intuitive and easy to navigate by 20% of respondents, contributing to a smoother learning process. 15% of students noted that the immersive nature of the VR module enhanced their engagement and motivation.

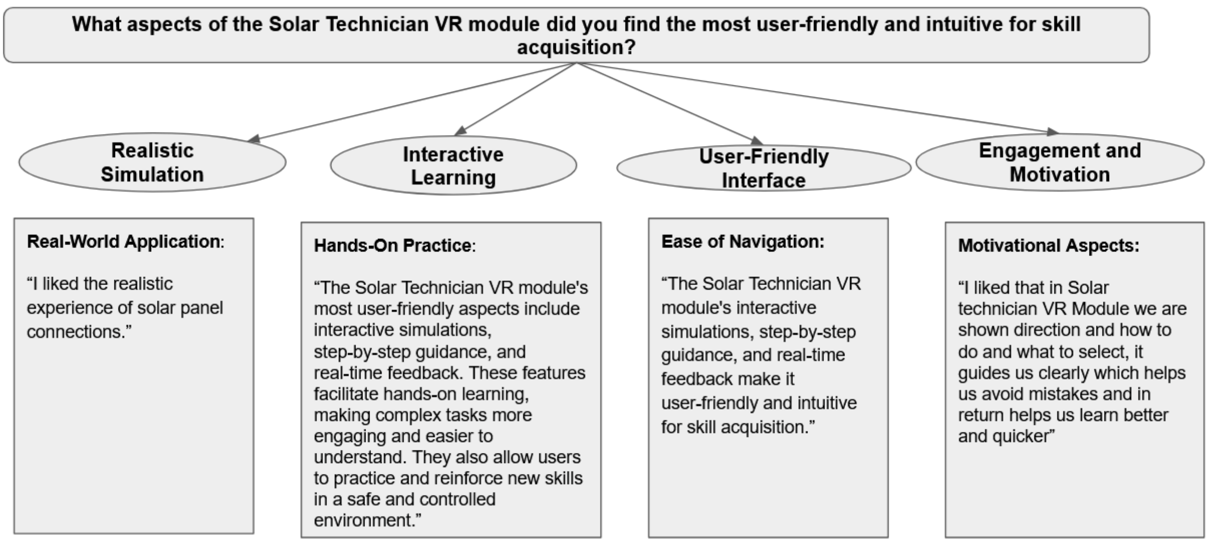


Figure 5: Thematic Analysis of Solar Technician Students' Responses to the Question: "What aspects of the VR modules did you find the most user-friendly and intuitive for skill acquisition?"

Enhancing Understanding of Complex Procedures or Concepts

The VR module was effective in enhancing students' practical understanding, with 60% of participants reporting that it improved their ability to simulate real-world tasks. The realistic experience provided by the VR environment was appreciated by many (40%), while 20% emphasized the importance of safety procedures highlighted in the module. Additionally, 33% of students noted that the VR module clarified complex concepts, particularly those related to system connections and component functions. A smaller portion of students (13%) reported increased confidence in performing tasks independently after using the module, thanks to the opportunity to practice in a risk-free environment. These findings indicate the VR module's strong potential to enhance both practical skills and conceptual understanding, though further research is needed to confirm these perceptions.

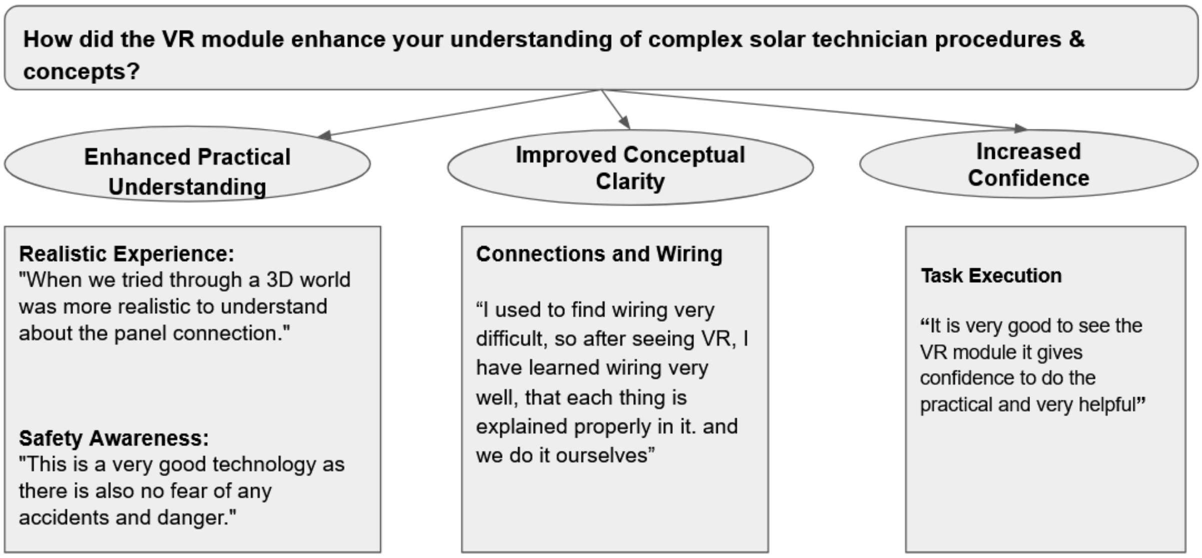


Figure 6: Thematic Analysis of Solar Technician Students' Responses to the Question: "How the VR module enhanced your understanding of complex solar technician procedures and concepts?"

In summary, the VR module received positive self-reported ratings, with the majority of students finding it easy to use and agreeing that it provided a more effective learning experience than traditional methods. Additionally, the module was noted for enhancing skill acquisition, understanding of complex procedures, and offering realistic, hands-on experiences, with many students highlighting its immersive and user-friendly design.

3.4 Overall Student Feedback Using Skill-eLabs Package

Key emerged themes from student feedback

- **Safety and Risk Management**: Skill-eLabs provides a safer alternative to real-world exercises, allowing students to experiment freely.
- **Enhanced Learning and Confidence**: Simulations and repeated exercises improve comprehension, and confidence..
- **Resource and Time Efficiency**: The use of virtual simulations reduces material wastage and resource consumption, making it a sustainable option.
- **Realism Gap**: There is a noted gap in hands-on experience, suggesting that physical practical exercises remain crucial.
- **VR/AR Engagement**: Immersive technologies significantly enhance engagement and understanding.

A thematic analysis was conducted on the qualitative data collected from participants who shared their experiences through open-ended survey responses. This analysis identified key themes, sub-themes, and included relevant direct quotes from the participants. The following sections present a summary of the key findings from the thematic analysis, based on the feedback provided by the students.

1. Safety and Risk Management

The analysis revealed that safety was a significant advantage of using the skill-eLabs platform. Many participants (60%) highlighted the risk-free learning environment as a notable improvement over traditional practical exercises, which involve hazards like electric shocks and short circuits. This was particularly emphasised in the context of virtual reality (VR) modules, where students could make mistakes without fear of damaging equipment or injuring themselves. Participants appreciated the controlled, simulated environments, which allowed for safer experimentation, fostering a deeper focus on learning rather than managing risk.

> *"In VR and normal practicals, I noticed that in normal we are able to learn and understand quicker... there is no fear of damage to equipment and in practical you cannot make mistakes"*

2. Learning and Understanding; Improved Confidence

The skill-eLabs platform was praised for enhancing learning through its interactive nature. Over (70%) expressed that Skill-eLabs simulations and VR modules facilitated better comprehension. Improved confidence (30%) in performing solar technician tasks was another prominent theme, as participants gained hands-on experience in wiring, installation, and component-specific knowledge. The ability to repeat exercises multiple times, without the constraints of time or resource consumption, allowed learners to reinforce their understanding and skills. This capability proved particularly useful in solidifying theoretical knowledge through practical application.

> *"Skill e-labs exercises give us the opportunity to learn in detail with assistance. An exercise can be repeated again and again; there is no wastage of time and materials"*

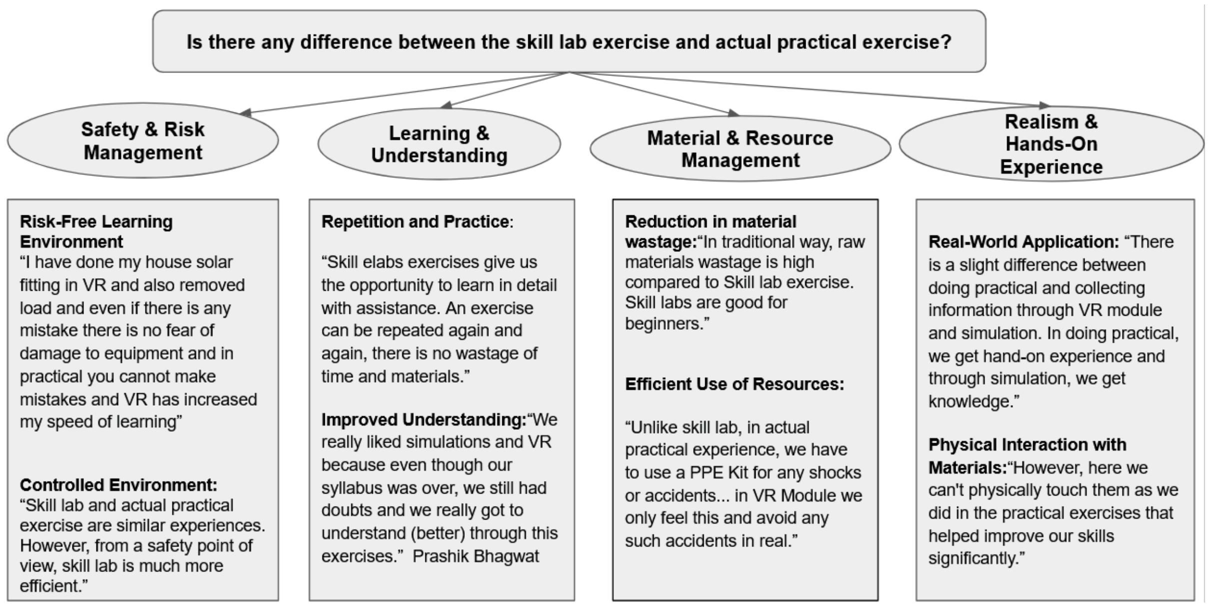


Figure 7: Thematic Analysis of Solar Technician Students' Responses to the Question: "Is there any difference between the skill lab exercise and actual practical exercise ?"

3. Material and Resource Management; Time Efficiency

Twenty-five participants (50%) pointed out that using the skill-eLabs platform resulted in more efficient resource use. Unlike traditional practical exercises, which often result in high material wastage (e.g., wires and other consumables), simulations allowed students to practise tasks without consuming physical resources. This not only reduced costs but also made the exercises more sustainable, a crucial consideration for vocational training. Time efficiency (24%) was also highlighted, with many noting the ability to learn complex tasks in a much shorter time than traditional methods.

> *"In traditional ways, raw material wastage is high compared to Skill lab exercises. Skill labs are good for beginners"*

4. Realism and Hands-on Experience

While the simulations offered safety and resource efficiency, some students expressed concerns about the lack of realism and physical interaction with materials. Twenty participants (40%) indicated that the skill-eLabs exercises, despite their educational value, did not fully replicate the hands-on experience gained from real-world tasks. This gap was noted in terms of using actual tools and physically handling materials, which are critical for developing fine motor skills necessary in solar panel installations and maintenance.

> *"There is a significant difference between skill lab exercises and actual practical exercises. In practical we use real tools, whereas in skill lab exercise we don't use any real tools (only virtual tools)"*

5. Engagement through VR and AR

The most engaging aspects of the skill-eLabs package were its VR and AR components, with 58% of participants highlighting these features. Students found the immersive, game-like environment enjoyable and educational, which helped them better understand complex concepts like wiring and solar panel setups. The gamified learning process contributed to higher engagement levels, making the learning experience more interactive and fun compared to traditional methods.

"The VR module with the game (3D effect) was the most interesting"

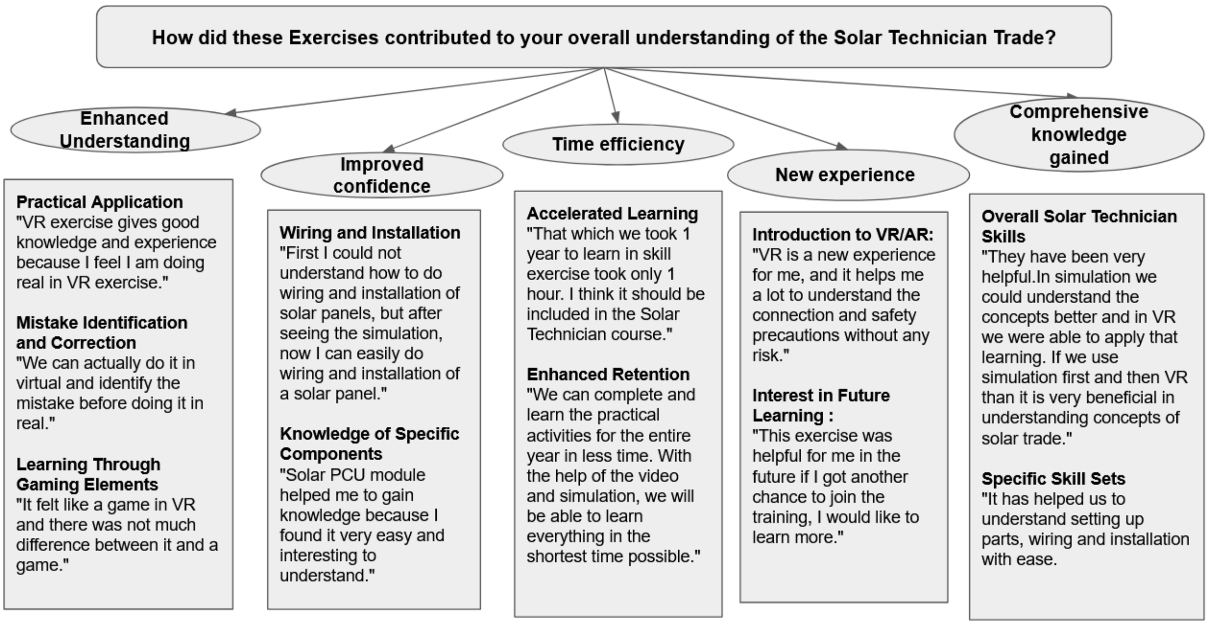


Figure 8: Thematic Analysis of Solar Technician Students' Responses to the Question: "How did these exercises contribute to your overall understanding of the solar technician trade ?

6. Challenges Encountered

Although the majority of students did not encounter significant challenges, 15% of participants reported technical issues with the VR/AR modules. These included system glitches and discomfort using the VR headsets. Some students (5%) also struggled with understanding specific tasks, such as wiring connections or tool usage. These challenges were typically resolved through additional instruction or assistance from instructors.

"In VR module I had trouble operating the button the first time but later I understood everything"

7. Improvements Suggested

Several areas for improvement were suggested by the students. Enhancements to the graphics and realism of VR/AR simulations were recommended by 17.8% of participants. Additionally, some students (8.3%) noted language barriers in understanding complex instructions, especially in Hindi, which could be addressed by simplifying the language or incorporating familiar terms. Immediate feedback mechanisms during exercises and post-test evaluations were also requested by 11.9% of participants, indicating the need for real-time correction to facilitate better learning outcomes.

"Provide immediate constructive feedback in assessments. This can help learners correct mistakes and understand the material deeply"

SECTION C:

ELECTRONICS MECHANIC-RESULTS AND ANALYSIS

- Pre Survey Results
- Improvement in Skill Acquisition and Knowledge
- Student Reported Feedback (Skill-eLab package)

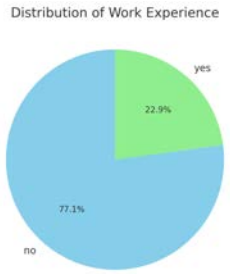
Electronics Mechanic

1. Pre-Survey Results

The pilot study for Electronics Mechanic, 20 student trainees were randomly selected from a pool of 40 students enrolled in the Electronic Mechanic trade at the four participating institutions, which included two ITIs and two NSTIs.

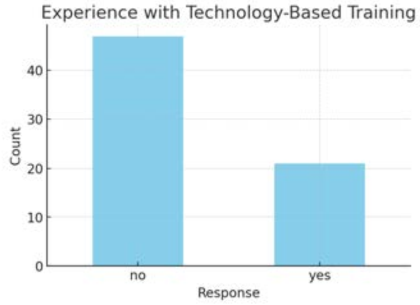
The total cohort for the study comprised 80 students, evenly split into experimental (40) and control (40) groups. This structure allowed for a comparative analysis of the effects of the interventions used in the experimental group versus traditional methods employed in the control group. The age distribution within the cohort showed a diverse range, with a notable concentration of younger students; 84.3% of the participants were between the ages of 16 and 25, while the remaining 15.7% were in the 26-35 age bracket. Notably, 85.7% of the students were first-generation learners in Vocational Education Training (VET).

Prior work experience: A significant 77.1% of the students had no prior work experience, indicating that the majority were likely encountering practical, vocational skills for the first time.



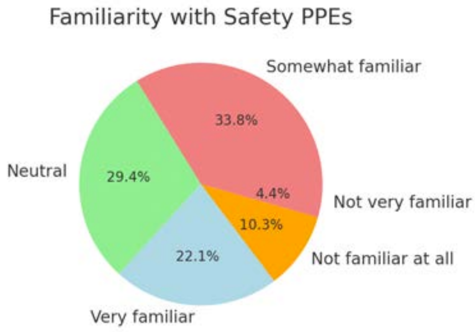
Distribution of work experience

Experience with technology enhanced learning: A significant majority, 60.5%, reported having no prior experience with technology-based training methods such as AR, VR, or simulation, suggesting that a considerable portion of trainees may require introductory or foundational exposure to these technologies. Only 39.5% have experience, indicating that while there is some familiarity, the majority may benefit from basic training modules to bring them up to speed with modern, technology-enhanced learning tools.



Technology based training experience

Familiarity with Safety PPE: In terms of familiarity with PPE 78.4% of respondents are moderately or highly familiar with its use, while 26.3% remain neutral in their knowledge. However, a small but notable percentage (5.2%) are not very familiar or completely unfamiliar with PPE, highlighting a potential gap in safety training that should be addressed to ensure all trainees meet basic safety standards. This suggests that, although a majority have some level of understanding, there is still a need for comprehensive PPE training, especially for those less familiar.



Familiarity with safety PPEs

Motivation for Choosing the Electronics Mechanic Trade: When it comes to motivations for choosing the electronic mechanic trade, 44.7% of respondents cited genuine interest in the field as their primary reason, while 39.5% chose the trade to enhance their job prospects, making these two factors the dominant motivators. Additionally, 10.5% of respondents are driven by a passion for electronics, and a smaller group, 5.3%, cited external influences, such as family or societal pressures, as their reason for entering the trade. This distribution indicates that the training program should not only focus on improving job prospects but also nurture the genuine interest and passion that many participants have for the trade. By aligning the training content with these motivations, the program can better engage trainees and help them build both the skills and enthusiasm needed for long-term success in the field.

2 Improvement in Skill Acquisition and Knowledge

2.1 Comparison of Experimental and Control Groups

2.1.1 Highlights

Key findings

- **Significant improvement in Performance and Learning Outcomes:** Students who participated in the skills eLab course demonstrated significantly higher overall performance and learning outcomes in practical tests compared to those in the control group

- **Increased Independence:** The skills eLab course effectively reduced the need for instructor assistance during practical exercises

- **Improved Adherence to Safety Protocols:** Students who completed the skills e-lab course adhered more closely to safety protocols during practical exercises

2.1.2 Detailed Statistical Analysis:

2.1.2.1 Pre-Intervention Baseline Data Comparison:

During the pre-survey assessment before the beginning of the training, the following two key questions were also asked in the Electronics Mechanics group and can be used to ensure that the experimental and control groups were similar regarding their prior experience level:

3. *Do you have any prior experience with technology-based training, including video, 3D simulation, augmented reality (AR), virtual reality (VR), or similar methods? Responses were recorded as:*
    - *Yes*
    - *No*
4. *Please rate your familiarity with Personal Protective Equipment (PPE) on a scale from 1 to 5:*
    - *1 = Not familiar at all*
    - *2 = Not very familiar*
    - *3 = Neutral*
    - *4 = Somewhat familiar*
    - *5 = Very familiar*

For the Electronic Mechanic course as well, normality tests conducted on the responses to both pre-test questions indicated that the data distributions were non-normal. Consequently, non-parametric statistical methods were employed to compare the control and experimental groups.

A Chi-square test was conducted with 68 participants to examine differences in prior experience with technology-based training between the control and experimental groups. The proportion of participants who reported having no prior experience (61.5% in the experimental group and 79.3% in the control group) did not differ between the groups, X2 (1, N = 68) = 2.461, p = .117.

Also, a Mann-Whitney U test was performed with 68 participants to assess differences in familiarity with PPE between the control and experimental groups. The results revealed a statistically significant difference in mean rank between the experimental group (38.97) and the control group (28.83), U=400, z=-2.184, p = .029. The median for the experimental group was 4.00 and the control group was 3.00.

2.1.2.2 Instructor Evaluation Results

- An independent sample t-test was done to compare the students' overall performance and learning outcome in the practical tests in the experiment and control group. Experimental group students had statistically significantly higher performance (4.138 ± 0.76) than control group students (2.95 ± 1.57), t(78) = 4.311, p

< 0.001.

- A Mann-Whitney U test was run on 76 participants to determine if there were differences in the number of times the student required assistance or guidance from instructors to complete practical exercises between control and experimental group. Mean rank for the experiment group (32.03) was significantly lower, U=461, z=-2.823, p = .005 than the control group (45.69). The median for the experiment group was 2.00 and the control group was 2.00.

- A Mann-Whitney U test was run on 79 participants to assess whether there were differences in the adherence to safety protocols by students during practical exercises between the control and experimental groups. Mean rank for the experiment group (48.45) was significantly higher, U=442, z=-3.835, p < .001, than the control group (31.33). Median for the experiment group was 3.00 and the control group was 3.00.

2.2 Skill Acquisition of the Control Group After they Received an Additional Skill-eLabs Training

2.2.1 Highlights

Key Findings

- **Significant improvement in Performance and Learning Outcomes:** The Skill-eLabs course led to a statistically significant improvement in students' overall performance and mastery of learning outcomes.

- **Increased Independence:** The Skill-eLabs course effectively fostered student autonomy.

- **Improved Adherence to Safety Protocols:** The Skill-eLabs course also significantly increased students' adherence to safety protocols during practical exercises.

These findings suggest that differences between experiment and control group in independent task performance and adherence to safety protocols vanishes when the control group students also take the skill eLabs course.

2.2.2 Instructor Evaluation Results

After the control group participants went through the Skill-eLabs course:

- A paired sample t-test showed that a skills e-lab course elicited a statistically significant Improvement in student's overall performance and learned outcome (t(39)=-7.353, p < .001). The mean increased from 2.95 ± 1.57 prior to the skill Elabs course to 4.21 ± 1.04 after the skill eLabs course.

- A Wilcoxon signed-rank test showed that the Skills-eLab course elicited a statistically significant decrease in student's requirement for assistance or guidance (Z = -4.478, p < 0.001). Prior to the skill eLabs course, the median for the number of assistance or guidance from instructors was 2 (1-3 times). The median reduced to 1 (0 times) after the skill eLabs course.

- A Wilcoxon signed-rank test showed that the Skills-eLab course elicited a statistically significant increase in the adherence to safety protocols by students during practical exercises (Z = -4.231, p < 0.001). The median was 2 (“some followed”) prior to the skill eLabs course and it improved to 3 (“all followed”) after the skill eLabs course.

2.3 Comparison of NSTI and ITI performance after Skill Elabs courses in conceptual and practical skills

2.3.1 Highlights

Key Findings

- **Stronger Cognitive Performance among NSTI Students:** NSTI students demonstrated a significantly stronger grasp of the material assessed in both simulations and quizzes compared to ITI students. This suggests that NSTI students possess higher levels of understanding in these areas following the completion of the skill eLabs courses.

2.3.2 Improvement in Knowledge and Understanding (Performance in Quiz)

After completing the e-skills lab course, students participated in a quiz to assess their knowledge levels. Each student completed three simulation exercises, and their simulation marks were recorded during the simulation exercise. Additionally, a formal quiz was administered at the end of each exercise. Students were permitted to make multiple attempts on the quiz until they achieved a score of at least 60%.

In the first attempt of the quiz, more than one-third of the ITI students did not pass. The table below shows the number of students who passed or failed each quiz attempt for both NSTI and ITI students:

Although ITI students initially had a lower pass rate compared to NSTI students, after three attempts, all ITI students were able to reach a performance level comparable to that of NSTI students.

	Quiz 1 (Pass)	Quiz 1 (Fail)	Quiz 2 (Pass)	Quiz 2 (Fail)	Quiz 3 (Pass)	Quiz 3 (Fail)
NSTI	34	5	33	6	37	2
ITI	16	23	27	11	30	8

Table 7 - Quiz Pass and Fail comparison between NSTIs and ITIs

A statistical comparison was made between the performance of NSTI and ITI students after both their first final quiz attempts. It was observed that NSTI students consistently scored significantly higher than ITI students across all three simulation exercises and in the quiz. The results are presented below.

Comparison of simulation marks:

- Simulation 1: NSTI (90.54 ± 7.394), ITI (80.18 ± 9.917), $t(77) = -5.255$, $p < 0.001$
- Simulation 2: NSTI (88.82 ± 7.178), ITI (83.54 ± 9.564), $t(76) = -2.759$, $p = 0.007$
- Simulation 3: NSTI (91.08 ± 6.339), ITI (84.26 ± 9.885), $t(64.729) = -3.627$, $p < 0.001$

Comparison of first attempt of the quiz:

- Simulation 1: NSTI (7.26 ± 1.650), ITI (5.18 ± 1.852), $t(77) = -5.27$, $p < 0.001$
- Simulation 2: NSTI (7.41 ± 1.428), ITI (6.03 ± 2.058), $t(76) = -3.452$, $p < 0.001$
- Simulation 3: NSTI (8.49 ± 1.254), ITI (6.51 ± 1.790), $t(76) = -5.642$, $p < 0.001$

Comparison of final attempt of the quiz:

- Simulation 1: NSTI (7.62 ± 1.067), ITI (6.95 ± 1.197), $t(77) = -2.606$, $p = 0.011$
- Simulation 2: NSTI (7.72 ± 1.099), ITI (7.23 ± 1.012), $t(76) = -2.036$, p 0 0.045
- Simulation 3: NSTI (8.49 ± 1.254), ITI (7.18 ± 1.211), $t(76) = -4.684$, $p < 0.001$

⭐ These findings indicate that NSTI students had a stronger grasp of the material and skills assessed in the simulations, suggesting a higher level of competency and understanding compared to their ITI counterparts following the completion of the skill-eLabs courses.

3. Participant Feedback

3.1 Impact of 3D Simulations

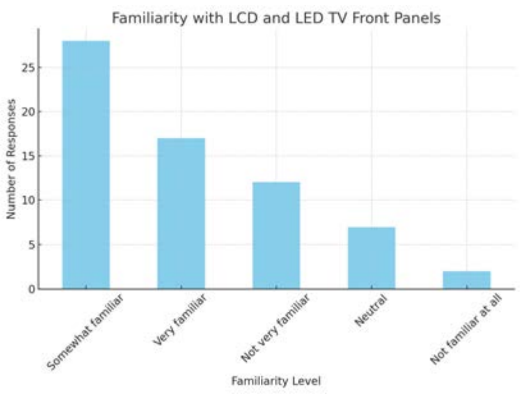
Key Insights from students' feedback

- **Confidence Boost:** Post-simulation, 77.46%-80.8% of students felt increased confidence in handling the procedures
- **Improved understanding of the process:** 93.33% reported that they successfully followed steps in the simulation; 12.9% struggled with identifying indicators and controls.
- **High Engagement:** 75.3% of students were highly engaged; only 1.4% were slightly engaged.

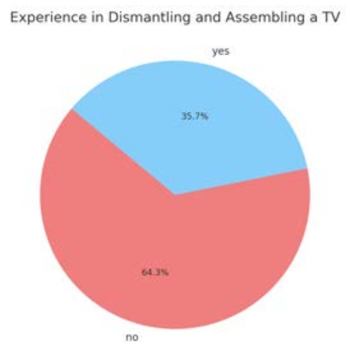
The students were given pre-module questions before engaging with the skill-eLabs packages. The pre-test assessed their current confidence levels and understanding of the exercise. After completing the 3D simulations and quiz, post-module questions were administered, which again evaluated their understanding and confidence levels. In the electronics mechanic trade, there were three simulations, and the results are shared below.

3.1.1 Simulation 1 - Dismantling & Identification of internal parts of LED/LCD tv.

In pre module results, 78.79% students voted a moderate to high level of familiarity with the front panels of LCD and LED TVs. Despite this familiarity, 64.29% had never dismantled or assembled a TV, indicating a significant gap in hands-on experience. This lack of practical exposure likely impacted their overall confidence and understanding of the hardware.

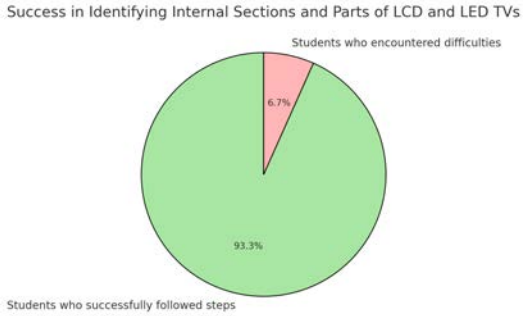


Familiarity with LCD/LED front panels

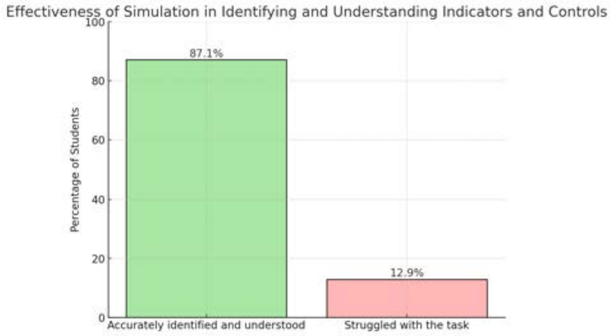


Experience in dismantling and assembling a TV

In post module results, In terms of practical application, 93.33% of students were able to successfully follow the steps in the simulation to identify internal sections and parts of LCD and LED TVs. However, 6.67% encountered difficulties, signaling the need for minor adjustments to better accommodate diverse learning styles. The simulation's effectiveness is further emphasized by the fact that 87.1% of students were able to accurately identify and understand the indicators and controls on the virtual front panels post-simulation. A small group, 12.9%, struggled with this task, suggesting that additional instructional support may be required to address their difficulties.



Success in identifying internal sections of TV

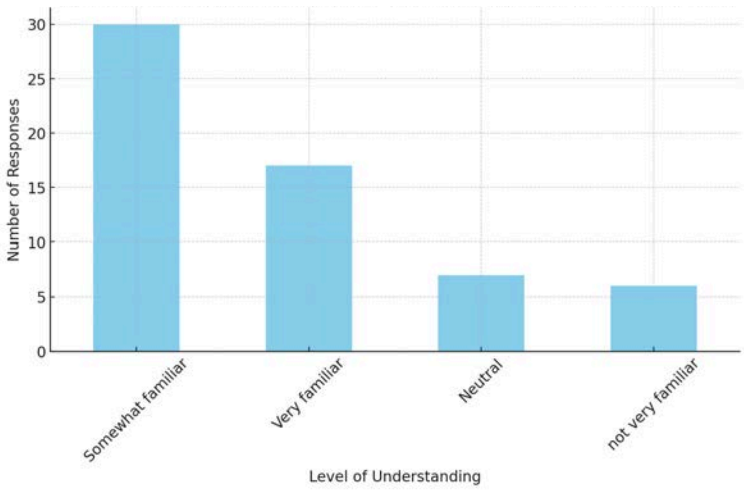


Effectiveness of simulation

This suggests that the Skill-eLabs module had a positive impact on students' confidence in identifying and explaining various controls / indicators of an LED/ LCD TV front panel.

3.1.2 Simulation 2 - Debug- No power issue in LED/LCD TV

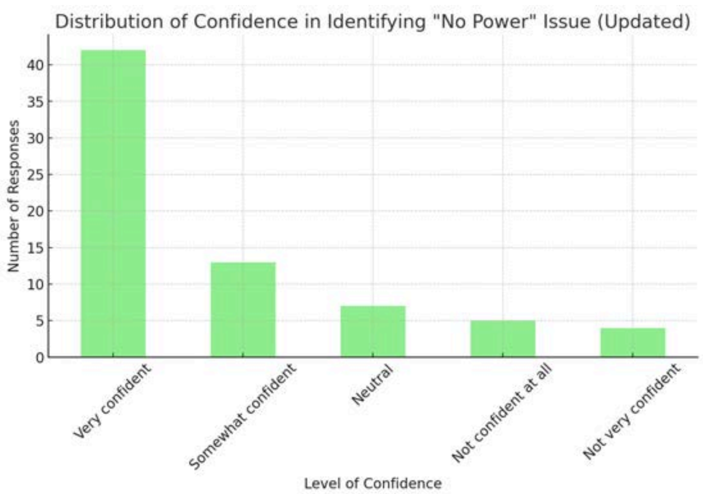
Pre-module results on troubleshooting "No Power" issues in LED/LCD TVs, participants had varying levels of familiarity with the process. A majority (78.33%) reported being at least somewhat familiar, with 50% feeling "Somewhat familiar" and 28.33% identifying as "Very familiar." However, 21.67% of participants fell into the "Neutral" or "Not very familiar" categories, indicating that a significant portion lacked a strong understanding of the troubleshooting process.



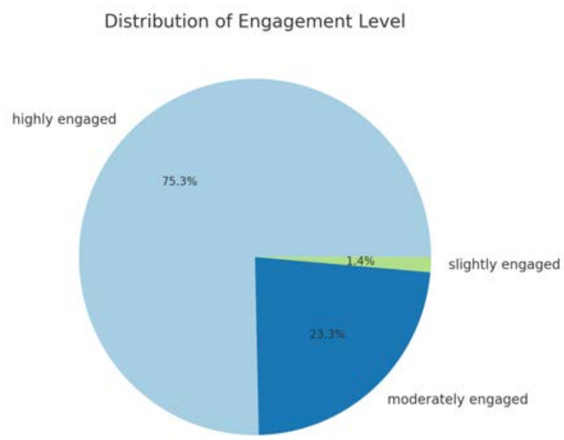
Familiarity with 'No power' issue in TV

In Post-module results, confidence levels in identifying "No Power" issues improved substantially. A majority of participants (77.46%) expressed confidence, with 59.15% feeling

"Very confident" and 18.31% "Somewhat confident." However, 17.53% of participants, split between "Neutral" (9.86%), "Not confident at all" (7.04%), and "Not very confident" (5.63%), still lacked full confidence, suggesting room for further improvement and additional practice.
In terms of engagement, the simulation was highly effective, with 75.3% of students reporting they were "Highly engaged" and 23.3% "Moderately engaged." Only 1.4% felt "Slightly engaged," indicating the need for strategies to enhance engagement for a small minority of students who may not have connected fully with the simulation.



Confidence in Identifying No power issue



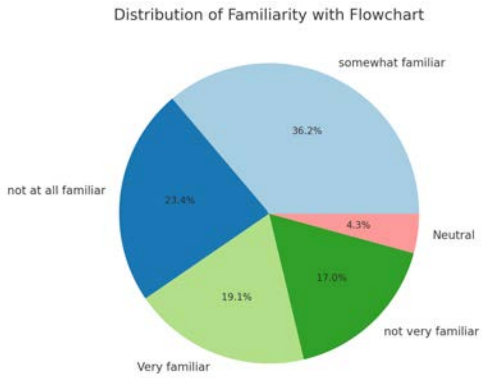
Simulation engagement levels

This suggests that while the simulation was largely effective in building familiarity and confidence, additional support or follow-up training may be needed to assist the small group of participants who remain less confident in the process. The high engagement levels further validate the effectiveness of the simulation as a learning tool, though efforts to enhance engagement for all learners could lead to even better outcomes.

The results suggest that the Skill-eLabs module significantly improved participants' confidence in identifying “No Power” issue faults in an LED TV..

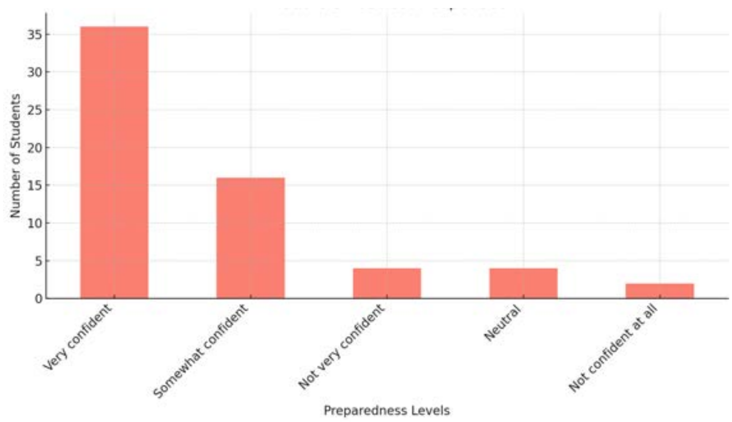
3.1.3 Simulation 3 - No Picture No Sound issue troubleshooting in LED/LCD tv

In the pre-module results, 55.3% of students reported being familiar with the flowchart method for troubleshooting, with 36.2% "somewhat familiar" and 19.1% "very familiar." However, a significant portion (40.4%) lacked familiarity, with 23.4% "not at all familiar" and 17% "not very familiar." This highlights the need for additional foundational instruction to ensure all students can engage with the troubleshooting process effectively.

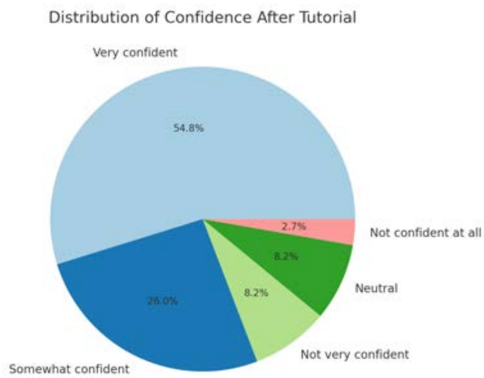


Familiarity with flowchart method for rectifying faults in LCD/LED TV

In Post module results, confidence levels improved significantly, with 80.8% of students feeling confident in identifying the "No Picture, No Sound" issue. Specifically, 54.8% felt "very confident" and 26% "somewhat confident." However, nearly 19% remained either neutral (8.2%) or lacked confidence, indicating that while the simulation was effective, there is still room for improvement in reinforcing key concepts for those students who struggled.



Preparedness levels to apply troubleshooting techniques to real world scenarios

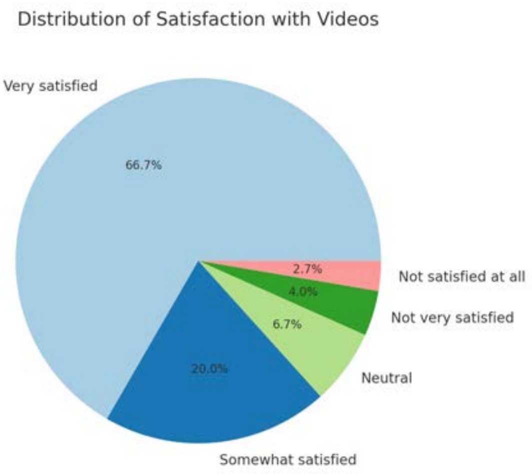


Confidence levels to identify and troubleshoot “No Sound” and “No Picture issue

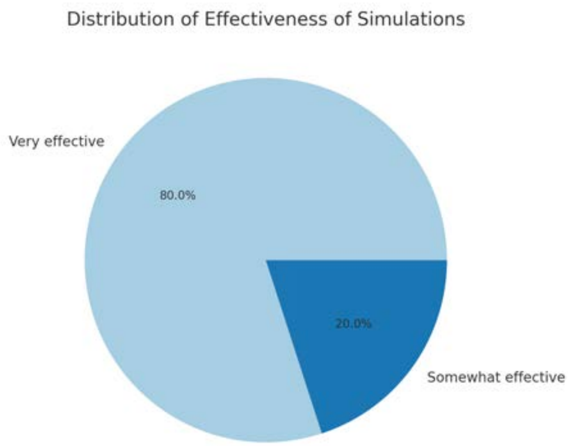
The tutorial videos supporting the simulation were generally well-received, with 66.7% of students "very satisfied" and 20% "somewhat satisfied." Despite this, a small group (6.7%) expressed neutrality or dissatisfaction, suggesting that enhancements to the video content could help improve the overall learning experience for all participants.

The simulations themselves were rated highly effective, with 80% of students finding them "very effective" and the remaining 20% considering them "somewhat effective." This overwhelmingly positive feedback reflects the simulation's success in engaging students and helping them apply troubleshooting procedures in a practical, hands-on manner.

Overall, the simulation demonstrated strong effectiveness in enhancing student familiarity, confidence, and engagement, though further refinements to instructional support and video content could ensure even greater success for all learners.



Satisfaction with Instructional Videos



Effectiveness of the Simulations

The results suggest that the Skill-eLabs module significantly improved participants' confidence in applying the troubleshooting techniques to rectify faults in LED/ LCD TVs

3.2 Impact of Augmented Reality

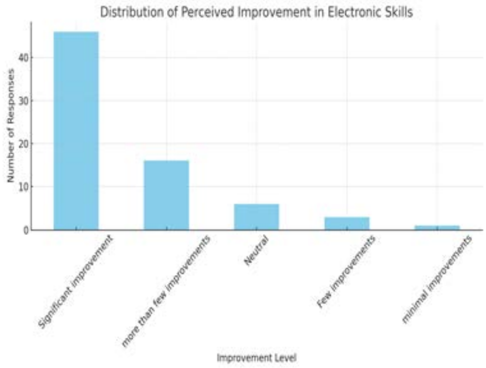
Key Insights from students' feedback

- **Skill Improvement**: 86.1% of students reported significant or moderate improvements in their skills.
- **Knowledge Application**: 88.9% reported increase in confidence in remembering and applying the knowledge gained.
- **Key Themes from Qualitative Feedback**:
    - Enhanced Visualization, Comprehension, and Faster Learning
    - Improved Retention, Engagement, and Practical Skill Development
    - Usability and Accessibility of AR Technology
    - Innovation, Creativity, and New Approaches to Learning

3.2.1 Quantitative Feedback on the AR Module

Perceived improvement in electronic mechanic skills

The majority of students (86.1%) reported "Significant Improvements" or "More than a few Improvements" in their electronic mechanic skills after using the AR Module, indicating a positive impact on skill development. Only 13.9% reported few improvements or remained neutral, suggesting overall success in enhancing learning.



Perceived improvements in electronic skills

Likelihood of applying knowledge gained from AR module

A significant majority (88.9%) of students stated they were "Very likely" or "Somewhat likely" to retain and apply the knowledge gained from the AR Module, demonstrating its effectiveness in fostering lasting, practical skills. A small portion (4.2%) felt it was unlikely they would retain the knowledge, while 6.9% remained neutral. This indicates that the AR technology is generally successful in creating memorable and applicable learning experiences for most students.

Likelihood of applying knowledge gained from AR

3.2.2 Qualitative Feedback on the AR Module

The analysis highlighted four key themes: enhanced visualization and comprehension, improved retention and engagement, usability and accessibility of AR technology, and the stimulation of innovation and creativity. These themes offer insights into the impact of AR technology on students' learning experience, demonstrating its potential to make complex technical concepts more accessible and engaging.

Enhanced Visualization, Comprehension, and Faster Learning

A significant portion of students (80%) reported that the AR module improved their ability to visualize and understand the intricate layers of LED and LCD displays, which are difficult to grasp using traditional learning methods like textbooks. The three-dimensional, interactive nature of the AR module allowed students to explore the internal components in greater detail, which enhanced their understanding of the subject matter.

One of the most commonly mentioned benefits was the AR module's ability to provide clarity on the structure and function of the different layers in display technology. For instance, students were able to observe how light passes through various layers, such as the backlight, colour filter, and liquid crystal layers, which they found challenging to visualize in a theoretical setting.

Additionally, many students reported that the AR module facilitated faster learning compared to traditional methods. The real-time interaction provided by the AR environment allowed them to grasp complex concepts more quickly, leading to a more efficient learning experience.

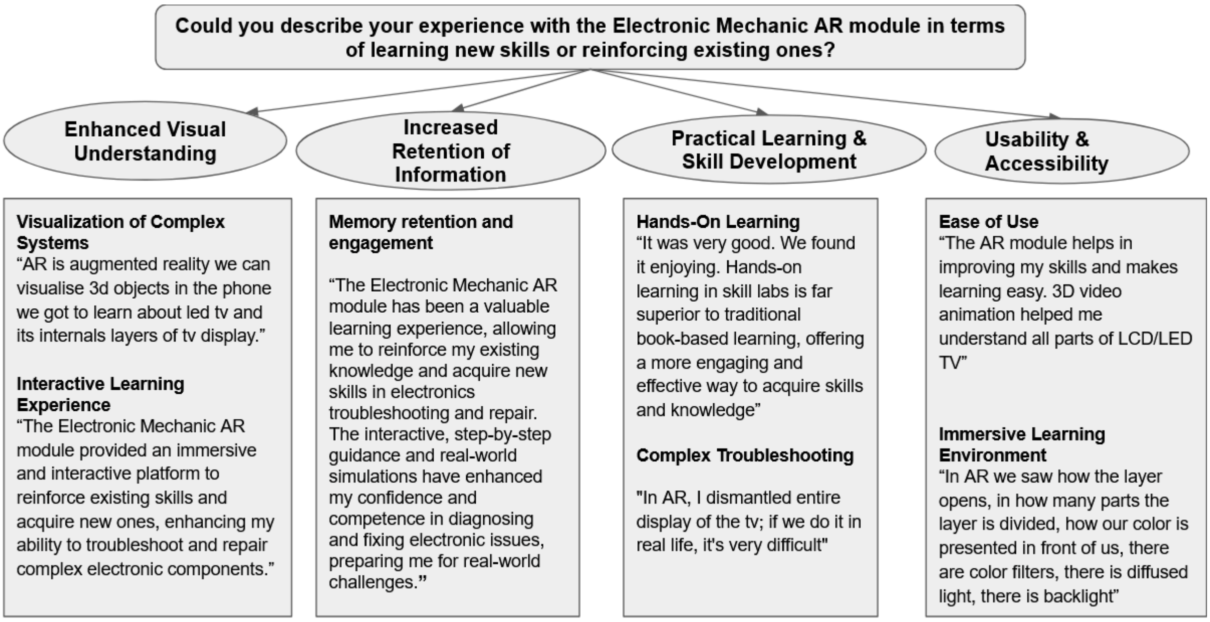


Figure 9: Thematic Analysis of Electronic Mechanics Students' Responses to the Question: "Could you describe your experience with the AR module in terms of learning new skills or reinforcing existing ones?"

Improved Retention, Engagement, and Practical Skill Development

Approximately 65% of students indicated that the AR module significantly improved their retention of information. The interactive and hands-on nature of the AR experience kept them engaged and made the learning process more enjoyable, leading to better long-term retention compared to traditional methods such as reading from textbooks or attending lectures.

Students particularly appreciated the module's practical applications, which allowed them to virtually dismantle and assemble components without the risk of damaging actual equipment. This risk-free, hands-on experience was seen as a key contributor to their skill development, helping them apply theoretical knowledge to practical tasks.

Many students also noted that the AR module bridged the gap between theoretical learning and real-world applications. They felt more confident in handling complex tasks, such as repairing or troubleshooting electronic displays, after interacting with the AR module, as it provided them with a deeper understanding of the internal workings of these devices.

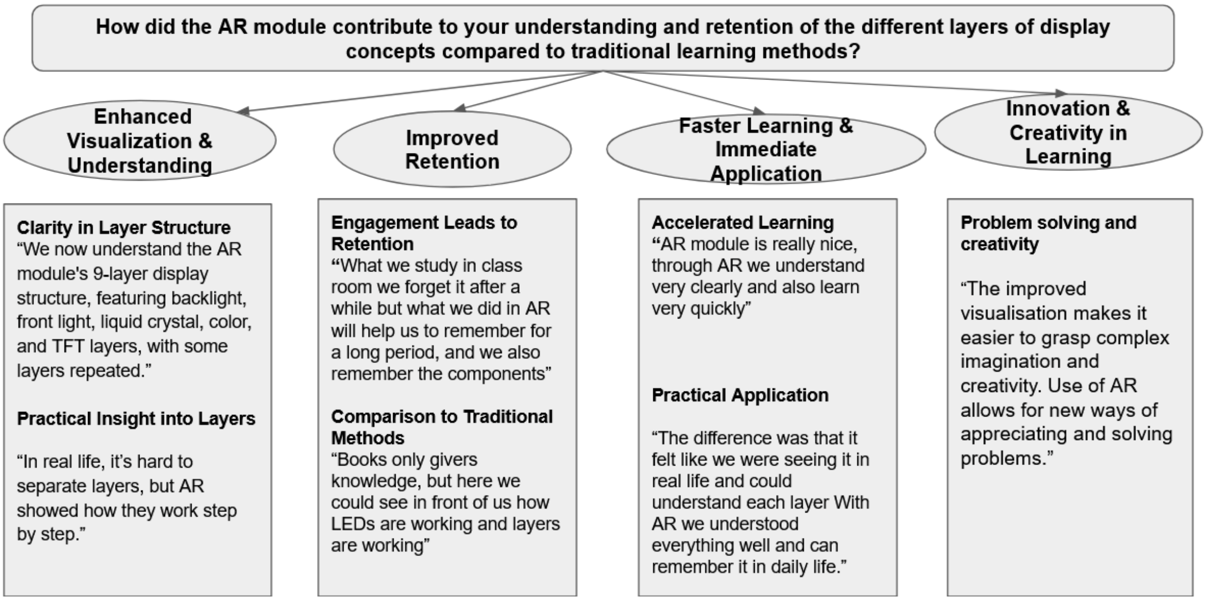


Figure 10: Thematic Analysis of Electronic Mechanics Students' Responses to the Question: "How did the AR module contribute to your understanding and retention of different layers of display concepts compared to traditional learning methods?"

Usability and Accessibility of AR Technology

While the majority of students found the AR module easy to use, around 20% mentioned experiencing some challenges with navigating certain layers within the AR environment. For most students, the AR technology was intuitive and made complex concepts more accessible, especially when studying components that are difficult to visualize using traditional methods.

However, a small portion of students reported confusion when trying to explore specific layers, which slightly hindered their learning experience. Despite these minor challenges, the overall feedback regarding the module's usability was positive, with students appreciating the opportunity to interact with the material in a more immersive way.

Innovation, Creativity, and New Approaches to Learning

Approximately 30% of students felt that the AR module fostered creativity and introduced new approaches to problem-solving. The immersive and interactive nature of the AR environment stimulated their creative thinking, allowing them to approach technical challenges in ways that would not be possible through traditional learning methods.

Students mentioned that the AR module provided a fresh perspective on learning, encouraging them to think more critically about complex technical problems. The ability to experiment with different solutions in the AR environment gave them new insights into problem-solving and helped them develop innovative approaches to understanding difficult concepts.

3.3 Overall Student Feedback using Skill-eLabs package

⭐ **Key emerged themes from student feedback**

- **Improved Learning Speed:** Skill-eLabs facilitated faster learning, particularly through interactive 3D visuals and simulations.
- **Enhanced Safety:** Simulated exercises provided a safe, risk-free environment for practice.
- **Resource Conservation:** Virtual simulations helped reduce material wastage.
- **Real-World Readiness:** Skill-labs effectively prepared students for practical applications by offering a low-risk environment for skill development.
- **Increased Engagement:** Immersive learning tools contributed to higher engagement levels.

A thematic analysis was conducted on the qualitative data collected from participants who shared their experiences through open-ended survey responses. This analysis identified key themes, sub-themes, and included relevant direct quotes from the participants. The following sections present a summary of the key findings from the thematic analysis based on the feedback provided by the students.

1. Learning Efficiency and Comprehension

A significant portion of participants (41%) expressed that Skill-eLabs facilitated faster learning and improved comprehension of complex concepts. The interactive simulations and 3D visuals helped students better understand electronic systems, including component identification and troubleshooting.

> *"Skill-eLabs training enhances our practical understanding, enabling us to better comprehend and identify components and apply our knowledge effectively in real-world scenarios."*

This shows that the visual and interactive learning methods used in Skill-eLabs effectively bridge the gap between theoretical and practical knowledge.

2. Safety and Risk Management

Fifty percent of participants highlighted the safety advantages of using Skill-eLabs. In practical exercises, there is a higher risk of damaging equipment or encountering safety hazards like electric shocks. However, in the skill-labs, students could practise and refine their skills in a safe, controlled, virtual environment.

"Skill-eLabs exercises allow us to learn and practice skills in a simulated environment before moving on to practical exercises, reducing the risk of damage and injury."

This demonstrates how simulated environments can mitigate the risks associated with hands-on practical exercises, allowing students to gain confidence without worrying about potential hazards.

3. Resource Management

Thirty-six percent of students noted that Skill-eLabs were more efficient in terms of both time and material resources. Since skill-labs don’t require the use of physical materials, they reduce waste while allowing students to practise repeatedly, thus optimising learning.

"In practical, there is a lot of wastage of materials. In the Skill-eLabs we don’t need tools or raw materials, which reduces wastage"

This insight highlights the sustainability of using virtual tools to minimise physical waste, a significant consideration for resource-intensive vocational training.

4. Practical Application and Skill Enhancement

Twenty-seven percent of participants found that Skill-eLabs helped them transition smoothly to actual practical exercises. The repetitive nature of simulations allowed students to refine their skills before tackling real-world problems, which ultimately improved their confidence.

"Skill-eLabs focuses on skill development, while the actual lab focuses on applying skills to real-world projects"

This theme suggests that Skill-eLabs effectively prepare students by simulating practical scenarios, enhancing their technical abilities and boosting their confidence.

Figure 11: Thematic Analysis of Electronic Mechanics Students' Responses to the Question: "Is there any difference between the Skill-eLabs exercise and actual practical exercise?"

5. Engagement and Motivation

About 21% of participants indicated that the interactive nature of skill-labs kept them more engaged and motivated compared to traditional practical exercises. Many appreciated the use of advanced technologies like augmented reality (AR) and virtual reality (VR), which made learning enjoyable.

> *"I thoroughly enjoyed the AR and VR computer simulations. In VR, I received interactive guidance on how to manipulate and explore 3D objects, which was a fascinating experience"*

The engaging, game-like elements in VR/AR modules promote a more immersive learning experience, making it easier for students to stay motivated and focused.

6. Challenges Encountered

Despite the generally positive feedback, some participants (18%) faced specific challenges, particularly in handling technical tasks or a lack of sufficient information in some exercises. These challenges were typically addressed by using hints or consulting videos.

> *"Exercise number 2: No power issue there were some steps that was hard, and on how to connect the wires, I had to use the hint option repeatedly."*

This finding highlights areas where more comprehensive guidance and detailed instructions could improve the learning experience.

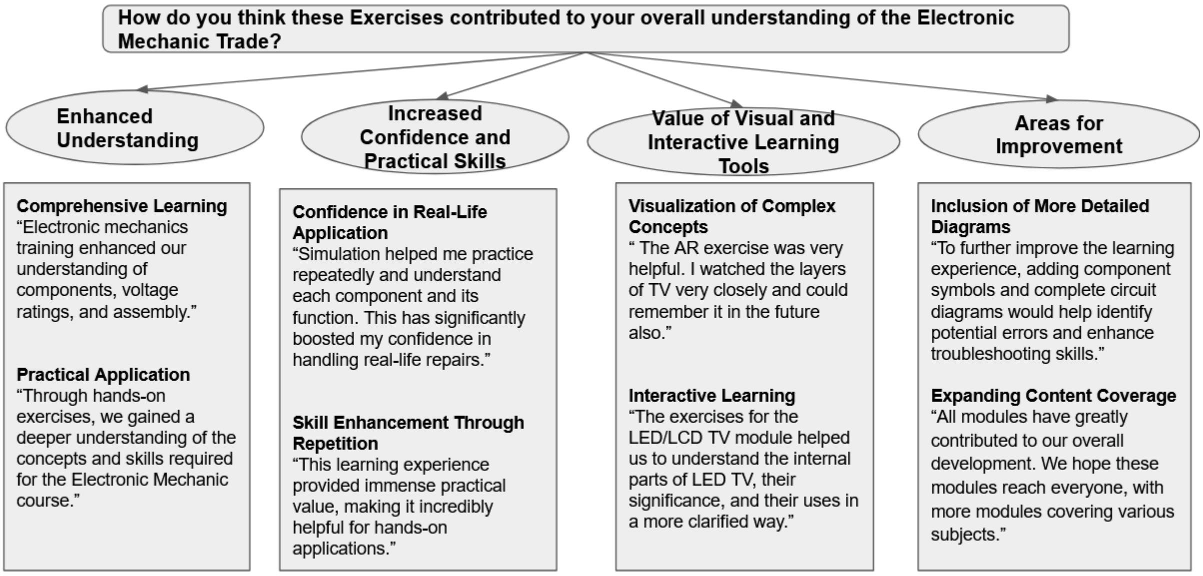


Figure 12: Thematic Analysis of Electronic Mechanics Students' Responses to the Question: "How do you think these exercises contributed to your overall understanding of the electronic mechanic trade?"

7. Improvements Suggested

Several participants provided constructive feedback, particularly around enhancing the simulation content. Suggestions included expanding the coverage of technical topics, improving graphics, and adding more detailed circuit diagrams and symbols to aid understanding.

> *"The simulation shows only how to replace the PCB, but it should also teach the parts on the PCB, like capacitors, and how to repair the main board."*

These suggestions point towards a need for more depth in simulation exercises to cover advanced technical skills and improve the overall learning experience.

8. Increased Confidence and Practical Skills

Fifty-six percent of participants reported increased confidence in handling real-life repairs after engaging with the simulations. The repetitive exercises provided students with the chance to master skills before applying them in actual scenarios, which significantly boosted their confidence.

> *"Simulation has helped me practice repeatedly and understand each component and its function thoroughly. This has significantly boosted my confidence in handling real-life repairs."*

This theme reflects how virtual simulations contribute to building the competence necessary for students to succeed in practical applications.

SECTION D:
USABILITY SURVEY RESULTS

1.Summary of the Usability Survey Results

This section summarizes the findings from a usability survey conducted with 160 students from the Electronics Mechanic and Solar Technician trades. The survey was completed after each batch had completed the Skill-eLabs pilot. Participants provided feedback on different aspects of the Skill-eLabs package, which is detailed in the following table. The feedback was collected via a Google Form highlighting their overall experience with the Skill-eLabs packages.

Aspect	Key Findings
User Experience	91% rated Good or Very Good, indicating positive experience.
Design & Layout	80% rated Good or Very Good; some improvements possible
System Usability	85% rated usability as Good or Very Good, showing intuitive design.
Navigation	79% rated navigation Good or Very Good; 19% rated Average, suggesting potential improvements.
Visual Aesthetics	82% rated aesthetics Good or Very Good, indicating positive impact on user experience.
Response Time	85% rated response time positively, showing satisfactory performance.
Content Quality	84.2% rated content as Very Good or Good, indicating that content was relevant, engaging, and effective in conveying the intended skills and knowledge.
System Functionality	89% rated functionality as Good or Very Good, reflecting strong and reliable system features.
Error Messages	68% rated error messages Good or Very Good, but 30% rated Average, suggesting room for improvement.
Overall Satisfaction	88.6% rated overall satisfaction Good or Very Good.
Text/Fonts Usability	90% found text and fonts easy to read.
Voice-Over Clarity	87% rated voice-over clarity positively, showing effective guidance.
Hindi Text Accuracy	86.8% found Hindi text accuracy as Good or Very Good, indicating text to be accurate and easy to understand.
Hint Option	90% found the hint option helpful.
Quiz Difficulty	80% rated quiz difficulty as Good or Very Good, with balanced challenges.

Table 4 - Summary of the Usability Survey Results

2. Findings / Suggestions for Improvement

The positive feedback highlights the overall effectiveness and user satisfaction with the Skill-eLabs package. With high ratings in user experience, system usability, and functionality, the core elements of the package are well-received. However, areas like navigation and error messages indicate opportunities for further refinement. Addressing these concerns could enhance the overall usability and user experience.

The main areas that can be improved from the pilot study after usability testing with the users is addressed below

Design and Layout: In the initial deployment of the Skill-eLabs package at NSTI Mumbai and Govt. ITI Jhajjar, students found the size of buttons and icons too small, making interactions challenging and less intuitive. This feedback came from students who were completely new to simulation based learning.This feedback highlighted accessibility issues, particularly for students less familiar with digital interfaces. To address this, the interface was redesigned and improved before moving to the second phase of the same deployment thus increasing the size of buttons and icons to improve usability. Larger interface elements enhance accessibility, and improves overall user comfort. These adjustments ensure that students can navigate throughout the simulation more easily, allowing them to focus on learning without frustration caused by difficult-to-use interface elements.

Navigation: A small portion of students, 19%, rated the navigation experience as average, indicating a need for improvements in the simulation. Students found navigating between content, especially popups and steps, somewhat difficult. Many compared the simulation to video games, suggesting that reducing popups and incorporating more direct, interactive elements would enhance engagement. First-time users, in particular, struggled with adjusting to the navigation, which impacted their experience. By simplifying navigation and decreasing interruptions caused by popups, the simulations can offer a more fluid, game-like experience. These changes will make the simulation more intuitive, helping students engage with the content more effectively.

Error Messages: Thirty percent of students rated the feedback on error messages as average, pointing to the need for clearer guidance during the simulation. Many students felt that error messages could be better timed and more informative, providing the necessary cues without overwhelming them. An improved error reporting system, where students are given multiple attempts before receiving feedback, would encourage exploration and critical thinking. For example, instead of immediate corrections, students could be allowed to experiment more before being guided toward the correct answer. This approach promotes deeper engagement and helps students develop problem-solving skills, leading to more effective learning outcomes.

Hindi Text Accuracy: Accurate and contextually appropriate use of Hindi is crucial for students who rely on it for learning and communication. Since Hindi is the primary language spoken among peers and instructors in NSTI Mumbai and NSTI Dehradun, providing high-quality Hindi text ensures that students can fully understand and engage with the content. Poor translations or incorrect usage can lead to confusion and misunderstandings. By focusing on improving the accuracy and relevance of the Hindi text in simulations, students will have a clearer understanding of concepts and tasks. This not only enhances their learning experience but also helps bridge the gap between theoretical knowledge and real-world applications.

Content Quality: Students highlighted the importance of incorporating more real-world scenarios and detailed instructions into the simulation. Realistic content that mirrors actual industry challenges helps students apply their learning in practical situations. Including detailed descriptions of tools, equipment, and materials, along with explanations of how they are used, would significantly improve content quality. This feedback was mainly given by students of ITI Jhajjar and ITI Goa. This level of detail ensures that students can better connect their simulation experience to real-life problems, enhancing their understanding and problem-solving abilities. More relevant, practical content will increase engagement, leading to higher satisfaction and improved learning outcomes as students feel more prepared for real-world challenges.

Overall, the Skill-eLabs package received positive feedback with clear areas for potential improvement.

SECTION E:

INSTRUCTOR FEEDBACK ON SKILL-ELABS PACKAGE IMPLEMENTATION

1.Introduction

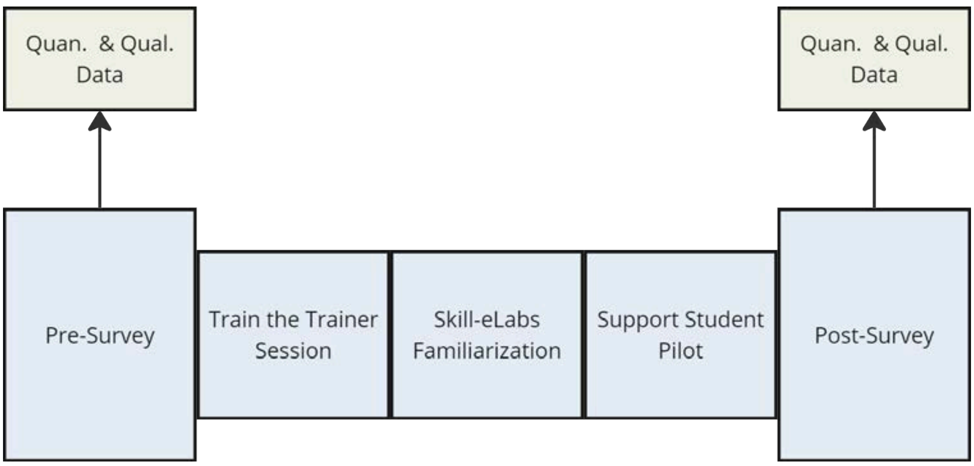
One of the aims of the pilot implementation of the Skill-eLabs package was to enhance the capacity of instructors to integrate technology-based learning tools, including 3D simulations, Augmented Reality (AR), and Virtual Reality (VR), into their existing teaching methods. Conducted across four institutions, the pilot involved 17 instructors from the Solar Technician and Electronics Mechanic trades. The objective was twofold: to provide instructors with hands-on experience using the Skill-eLabs package and to gather their feedback on the effectiveness of the package in delivering practical skills training to students. This section outlines the activities undertaken during the pilot, from initial pre-surveys and training sessions to post-survey evaluations, providing insights into instructors' experiences, the challenges they faced, and the improvements they observed in their trainees' learning outcomes. Additionally, the section explores the instructors' perceptions of the ease of technology integration and the overall impact of the Skill-eLabs package on enhancing vocational education.

	Instructor Count *Solar Technician*	**Instructor Count** Electronics Mechanic
NSTI Mumbai	2	2
NSTI Dehradun	2	2
Govt.ITI Jhajjar, Haryana	3	2
Govt. ITI Bicholim, Goa	2	2

Number of instructors per trade per institution

2.Activities

This flow diagram illustrates the step-by-step process instructors underwent during the pilot program.



1. **Pre-Survey**:
    - Instructors completed a pre-survey capturing quantitative and qualitative data on their teaching experience, familiarity with learning technologies, confidence in integrating them, and perceptions of technology-enhanced learning.
2. **Train the Trainer Program**:
    - Instructors underwent training to familiarise themselves with learning technologies, focusing on integrating these into their classrooms.
    - They explored all components of the Skill-eLabs package relevant to their trades.
3. **Student Pilot Participation**:
    - Instructors observed mentors conducting training during the student pilot phase.
    - They actively supported students by addressing queries and assisting in pilot implementation.
4. **Reflection and Mentor Support**:
    - Instructors reflected on their understanding of the Skill-eLabs packages and sought additional guidance from mentors where needed.
5. **Post-Survey**:
    - Instructors completed a post-survey assessing ease of integrating Skill-eLabs packages, perceived effectiveness of 3D simulations, AR, and VR, and their confidence in using these technologies.
    - Qualitative feedback was gathered on challenges faced, student improvements, and additional insights.

3. Pre-Survey Results

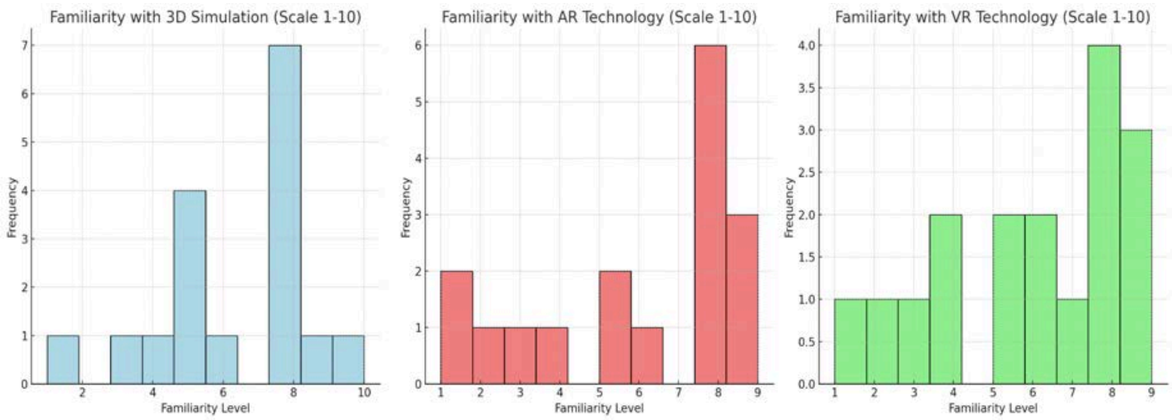
3.1 Quantitative Analysis

Most instructors (54%) have 10+ years of teaching experience, with 46% upto 5 years of experience.

Years of teaching experience

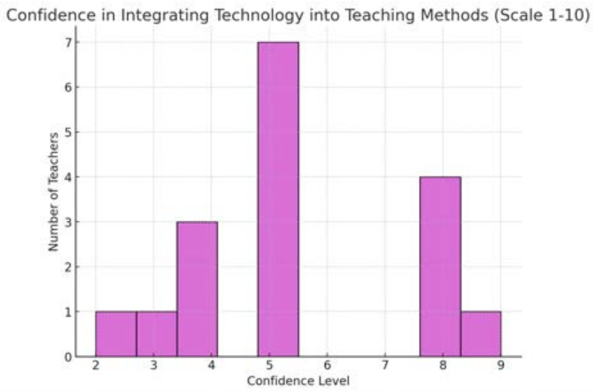
Prior experience with packages similar to Skill-eLabs: The majority of instructors (14 out of 17) had no prior experience using skill-eLabs or similar technology packages. Only three instructors, all from NSTI and the Electronics Mechanic trade, had previous experience with similar technology-enhanced learning methods. They reported using "Circuit Maker software" as part of their teaching.

Familiarity with 3D Simulation, AR, and VR: Instructors showed a **high familiarity** with both 3D Simulation and AR Technology, with a median score of 8 out of 10. This suggests that the majority of the instructors have substantial exposure or understanding of these technologies. For VR Technology, the median familiarity was slightly lower, at 6 out of 10, indicating that while instructors are somewhat familiar with VR, there may be room for further improvement in their knowledge and use of this technology.



Familiarity with 3d simulation, AR, and VR technology

Confidence in integrating technology in teaching methods: Instructors (both NSTI and ITI) reported moderate confidence in incorporating technology into their teaching methods, with a median score of 5 out of 10. This suggests that while many instructors feel capable of adopting technology, there may still be reservations or gaps in full confidence. Despite differences in their (NSTI and ITI instructors) backgrounds and potential exposure to skill-eLabs or similar technologies, both groups appear to feel moderately confident about incorporating new technological tools into their teaching. This indicates that any future training or support initiatives to boost technology integration could be similarly applied across both NSTIs and ITIs, as their needs appear to align closely.



Confidence in integrating technology into their teaching methods

3.1 Qualitative Analysis

The qualitative analysis of the respondents' feedback provides valuable insights into their expectations, desired outcomes, anticipated challenges, and current teaching methods related to the Skill-eLabs package for electronic mechanic and solar technician trades.

1. Initial Expectations from the Skill-eLabs Package

Respondents expected the Skill-eLabs package to deliver **comprehensive, hands-on training** covering fundamental principles and real-world applications in electronics and solar technology. Many mentioned the desire for the package to include **industry-relevant tools and technologies**, such as multimeters and solar panels, to provide practical training. Additionally, the use of **modern technologies**, particularly **Virtual Reality (VR)**, is highlighted, with the expectation that immersive learning experiences will make training more interactive and engaging.

There is an overall sense of **high enthusiasm** for the package, given its status as a pilot program, with respondents anticipating it will foster **intrinsic motivation** for learning. A few also emphasized the need for a **structured, topic-wise curriculum** that organizes content into manageable modules.

2. Skills or Outcomes Expected from the Skill-eLabs Solution

The primary expectations focus on **technical skills development**, with respondents hoping to see proficiency in areas such as **circuit analysis, troubleshooting, installation, and fault identification**. Practical, hands-on experience is considered crucial, and there is a strong emphasis on **problem-solving and critical thinking skills**, which are necessary for handling real-world technical challenges.

Some respondents highlighted the importance of **safety awareness** and adherence to **standard operating procedures (SOPs)**, ensuring that students are mindful of safety protocols while working with electrical components. Several respondents also expressed the desire for competency in **AR/VR technologies**, expecting the Skill-eLabs package to offer cutting-edge learning experiences through simulations.

Additionally, respondents hope the package will prepare students for **career readiness**, equipping them with the necessary skills to pursue employment or entrepreneurship. There was also mention of enhancing learning through **interactive and immersive experiences**, with a few respondents focusing on developing **proficiency in industry-standard tools and technologies**.

3. Challenges Anticipated in Using the Skill-eLabs Package

Several **technical and practical challenges** were highlighted by respondents, including concerns about **power outages, internet connectivity, and equipment maintenance**. Handling **VR technology** was also mentioned as a potential challenge, particularly in terms of its initial complexity.

Another key challenge is the **varying levels of prior knowledge and learning pace** among trainees. Some respondents anticipate that adapting teaching strategies to cater to diverse learning needs will ensure all trainees can keep up with the material.

Additionally, respondents expressed concerns about **physical and cognitive strain** associated with continuous usage of the package, especially VR, suggesting the need for breaks. Issues related to **access to technology** were also noted, with some trainees potentially lacking adequate infrastructure. **Instructor support** is seen as crucial for overcoming these challenges, particularly for trainees who may need additional guidance.

Lastly, **language barriers and cultural differences** were mentioned as potential hurdles, requiring **thoughtful communication and culturally sensitive facilitation** to ensure all trainees can effectively engage with the content. **Additional practice** was also highlighted as essential for trainees to gain full proficiency in the technical skills being taught.

4. Current Teaching Methods of the Instructors

Instructors reported using a **blended approach**, combining **theoretical instruction** with **hands-on practical training**. This approach emphasizes the application of concepts through **practical labs** and **demonstrations**. Many instructors continue to use **traditional methods**, including **classroom instruction, textbooks, and PowerPoint presentations**, supplemented by **visual aids** such as charts and models.

Some instructors incorporate **project work** to further enhance learning, while one respondent mentioned using **simplified language and relatable examples** to cater to the diverse learning needs of students, particularly in rural areas. While **technology integration**, such as **PowerPoint and simulation tools**, was mentioned, there was no significant emphasis on using **videos** or other advanced learning technologies.

The feedback from respondents highlights a general sense of optimism and enthusiasm for the Skill-eLabs package, with a focus on **hands-on training, technical skill development,**

and the integration of modern technologies like **VR**. However, there are also anticipated challenges, particularly regarding **technical issues, varying trainee abilities, and the need for support and adaptation**. Instructors tend to follow a **blended, traditional approach** to teaching, but there is an opportunity to further enhance their methods through greater use of **technology** and adaptive learning strategies to cater to diverse student needs.

4. Post-Survey Results

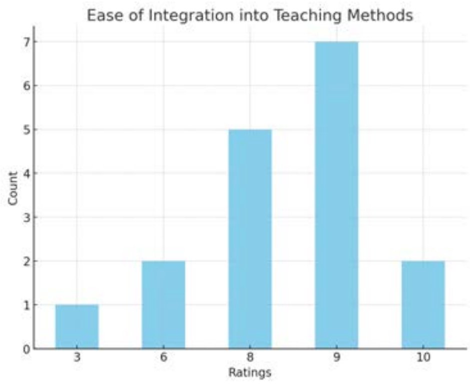
Key insights from Instructor Feedback

- All instructors unanimously agreed that the Skill-eLabs package met or exceeded their expectations, particularly in providing a comprehensive hands-on learning experience.
- The package significantly improved educators' confidence in integrating technology into their teaching, with median confidence levels rising from 5.0 to 9.0 after the intervention.
- 3D simulations, AR, and VR technologies were highly rated for enhancing learning, with a median score of 9 out of 10, emphasising their perceived value in improving practical skills and engagement.
- Instructors reported that the trainees demonstrated clear improvements in problem-solving, critical thinking, and practical skills, particularly in electronics mechanics and solar panel installation, due to the immersive and mistake-based learning environment.
- While most instructors faced no challenges, technical difficulties such as internet connectivity issues and initial unfamiliarity with digital tools were reported as barriers for some trainees.
- There is strong consensus (100%) among respondents recommending the Skill-eLabs package for future trainees, citing its ability to combine theory with hands-on training, boosting both practical skills and employability.

After the intervention, the instructors were given a post-survey consisting of quantitative and qualitative questions. The responses provided insights into their perceptions of the effectiveness of the technologies, the ease of integrating them into their teaching methods, whether they met their initial expectations, their confidence in using them, the challenges they faced, improvements, etc. This section will detail the results.

4.1 Quantitative Analysis

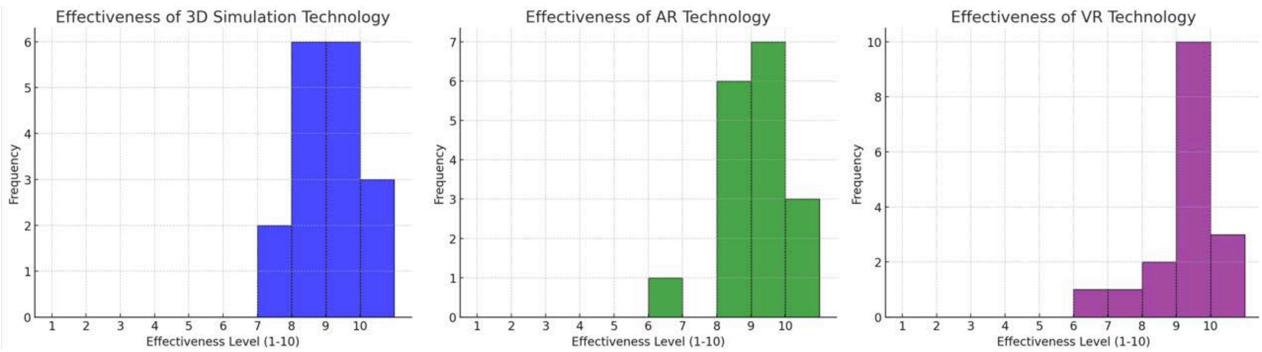
All instructors (100%) indicated that the Skill-eLabs package met their initial expectations. The majority provided high ratings, with a **median score of 9 out of 10** across several key areas, including overall satisfaction, ease of integration into their teaching methods, and confidence in using the Skill-eLabs package. This suggests a strong alignment between the instructors' initial expectations and their experience with the package.



Ease of integration into teaching methods

Confidence in using the technologies

Regarding the **effectiveness of 3D simulations, AR, and VR technologies**, respondents consistently rated all three tools highly. The **median effectiveness score** for each technology was **9 out of 10**, highlighting their perceived value in enhancing learning. These results indicate a strong positive perception of the technologies' impact on improving the learning experience, as observed during the Skill-eLabs training and pilot implementation. This high level of perceived effectiveness suggests that 3D simulations, AR, and VR contributed significantly to the practical and immersive learning outcomes for trainees.



Effectiveness of the technologies in enhancing learning

Comparison of confidence in integrating technology into their teaching methods before and after the implementation of the skill-eLabs intervention.

Statistical Test: A Wilcoxon Signed-Rank Test was conducted to compare the medians of confidence levels before and after the intervention. This test is appropriate for paired data and was used to evaluate whether the skill-eLabs intervention had a statistically significant effect on educators' confidence.

Results: The median confidence level in integrating technology before the intervention was 5.0, which increased to 9.0 after the intervention with the Skill-eLabs package. A Wilcoxon

Signed-Rank Test revealed a significant improvement, with a test statistic of 4.5 and a p-value of 0.00248.

The increase in median confidence from 5.0 to 9.0 demonstrates a substantial improvement in educators' confidence after the skill-eLabs intervention. This suggests that the Skill-eLabs package had a positive impact on educators' confidence in using technology-based tools and simulations for teaching.

⭐ Implementing the skill-eLabs intervention significantly improved educators' confidence in integrating technology into their teaching methods. Before the intervention, educators felt moderately confident, but after experiencing the Skill-eLabs package, their confidence levels rose considerably, reflecting the effectiveness of the intervention in enhancing their skills and comfort with technology.

4.2 Qualitative Analysis

Did the Skill-eLab package meet the initial expectations? All 17 respondents reported that the Skill-eLabs package met their expectations, with one respondent indicating that the package partially met the initial expectations.

- "*Yes. It was much more than my expectations. This method is very good for students' learning. They can do well after watching videos and practicing through simulations.*"
- "*Yes, the Skill-eLabs package exceeded my initial expectations by providing a comprehensive, structured, and hands-on learning experience that effectively enhanced my trainees' practical skills and knowledge.*"

- “*The Skill-eLabs package partially met my initial expectations, providing valuable resources and hands-on activities, but requiring additional support and adaptation to suit the diverse needs and skill levels of my trainees.”*

Improvements observed in trainees’ learning and confidence: All the respondents reported positive improvements in the trainee’s learning and confidence.

- “*Yes, this technology-based solution will give the trainees more confidence and knowledge*.”
- “*The trainees were able to effectively integrate theoretical concepts with practical activities, demonstrating a clear understanding and proficiency in the trade*.”
- “*I observed significant improvements in trainees’ problem-solving abilities, critical thinking, and confidence in applying theoretical concepts to real-world scenarios, with enhanced hands-on skills and reduced anxiety in handling complex electronics*.”
- “*They really enjoyed and interacted with the simulation, which makes them more comfortable to do the exercises*. “

What specific skills or knowledge do you think were most enhanced by the Skil-eLabs package?

The instructors reported that the skill lab package significantly improved trainees’ **practical** abilities in electronic mechanics and solar technology. Key enhancements include **fault finding**, **tool proficiency**, **circuit analysis**, **troubleshooting**, and **solar panel installation**. The use of **VR/AR simulations** allowed for a better understanding of processes and safe **mistake-based learning**. Trainees also improved in **digital skills**, **safety protocols**, and **problem-solving**. Overall, the package bridged the gap between **theoretical knowledge** and **practical application**, preparing trainees more effectively for real-world scenarios in their fields.

- “*Trainees have started to remember the tools and methods better, including digital skills, tools, and equipment*.”
- “*Learning using making mistakes is one of the key feature of the simulation. Also solar panel placement is really liked*.”
- “*The skill lab package most enhanced hands-on skills in solar panel installation, electrical wiring, and circuit analysis, as well as knowledge of safety protocols, troubleshooting, and problem-solving in electronics*.”
- “*The skill lab package most enhanced my trainees’ hands-on skills in circuit analysis, wiring, and troubleshooting, as well as their knowledge of solar panel installation, maintenance, and repair*.”

- "*3d simulation are good to learn step by step process. AR is good for understanding the solar panel placement. VR is good for physical activities.*"

What were the most significant challenges you faced while using the skill lab package? While 10 participants reported that they did not face any challenge, 7 participants shared their experience. Technical difficulties were a primary concern, including issues with internet connectivity, power outages, and limited accessibility to digital tools. Some trainees struggled due to unfamiliarity with digital technology, particularly in the initial stages of using Virtual Reality (VR) systems. Language barriers were also noted, with suggestions for simpler Hindi instructions. Additionally, health concerns such as eye strain from prolonged digital use were mentioned as potential drawbacks in adapting to this digital learning environment.

- "*Adapting to the digital world can lead to eye strain*."
- "*The most significant challenges faced while using the skill lab package included technical issues, limited accessibility, and power outages*."
- "*Limited internet connectivity and lack of familiarity with digital tools and technology among some trainees were the most significant challenges in understanding the skill lab package*."
- "*Operation of VR at initial stages.*"
- "*Sometimes I felt the Hindi language should be easy.* "

Suggestions for Improving the Skill Lab Package: The instructors desired a more comprehensive, realistic, and accessible skill lab package that is well-integrated with the curriculum and regularly updated to match industry needs. The emphasis is on expanding the package's scope to several more exercises and trades while making it more user-friendly and practically relevant. Key points include the need for more interactive and diverse content, better alignment with real-world scenarios, and improved accessibility for users with varying levels of technological proficiency. There's also a focus on allowing students to learn through a process of making and learning from mistakes in a safe, simulated environment. Additionally, proper training for instructors and integration with existing teaching methods are seen as important factors for the successful implementation and improvement of the skill lab package.

- "*This can be added as a practical and incorporated into the curriculum.*"
- "*If it can be extended to other trades, it would benefit all students*."
- "*Add more critical exercises in VR that are not possible in the practical lab.*"
- "*...by incorporating more interactive simulations, virtual labs, and real-world examples to enhance student engagement and practical understanding. Additionally, regular updates and expansions to the package could ensure relevance and alignment with industry developments*."

- “...*by providing user-friendly interface to support teaching and learning for less tech-savvy individuals.*”
- “*By proper training of trainers and making an atmosphere for it in the training.*”

Would you recommend this skill lab package to other trainees? Why or why not? The overwhelming consensus (100%) among respondents is a strong recommendation for the skill lab package for other trainees. The primary reasons cited include its relevance for future instructors and alignment with digital learning. They highlight its ability to combine hands-on training with theoretical knowledge, enhancing practical skills in electronics and solar technology while boosting employability. The package is praised for improving retention, saving resources, and reducing the risk of equipment damage. Despite initial tech challenges, it builds confidence, fosters intrinsic motivation, and is adaptable even in resource-limited settings. Overall, it’s seen as a valuable tool for skill development and career readiness.

- “*Yes, it is necessary for the next generation of trainers. The Skill e-Labs package helps to produce quality instructors and trainees*.”
- “*Yes, I would highly recommend this skill lab package to other trainees. It offers thorough hands-on training, uses state-of-the-art tools, and imparts practical knowledge essential for careers in electronics and solar technology. The comprehensive approach ensures that trainees gain both theoretical understanding and practical proficiency, making it an excellent resource for skill development.*”
- “*Yes, because it is a very helpful method of understanding theory and practicals without much raw materials usage, damage of instruments, and time-saving.*”
- “*Yes, I do because it is very important for intrinsic motivation.*”
- “*Yes, even if the facility/equipment is not available physically, we can still easily implement these procedures in the Skill-eLabs package*.”

Additional Comments and Suggestions from Instructors: The responses touched upon many areas. The comments suggest that the Skill-eLabs package should be implemented across all institutes, as it is seen as highly valuable for producing quality instructors and trainees. There is a call to introduce the package to more trades and extend its duration for more in-depth learning and retention. Regular updates, opportunities for feedback, and trainee assessments were recommended to further enhance its effectiveness. Respondents praised the use of AR/VR technologies, noting increased confidence among trainees, and suggested adding critical experiments through VR that are too costly or complex to perform in physical labs. Additionally, improving simulations to reflect real field experiences and offering more advanced practical sessions were highlighted as areas for growth. Overall, the feedback was positive, specifically mentioning enhanced trainee skills in areas like TV troubleshooting and solar technology.

- “*All institutes should have Skill-eLabs with a comprehensive package*.”

- "*Add simulations for more exercises from these trades. Add critical experiments/ exercises in VR module that are not possible in the lab and for those exercises where equipment cost is high.*"
- "*The duration of the skill lab package should be extended to allow for more in-depth learning, additional practice, and better retention of complex concepts and skills in the electronic mechanic and solar technician trades*."
- "*Regular updates and additions to the package, as well as opportunities for instructor feedback and trainee assessment, would further enhance its effectiveness and relevance in preparing trainees for the workforce*."
- "*Need some better and advanced practical session.*"

SECTION F:

DISCUSSION & RECOMMENDATION SECTION

Discussion

- Student Outcomes and Experiences
- Instructor Experiences and Feedback
- Implementation Team-Challenges and Insights

Recommendations

1.Discussion

The pilot implementation of the Skill-eLabs package across four institutions in India has provided valuable insights into the potential of digital vocational education and training (VET) in the context of Solar Technician and Electronic Mechanic trades. This discussion synthesizes the key findings from both student and instructor perspectives, and their implications for the future of VET in India.

1.1 Student Outcomes and Experiences

1.1.1 Student Background and Preparedness

Both Solar Technician and Electronics Mechanic students showed similar characteristics:

- A majority (85.7% for Solar Technician, 77.1% for Electronics Mechanic) had no prior work experience, indicating that most students were new to practical, vocational skills.
- Most students (80.5% for Solar Technician, 60.5% for Electronics Mechanic) lacked prior experience with technology-enhanced learning methods such as AR, VR, or simulations.
- There was generally good familiarity with safety PPE (85.62% for Solar Technician, 78.4% for Electronics Mechanic), though a small percentage in both trades needed additional safety training.

These findings highlight the importance of introductory modules in both vocational skills and technology-enhanced learning methods.

1.1.2 Effectiveness of Skill-eLabs in Skill Acquisition

Both trades demonstrated significant improvements in skill acquisition:

- Students who used Skill-eLabs showed higher overall performance and learning outcomes in practical tests compared to the control group.
- The Skill-eLabs course effectively reduced the need for instructor assistance during practical exercises, fostering student autonomy.
- Students who completed the Skill-eLabs course adhered more closely to safety protocols during practical exercises.

Notably, when the control group later received Skill-eLabs training, the performance gap between the groups disappeared, suggesting that Skill-eLabs can effectively supplement traditional training methods.

1.1.3 Impact of 3D Simulations, AR, and VR

1. **3D Simulations:**
    - Both trades reported significant boosts in confidence (68.5-87% for Solar Technician, 77.46-80.8% for Electronics Mechanic).
    - High engagement levels were reported (over 75% for both trades).

    - Improved understanding of key concepts and processes was noted.

2. **Augmented Reality (AR):**
    - Both trades reported significant skill improvement (86.1% for both).
    - High percentages (87.7% for Solar Technician, 88.9% for Electronics Mechanic) reported increased confidence in remembering and applying knowledge.
    - Qualitative feedback highlighted enhanced visualization, comprehension, and faster learning.

3. **Virtual Reality (VR) - Solar Technician only:**
    - High usability (82.3%) and effective learning (85.4%) were reported.
    - Key benefits included realistic simulation, engaging interactivity, and improved practical skills.

1.1.4 Comparison of NSTI and ITI Performance

NSTI students demonstrated stronger cognitive performance in both simulations and quizzes compared to ITI students across both trades. This suggests a potential need for additional support or tailored content for ITI students to bridge this performance gap.

1.1.5 Overall Student Feedback

Common themes across both trades included:

- Improved learning speed and engagement through interactive, immersive technologies.
- Enhanced safety through risk-free simulated environments.
- Resource conservation through simulations.
- Increased readiness for real-world applications.

For Solar Technicians, there was a noted gap in hands-on experience, suggesting that physical practical exercises remain crucial alongside digital learning.

Challenges: The feedback from students regarding the skill-eLabs package revealed both challenges and areas for improvement. While the majority of participants reported no significant challenges, a subset encountered various issues. These included technical difficulties, primarily related to VR/AR glitches and software problems, as well as learning curve challenges in understanding exercises and wiring. Some students experienced physical discomfort, specifically eye strain from VR use, while others noted language barriers with complex terminology and time constraints. A small number of participants also reported confidence issues or unspecified challenges.

Improvements: Students provided valuable suggestions for enhancing the skill-eLabs experience. The most prominent recommendations included expanding and deepening the content, particularly by incorporating more practical examples. There was a strong emphasis on improving the user experience through increased interactivity, such as adding more questions, challenges, and varied exercises. Technical improvements, focusing on enhanced graphics and simulation realism, were also suggested. Additionally, students proposed addressing language barriers, refining the assessment system with more comprehensive quizzes and result reviews, and increasing learning time. Notably, there was a suggestion to make these resources freely available to all students for self-learning, indicating a desire for wider access to these educational tools.

1.2 Instructor Experiences and Feedback

1.2.1 Instructor Background and Preparedness

- The majority of instructors (54%) had over 10 years of teaching experience, while 46% had up to 5 years of experience.
- Most instructors (14 out of 17) had no prior experience with skill-eLabs or similar technology packages.
- Instructors showed high familiarity with 3D Simulation and AR Technology (median score 8/10), but slightly lower familiarity with VR Technology (median score 6/10).
- Initial confidence in integrating technology into teaching methods was moderate (median score 5/10).

1.2.2 Impact of Skill-eLabs on Instructors

1. **Increased Confidence**: The Skill-eLabs package significantly improved educators' confidence in integrating technology into their teaching, with median confidence levels rising from 5.0 to 9.0 after the intervention.
2. **Meeting Expectations:** All instructors reported that the Skill-eLabs package met or exceeded their initial expectations, particularly in providing comprehensive hands-on learning experiences to students.
3. **Effectiveness of Technologies**: 3D simulations, AR, and VR technologies were highly rated for enhancing learning, with a median score of 9 out of 10, emphasizing their perceived value in improving practical skills and engagement.
4. **Ease of Integration**: Instructors reported high levels of ease in integrating the Skill-eLabs package into their teaching methods (median score 9/10).

1.2.3 Observed Improvements in Student Learning

Instructors reported significant improvements in students' learning outcomes, including:

- Enhanced problem-solving and critical thinking skills
- Improved practical abilities in electronic mechanics and solar technology

- Better understanding of processes through simulations/AR/VR
- Increased proficiency in fault finding, tool usage, circuit analysis, and troubleshooting
- Improved digital skills and adherence to safety protocols

1.2.4 Challenges and Areas for Improvement

1. **Technical Difficulties:** Some instructors reported challenges with internet connectivity, power outages, and limited accessibility to digital tools.
2. **Initial Unfamiliarity**: Some trainees struggled initially due to unfamiliarity with digital technology, particularly VR systems.
3. **Language Barriers**: There were suggestions for simpler Hindi instructions in some cases.
4. **Health Concerns**: Potential eye strain from prolonged digital use was mentioned as a concern.

1.2.5 Overall Reception

- There was unanimous consensus among instructors recommending the Skill-eLabs package for future trainees.
- The package was praised for its ability to combine theory with hands-on training, boosting both practical skills and employability.

1.3 Implementation Team - Challenges and Insights

Based on the challenges encountered by the Amrita Implementation team, during the pilot deployment of the Skill-eLabs package, the following recommendations are proposed to enhance future implementation and address the key areas of concern:

- **Ensure Reliable Internet Connectivity and Offline Alternatives**
  The pilot deployment faced consistent internet issues across multiple locations, necessitating the use of personal hotspots. To overcome this, it is crucial to ensure reliable internet infrastructure or develop offline alternatives, especially in areas with connectivity challenges.
- **Develop Comprehensive Training and Certification for Instructors**
  Instructors required additional guidance and support in mastering VR and AR technologies. It is recommended to implement continuous and comprehensive training programs to build instructors' proficiency in technology-enabled learning. This can be achieved by establishing a "Master Trainer" program at National Skill Training Institutes (NSTIs) to train and mentor Industrial Training Institute (ITI) instructors. Additionally, a certification program, coupled with assessment, should be developed for instructors in technology-enabled teaching.

- **Foster Student Engagement and Motivation**
  Some students, particularly from government ITIs, exhibited a lack of motivation at the outset. To enhance engagement, introducing reward-based systems, integrating interactive activities, and addressing underlying causes of disengagement are recommended. These strategies will help foster a more dynamic and participatory learning environment.
- **Strengthen Equipment Setup Procedures and Technical Support**
  The pilot encountered difficulties in setting up VR headsets and simulation software. It is advised to carry out pre-setup checks and provide instructors with comprehensive training on equipment usage. Additionally, ensuring that dedicated technical support is available during sessions can mitigate technical hurdles and reduce downtime.
- **Extend the Duration of Pilot Programs and Include Buffer Days**
  The five-day timeline per batch was inadequate and resulted in a tight schedule that was further compounded by other challenges. Future pilots should allow for a more generous time allocation, ensuring sufficient duration for each session. Incorporating buffer days will help accommodate unforeseen issues and ensure a smoother learning experience.
- **Localise Language and Content**
  Some regions encountered difficulties due to the simulations being conducted in Hindi. To ensure better comprehension across diverse linguistic groups, it is recommended to localise content and review it with student and instructor focus groups. This will help tailor the content to the local context and improve student understanding.
- **Enhance Space and Infrastructure Planning**
  Limited space for VR sessions and a shortage of power ports were reported. For future deployments, careful planning for adequate space and infrastructure is essential to ensure that the sessions run smoothly. This includes ensuring proper electrical support and spatial arrangements.
- **Monitor and Safeguard Student Health and Well-being**
  Some students reported discomfort and headaches due to prolonged VR usage. To safeguard student health, it is recommended to monitor VR usage, provide regular breaks, and educate students on best practices for VR interaction to minimise discomfort.
- **Facilitate Efficient Feedback Collection**
  The team encountered delays in feedback collection due to typing-related challenges, eventually transitioning to voice recordings. To streamline feedback collection, it is advised to implement voice or video feedback options. Moreover, students should be trained on how to provide detailed feedback to improve data quality.
- **Implement Structured Onboarding for New Students**
  Integrating new students who joined partway through the training posed challenges. To address this, it is essential to establish structured onboarding and catch-up sessions, enabling new students to integrate smoothly without disrupting the ongoing sessions.

2.Recommendations

Based on the combined insights from student outcomes and instructor feedback, we propose the following recommendations for scaling and improving the Skill-eLabs initiative:

1. **Embedding Skill-eLabs in VET Curriculum**: Implement Skill-eLabs across all institutes, integrating it into the curriculum as a core component of practical training.
    a. Develop a standardized blended learning model to embed and implement skill-eLabs as part of curriculum
    b. Implement Skill-eLabs across all ITIs and NSTIs
    c. Integrate as a core component of practical training
    d. Establish guidelines for incorporating Skill-eLabs into daily teaching practices.
    e. Align with existing curriculum and assessment structures
2. **Expand Content Development:** To ensure the strategic development, relevance, and continuous improvement of Skill-eLabs content across various trades and skill levels, the following comprehensive approach to content creation and management is recommended:
    a. Develop criteria to select skills for developing skill-eLabs package components
    b. Conduct workshops with NSTI/ITI Experts to shortlist exercises and map to specific component of Skill-eLabs - 3D Simulation, AR, VR
    c. Set up a standards and review committee/ advisory board that will oversee and guide the mapping and content development process consisting of members from academia, industry and domain experts with expertise in learning technologies, curriculum development, and relevant domains.
    d. Establish SOPs for the development of the Skill-eLabs components.
    e. Create a roadmap for covering all major vocational trades over a 3-5 year period.
    f. Prioritize the development of Skill-eLabs modules for high-demand trades.
    g. Incorporate more real-world scenarios and case studies
    h. Create VR content for complex or high-risk experiments
    i. Create Instructor and student focus groups for initial review and feedback of the developed Skill-eLabs components.
    j. Implement a feedback system for instructors and students to suggest content improvements.
    k. Regularly update content to match industry developments
    l. Develop learning features to cater to different skill levels

m. Health and Safety Considerations: Integrate guidelines and best practices for the extended use of digital tools, addressing concerns such as eye strain and other potential health impacts.

3. **Enhanced Instructor Training:** To ensure the successful implementation of Skill-eLabs, a comprehensive instructor training and support system is essential. This multi-faceted approach includes a tiered certification program, continuous professional development opportunities, and real-time support mechanisms to empower instructors in effectively integrating technology into vocational education.

    a. Develop a multi-tier certificate training program for instructors, covering basic, intermediate, and advanced technology enhanced learning and teaching skills with a focus on:

        i. Technology integration strategies
        ii. Student Motivation and Learner Diversity
        iii. Effective Use of Multimedia and Immersive Technologies
        iv. Technical Proficiency and Troubleshooting

    b. Continuous Professional Development

        i. Regular webinars and online workshops on emerging technologies
        ii. Annual refresher courses to maintain certification
        iii. Mentorship program pairing experienced and novice instructors
        iv. Opportunities for instructors to contribute to Skill-eLabs content development
        v. Create a community of practice for knowledge sharing

    c. Establish a helpdesk system for real-time instructor support.

4. **Technical Infrastructure Improvement:** To ensure the successful implementation of Skill-eLabs, a focus on enhancing the technical infrastructure of participating institutions is essential:

    a. Assess the technical infrastructure of institutions to ensure all requirements are met, such as:

        i. Internet connectivity and power reliability.
        ii. Adequate hardware availability.
        iii. Space requirements for VR equipment.

    b. Conduct a national-level assessment to determine how many institutions have the technical infrastructure to implement Skill-eLabs modules effectively.

    c. Implement robust data security and privacy measures.

d. Establish technical support teams at the institutional level to ensure effective troubleshooting and maintenance.

Refer Appendix A*: Institution Infrastructure Checklist, that may be used for the infrastructure assessment. This was designed based on the experience from the pilot.*

5. **Breaking Barriers to Learning: Language and Accessibility:**

    a. Enhance language support, focusing on simplifying instructions in regional languages.

    b. Develop user-friendly interfaces to support teaching and learning for less tech-savvy individuals.

    c. Develop features for differently-abled learners.

    d. Adaptive Learning Features - Develop or ensure features in the delivery platform that cater to different performance levels (as observed between NSTI and ITI students), ensuring all students can progress at an appropriate pace.

    e. Develop and evaluate AI Tutor in regional languages - a proof of concept may be developed and evaluated to see its effect on learning in students, especially the ITI students.

    f. Develop mobile-responsive designs for access on various devices.

    g. Develop offline capabilities for core functionalities of Skill-eLabs to mitigate connectivity issues at training institutions.

    h. Create multilingual support documentation including glossary of terms and SOPs for ensuring standardized translations to regional languages.

6. **Continuous Assessment and Feedback:** To ensure Skill-eLabs modules remain cutting-edge and industry-relevant:

    a. Implement a system for ongoing evaluation of both student progress, instructor experiences and platform effectiveness.

    b. Regularly collect and incorporate feedback for continuous improvement.

    c. Establish a systematic process for regular content updates through regular reviews by industry.

    d. Establish a dedicated team for quality assurance and improvement.

7. **Industry Collaboration:** Strengthen partnerships with industry leaders to ensure the relevance of Skill-eLabs content and to provide opportunities for virtual internships or industry projects.

8. **Research on Long-term Impact:** Conduct longitudinal studies to assess the effect of Skill-eLabs on the employment outcomes and industry readiness of VET graduates. Publish the findings to guide policy development and support continuous improvements to the programme.

From Pilot to National Implementation

- Identify a platform to host Skill-eLabs learning resources
- Scale development of Skill-eLab packages for other trades
- Develop master trainers for Technology enabled learning
- Implement a train-the-trainer model for rapid scaling
- Engage/ Identify institutions with the required infrastructure
- Engage with state governments for localized implementation.

By implementing these recommendations, the Skill-eLabs initiative has the potential to revolutionize vocational education and training in India, enhancing skill development, improving employability, and contributing to the country's economic growth through a more skilled workforce. The positive reception from both students and instructors provides a strong foundation for the widespread adoption and continued development of this innovative approach to VET.

SECTION G:
CONCLUSION

Conclusion

The Skill-eLabs project represents a significant step forward in modernizing vocational education and training in India. Through the collaborative efforts of government bodies, educational institutions, and dedicated individuals, we have successfully demonstrated the potential of digital technologies to enhance skill development and learning outcomes.

The positive results from both students and instructors validate the effectiveness of the Skill-eLabs approach. As we look to the future, we are confident that the insights gained from this pilot study will pave the way for broader implementation, ultimately contributing to a more skilled and empowered workforce in India.

The success of this project underscores the importance of innovation, collaboration, and commitment to excellence in education. We look forward to building upon these achievements to further advance vocational training and support India's economic growth through enhanced skill development.

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- Mr.Srinivasa Rao (Director, NIMI)
- Dr. Bhavani Rao (Director, AMMACHI Labs, Amrita Vishwa Vidyapeetham)

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SECTION H:
APPENDIX

Appendix A: Institution Infrastructure Checklist

1. Equipment List and Specifications

Equipment	Specifications/ Requirements
Computer for VR	Minimum Specs: • CPU: Intel i5-4590 or AMD Ryzen 5 1400 or or equivalent • GPU: NVIDIA GTX 1050 Ti or AMD RX 470 or or equivalent • RAM: 8 GB • Storage: SSD - 256 GB Recommended Specs: • CPU: Intel i5-12600K or AMD Ryzen 5 5600X or or equivalent • GPU: NVIDIA RTX 3060 or AMD RX 6600 XT or or equivalent • RAM: 16 GB • Storage: SSD - 512 GB High-End Specs: • CPU: Intel i7-13700K or AMD Ryzen 7 7700X or or equivalent • GPU: NVIDIA RTX 4070 or AMD RX 6800 XT • RAM: 32 GB • Storage: SSD - 1 TB
Computer Specs for 3D simulations	Minimum Specs: • CPU: Intel Core i3-2100 or AMD FX-6300 or equivalent • GPU: NVIDIA GTX 750 Ti or AMD Radeon HD 7850 or equivalent • RAM: 4 GB • Storage: HDD with 20 GB free space Recommended Specs: • CPU: Intel Core i5-8400 or AMD Ryzen 5 2600 or equivalent • GPU: NVIDIA GTX 1660 Super or AMD Radeon RX 590 or equivalent • RAM: 8 GB • Storage: SSD with 50 GB free space High-End Specs: • CPU: Intel Core i7-12700K or AMD Ryzen 7 5800X or equivalent

	- GPU: NVIDIA RTX 3070 or AMD Radeon RX 6800 or equivalent - RAM: 16 GB - Storage: NVMe SSD with 100 GB free space
Mobile Device Specs for Augmented Reality	Operating System Version: - Android 7.0 (Nougat) or later. - Android 10 or later is recommended for optimal performance. AR Platform: - Google ARCore: Android's AR framework. Supported Devices: - A wide range of devices from manufacturers like Samsung, Google Pixel, Huawei, LG, Motorola, OnePlus, and others. - Note: Not all Android devices running Android 7.0+ are ARCore compatible. Compatibility depends on hardware capabilities. How to Check Compatibility: - Visit the Google ARCore supported devices list to confirm if your device is supported. - Alternatively, install the Google Play Services for AR app from the Google Play Store; it will notify you if your device is incompatible. Hardware Requirements: - CPU: Generally, mid- to high-end processors (e.g., Qualcomm Snapdragon 625 or higher). - Sensors: Must include accelerometer, gyroscope, and magnetometer. - Camera: High-quality rear-facing camera.
VR Headset	Oculus Quest 2 or similar

2.Institution Infrastructure Checklist

Institution Details

- Institution Name: ________________________
- Address: ________________________________
- Contact Person: _________________________
- Position/Title: _________________________
- Email: __________________________________

- Phone Number: ___________________________

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1. Trade Availability

- Is the specific trade available in your institution? ( ) Yes ( ) No
  - If yes, specify the trade(s): ______________________________

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2. Infrastructure Requirements

2.1 Physical Space for VR Training

- **Dedicated VR Space (Minimum 2m x 2m)**: ( ) Yes ( ) No

2.2 Computer Facilities

- **Computer Lab with Required Specs for Simulation**: ( ) Yes ( ) No
  - **Number of Computers**: ________
  - **Number of headphones/headsets**: ________
  - **Specifications**:
    - **Processor**: ________________________
    - **RAM**: ___________
    - **Graphics Card**: ____________________
- **VR-Ready Computers**: ( ) Yes ( ) No
  - **Number**: ________
  - **Specifications**:
    - **Processor**: ________________________
    - **RAM**: ___________
    - **Graphics Card**: ____________________
    - **VR Compatibility**: ________________

2.3 Mobile Devices for AR

- **Mobile Devices Supporting AR**: ( ) Yes ( ) No
  - **Number of Devices**: ________
  - **Device Specs (Model/OS/AR Features)**: ______________________

2.4 Internet Connectivity

- **Wi-Fi/Internet (Min 10 Mbps/machine)**: ( ) Yes ( ) No
  - **Actual Speed**: ________ Mbps
- **Wi-Fi for Laptops (if used in pilot)**: ( ) Yes ( ) No

2.5 Practical Lab Facilities

- **Practical Lab with Equipment for Trade**: ( ) Yes ( ) No

2.6 Power Supply

- **Backup Power Available**: ( ) Yes ( ) No

- **Type**: ( ) Generator ( ) UPS ( ) Other: ________________

---

3. Instructor Information

3.1 Instructor Details

- **Number of Instructors for the Trade**: _______
- **Instructor Details**:

Name	Experience (Years)	Qualifications

3.2 IT Familiarity

- **Instructors are familiar with**:
  - **Computers**: ( ) Yes ( ) No
  - **MS Office Suite**: ( ) Yes ( ) No
  - **Other Software**: __________________________

3.3 Familiarity with Learning Technologies

- **Technologies Used/Familiar**:

Technology	Familiar? (Yes / No)	Have used in classroom? (Yes / No)
Powerpoint Presentation		
Videos		
Simulations		
Augmented Reality		
Virtual Reality		
Learning Management System		

---

4. Additional Information

- **Wi-Fi for Laptops in Pilot Program**: ( ) Yes ( ) No
- **Additional Comments/Requirements**: ____________________________

Acknowledgment

I confirm that the information provided is accurate and complete.

- **Name**: ______________________
- **Signature**: __________________
- **Date**: _______________________

Instructions: Fill out all sections. Provide detailed information to facilitate assessment. For questions, contact [Contact Person/Department at NIMI].

Appendix B: Guidelines for Skill-eLabs Design

GENERAL GUIDELINES

To design effective learning-based simulations, consider the following guidelines. These recommendations draw from established best practices and incorporate recent insights gathered from the Skill-eLabs pilot program.

1. User-Centered Design

- **Know Your Audience**: Tailor the simulation to the students' skill levels, technical familiarity, and educational background.
- **Inclusive Design**: Consider accessibility features like multilingual support, simple language, and readable fonts.

2. Clear and Simple Navigation

- **Consistency**: Keep the navigation consistent throughout the simulation to avoid confusion.
- **Step-by-Step Guidance**: Break tasks into clear, manageable steps and provide visual cues or hints to guide users.
- **Feedback**: Immediate feedback after each step or task, including correct or incorrect responses in quizzes, helps learners understand their progress.

3. Effective Use of Visual and Audio Elements

- **Minimize Cognitive Load**: Avoid overwhelming users with too much information at once. Present data visually through diagrams, icons, and minimal text.
- **Text Instructions:** Include instructions viewable in text format for the student to access when needed.
- **Audio Instructions**: Include clear, concise audio instructions, especially for tasks requiring detailed attention. Ensure they can be replayed.

- **Visual Hierarchy**: Use a well-defined visual hierarchy to emphasize important UI elements like tasks, next steps, or quizzes.

4. Task Breakdown and Modular Learning

- **Micro-Learning**: Break tasks and lessons into smaller, easily digestible units to prevent cognitive overload and improve retention.
- **Progressive Complexity**: Start with simple tasks and gradually increase complexity as students progress through the simulation.
- **Safety Integration** Prioritize safety awareness across all modules by incorporating interactive demonstrations of proper procedures and potential consequences of negligence. Use visual cues and simulations to reinforce key safety concepts, fostering a culture of responsible practice that prepares students for real-world scenarios.
- **Real-Life Tasks:** Include tasks such as installation, debugging, inspection and testing features that mimic real-world activities.

5. Interactive and Engaging Design

- **Gamification**: Include elements like scoring, progress tracking, and rewards (e.g., badges) to motivate users.
- **Challenges and Experimentation**: Incorporate challenges and options to experiment to keep learners engaged and improve learning.
- **Quizzes and Assessments**: Use frequent quizzes with instant feedback to reinforce learning and ensure knowledge retention.
- **Hints and Help**: Ensure a hint system is readily available, but optional, so users can attempt tasks independently before seeking help.
- **Limit Hints:** Use hints sparingly to encourage independent learning.
- **Offer students two learning options:**
    - Learn /Guided Mode: Provides structured, step-by-step instructions.
    - Test / Unguided: Allows free experimentation without direct guidance.

  Both modes may include an optional hint system to support learning while maintaining the distinct nature of each approach.
- **Results:** Ensure a final result screen, that displays the students performance including quiz results, hints used, time taken etc.

6. Assessment and Feedback Mechanisms

- **Score and Progress**: Display progress bars and scores to show how much has been completed and where the user stands.
- **Real-Time Feedback:** Offer immediate, constructive responses to student actions.
- **Feedback on Errors**: Provide detailed feedback on mistakes to help learners understand what they missed and how to improve.
- **Incentivize Improvement:** Use points or achievements to encourage repeated attempts and continuous learning.

7. Language and Terminology

- **Multilingual Support**: Ensure that language settings are easily accessible and provide support for multiple languages, especially for a diverse group of students.
- **Simple Language**: Use clear and simple terminology that aligns with the students' comprehension levels, avoiding technical jargon unless absolutely necessary.

8. Consistency and Standardization

- **Design Patterns**: Use consistent UI patterns (button placements, colours, icons) so users can predict interactions and focus on learning instead of navigating.
- **Uniform Scoring System**: Standardize how quizzes are scored to avoid confusion and ensure fairness.

9. Mobile and Device Optimization

- **Cross-Platform Compatibility**: Ensure that the simulation is responsive and works well on different devices (desktop, tablet, mobile) and platforms.
- **Minimal Hardware Requirements**: Design the simulations to work on low-end devices with limited hardware or internet connectivity, ensuring accessibility for all. Ensure compatibility with a wide range of hardware configurations.

10. Testing and Usability Evaluation

- **Usability Testing**: Regularly test the simulation with students and instructors to ensure it is intuitive, effective, and meets learning objectives.
- **Iterative Design**: Use feedback from testing to make improvements, iterating the design based on real-world usability.
- **Smooth Operations:** Ensure transitions and functions run without glitches to maintain engagement.

11. Engagement through Realism

- **Real-World Scenarios**: Simulations should closely mimic real-world tasks that students will encounter in their vocational training or careers.
- **Realistic Graphics**: Use realistic graphics mimicking real world balancing the performance and size of the modules.
- **Immersive Elements**: Where applicable and justified, include AR and VR elements for better engagement.
- **Accurate Proportions:** Scale tools and machines to match real-life sizes for authenticity.

12. Support for Self-Paced Learning

- **Pause and Resume**: Allow users to pause and resume simulations so they can learn at their own pace.
- **Replay**: Ensure users can replay tasks or steps they struggle with for better mastery.

13. Integrate Theory and Instructor Support

- **Accessible Theory Content:** Ensure theoretical background is available within the modules.
- **Encourage Instructor Involvement:** Support from instructors for complex topics enhances understanding.

Basic UI Elements

The skill-eLabs package modules incorporated essential UI elements that were proven effective. Additional UI components may be included as needed, based on the specific requirements of each exercise.

UI Element	Description
Main Task	The primary objective or activity in the simulation.
Sub Task	A smaller task within the main task.
Task Description	Brief details about the task at hand / Voice over narration content for the specific task.
Score	Displays the quiz result or performance score.
Step Progress	Visual indicator showing task completion stages.
Replay Audio	Button to replay task instructions or audio cues.

Settings	Allows changes to language and volume settings.
Hint Button	Highlights the correct clickable area for guidance.
Quiz Screen	A screen showing a question with four answer options.
Pop-up Screens	Displays important alerts or messages during the simulation.

Appendix C: Evaluation Questions and Rubrics

The following questions and rubrics were used in the practical skill evaluation for both the trades.

1) On a scale from 1 to 5, with 1 being poor and 5 being excellent, how would you rate the student's overall performance in the practical tests (trade practical/professional skills)?

o 1 (Poor)
o 2 (Average)
o 3 (Above average)
o 4 (Good)
o 5 (Excellent)

Rubrics

The average from the rubrics was calculated for the practical performance.

Criteria	**1 (Poor)**	**2 (Average)**	**3 (Above average)**	**4 (Good)**	**5 (Excellent)**
Technical skills in the use of tools	Student lacks the necessary technical skills; frequent errors in handling tools	Some technical skills demonstrated with use of tools but with several errors	Demonstrates basic technical skills with use of tools, occasional errors	Good technical skills with use of tools with few errors	Excellent technical skills with use of tools few to no errors
Accuracy achieved while undertaking task/ skill	Below 50% accuracy achieved while undertaking different tasks / skills.	50-60% accuracy achieved while undertaking different tasks / skills.	60-70% accuracy achieved while undertaking different tasks / skills.	70-80% accuracy achieved while undertaking different tasks / skills.	Above 80% accuracy achieved while undertaking different tasks / skills.
Task completion efficiency (time taken to perform the task)	Tasks completed with significant delays or not completed	Tasks completed but with significant delays	Tasks completed within acceptable timeframes	Tasks completed efficiently with minor delays	Tasks completed efficiently and ahead of time
Quality of work (Neatness and consistency in the finish)	Poor workmanship, frequent re-dos required	Work often lacks quality and needs improvement	Work meets minimum standards, may need occasional rework	Produces quality work with few corrections	Delivers high-quality work with no corrections needed

2) How many times did the student require assistance or guidance from instructors to complete practical exercises?

o 1 (0 times)
o 2 (1-3 times)
o 3 (4-6 times)
o 4 (More than 6 times)

3) How many safety protocols did the student follow correctly during practical sessions, as per the checklist provided?

1 None followed
2 Some followed
3 All followed

4) Have the students met the outcome (mapped to the trade theory/ professional knowledge) for the specific exercise? (Excellent, good, above average, average, poor)

o 1 (Poor)
o 2 (Average)
o 3 (Above average)
o 4 (Good)
o 5 (Excellent)

Rubrics

The average from the rubrics was calculated for the learning outcomes.

Criteria	**1 (Poor)**	**2 (Average)**	**3 (Above average)**	**4 (Good)**	**5 (Excellent)**
Understanding of Key Concepts *(Example: What are the main components of a solar PV system? What is the function of SCC?)*	Lacks understanding of fundamental concepts	Limited understanding of key concepts; requires significant clarification	Basic understanding of key concepts but struggles with advanced topics	Good understanding of key concepts with minor gaps	Comprehensive understanding of key concepts, no major gaps
Comprehension of Technical Terminology	Does not understand or uses technical terminology incorrectly	Limited understanding and frequent incorrect use of technical terms	Understands basic technical terms but struggles with more advanced vocabulary	Demonstrates good comprehension of technical terminology	Demonstrates excellent grasp and appropriate use of technical terminology

Accuracy in delivering of the concepts	Struggles to communicate clearly while explaining theoretical concepts. Speaking is very unclear	Inconsistent clarity when explaining concepts.	Able to explain concepts with some clarity in communicatio n	Explains most concepts clearly with minimal errors	Explains theoretical concepts clearly, accurately and confidently
Retention of Information from the course	Struggles to retain even basic information	Retains only the most basic information; frequently forgets key concepts	Retains essential information but struggles with complex topics	Retains and recalls most theoretical information easily	Retains and applies theoretical knowledge with ease and clarity

Appendix D: Meeting Minutes -Presentation of Impact Evaluation Results of Skill-eLabs Project under Chairpersonship of Secretary, MSDE (19-Dec-2024)

F. NO. SD-17/70/2023-(IC)
Government of India
Ministry of Skill Development & Entrepreneurship

3rd Floor, Kaushal Bhawan,
New Moti Bagh, New Delhi,
Dated:16.01.2025

Office Memorandum

Subject: Forwarding of minutes of meeting to present findings of the Impact Assessment Report for 'Creation of Simulated Skill Training Packages (Skill E-Labs) for Vocational Education and Training (VET) project under SANKALP Programme of MSDE'- reg.

The undersigned is directed to refer to the subject cited above and to forward herewith minutes of the meeting to present the findings of the Impact Assessment Study conducted under the project 'Creation of Simulated Skill Training Packages (Skill E-Labs) for Vocational Education and Training (VET) under SANKALP Programme of MSDE', held under the Chairpersonship of Secretary, Ministry of Skill Development & Entrepreneurship on 19th December 2024 at 04:00 pm in Room No 304, Third Floor, Kaushal Bhawan, New Delhi for kind information and further necessary action.

2. This issues with the approval of the Competent Authority.

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(Shiv Nandan Kumar)
Under Secretary to the Govt. of India

Encl.: As above.

To:

1. Sr. PPS to Secretary, MSDE
2. Sr. PPS to Senior Economic Advisor, MSDE
3. PPS to DG (Training), MSDE
4. PPS to Director, NCVET
5. CEO, Electronics Sector Skills Council of India
6. CEO, Skill Council for Green Jobs
7. PS to Director (SANKALP), MSDE
8. SANKALP PMU, MSDE

Government of India
Ministry of Skill Development and Entrepreneurship
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Subject: Minutes of meeting to present the findings of the Impact Assessment Report for the project 'Creation of Simulated Skill Training Packages (Skill E-Labs) for Vocational Education and Training (VET) under SANKALP Programme of MSDE' - reg.

A meeting to present the content developed under the project and disseminate the findings of the Impact Assessment Study was held under the Chairpersonship of Secretary, MSDE on 19th December 2024 at 4:00 pm, in Room No 304, Third Floor, Kaushal Bhawan, New Delhi. The Senior Economic Advisor, MSDE; Deputy Director General, MSDE; Director, DGT; Director, NCVET; CEO, Electronics Sector Skills Council of India; Director, SANKALP, Director, NIMI along with representatives from AMMACHI Labs, Skill Council for Green Jobs and Principals from ITIs (Bicholim and Jhajjar) and NSTI (Mumbai and Dehradun) participated in the meeting. The details of participants are enclosed at **Annexure**.

2. At the outset, Director, SANKALP, MSDE welcomed the Chair and the participants. The agenda for the meeting was discussed and it was apprised that the project was approved during the 12th PAB Meeting held on 18th August 2022 at a project cost of Rs 81,64,884/-.

3. Further, it was informed that the e-skill lab content has been developed based on 6 competencies covering the Electronics Mechanic and Solar Technician trades offered in ITIs. As a part of the package, 6 demonstration videos, 6 simulation exercises, 2 Augmented reality exercises and 1 Virtual Reality exercise have been developed. Pilot demonstrations were conducted between June-July 2024 in 2 ITIs - Bicholim and Jhajjar and 2 NSTIs - Mumbai and Dehradun covering 160 students and 17 faculty members. Additionally, equipment comprising of one high-end computer, 2 virtual reality headsets and accessories have been provided in the 4 institutions. As a part of the project, an Impact Assessment Study was undertaken to assess the Skill-e lab package's usability, its impact on skill acquisition, retention, learner confidence, and its influence on instructors' confidence and technology integration. It was also informed that the draft Impact Assessment Study Report was circulated to the subject matter experts designated by NIMI, DGT and SANKALP team and the feedback provided has been incorporated in the Study report.

4. Thereafter, the AMMACHI team shared that the project aims to support MSDE's commitment to upgrading ITIs and NSTIs by providing evidence-based insights to guide the design and adoption of learning technologies for improved VET preparedness and success. A detailed presentation was made on the process adopted for development of content for the e-skill labs and pilot demonstration of the content which included hands on training of 160 students and 17 faculty members from the 4 selected institutions. The research design was based on mixed methods approach to ensure a comprehensive

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understanding of the participants' experiences and effectiveness of the technology. The overall results reveal that students participating in the skills-e labs course showed significantly higher performance and learning outcomes in practical tests compared to the control group. The course enhanced autonomy by reducing the need for instructor assistance and improved adherence to safety protocols during practical exercises. A short video encapsulating the key features of the project was also presented.

4. Secretary, MSDE summarized the discussions, and the following decisions were taken:

Sl. No	Decision	Action to be taken by
i.	Project video to be disseminated through MSDEs social media channels.	i. AMMACHI Labs ii. Media Team, MSDE
ii.	Framework for selection of trades/courses for development of content using AR/VR and aligned technologies needs to be prepared and submitted to MSDE. In addition, the parameters for deciding the mix of technologies need to be identified	i. AMMACHI Labs ii. NIMI
iii.	Two-page article on the project highlighting the findings of the Impact Assessment Report needs to be prepared for further publication.	i. AMMACHI Labs ii. NIMI iii. SANKALP team

5. The meeting ended with a vote of thanks to the Chair and participating members.

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Annexure

List of Participants

Sl. No	Name	Designation
	SANKALP DIVISION, MSDE	
1.	Sh. Nilambuj Sharan	Senior Economic Advisor, MSDE
2.	Sh. Arvind V. S	Director (SANKALP), MSDE
3.	Sh. Manish Gunjan	PMC, SANKALP
4.	Ms. Shefali Sharma	PMC, SANKALP
	DIRECTORATE GENERAL OF TRAINING	
5.	Sh. Ishwar Singh	Deputy Director General
6.	Sh. Hemant D Ganjare	Director
	NIMI	
7.	Sh. K.Srinivasa Rao	Executive Director, NIMI
8.	Sh. T.V. Rajasekar	Joint Director
9.	Sh. Nirmalya Nath	Deputy General Manager, NIMI
	NSTI	
10.	Sh Chandrakant Mahadev Diggewadi	Assistant Director, NSTI Mumbai
11.	Sh Manish Mamgain	Training Officer - NSTI Dehradun
12.	Sh. N. Bannibagi	Deputy Director, NSTI Ramanthapur, Hyderabad
13.	Sh. Jayant Paul	Training Officer - NSTI Vidyanagar, Hyderabad
	ITI	
14.	Sh Jeethpal	Principal - Govt ITI Jhajjar, Harayana
15.	Sh Kapil Aigal	Principal, Govt ITI Bicholim, Goa
16.	Sh. Vinod Satkalkar	Group Instructor - Govt ITI Bicholim, Goa
	Skill Council Green Jobs	
17.	Sh. Sarvesh Pratap Mall	Senior Manager – Technical
18.	Sh. Prem Prakash Bharti	Sr. Manager – Technical
	Electronics Sector Skill Council of India	
19.	Sh. Saleem Ahmed	CEO
20.	Sh. Varun Bhatia	Vice President-Project & Learning Solutions
	AMMACHI Labs	
21.	Sh Ajay Balakrishnan	Associate Director
22.	Ms Anu Sivan	Team Member
23.	Sh Chris Coley	Team Member

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Appendix E: Framework for selection of trades/courses and skills

These frameworks serve as calculators that MSDE can use to identify priority trades and courses for developing learning technologies. They also help in selecting relevant skills that can be shortlisted for simulations, AR, and VR development. By assessing multiple criteria through structured questions, these tools generate a score to support data-driven decision-making.

Link to Excel calculators:
https://drive.google.com/drive/folders/1q-xFKItsICXg_Lk3N6s7ZLjeOFFshDo7?usp=sharing

MODULE SELECTOR FOR SKILL-ELABS

Module:

SCORE (out of 100 Marks) **0.00**

Factors	Data Range	Weight	Responses	Score	Weighted Score
Re-usability & Relevance		**25%**			**0.00**
Is the curriculum mapped to National Occupational Standards?	Yes/No	25%		0	0.00
Is the competency relevant to multiple job roles within the sector? (High = Over 7 job roles, Medium = Between 4 and 7, Low = Below 4)	H/M/L	25%		0	0.00
Does the competency lend itself for self employment?	H/M/L	25%		0	0.00
Does the competency form part of the key competencies for the job role?	Yes/No	25%		0	0.00
Work environment		**15%**			**0.00**
Does the competency need infrastructure that is difficult to setup?	H/M/L	33%		0	0.00
Does the competency involve utilizing human or animal subjects to practice the skill?	H/M/L	33%		0	0.00
Does the competency require high level of safety & health considerations?	H/M/L	33%		0	0.00
Equipment & Materials		**20%**			**0.00**
Does the competency require equipment this is costly to procure and/or maintain?	Yes/No	25%		0	0.00
Does the competency require equipment, that may be operated only by certified technicians?	Yes/No	25%		0	0.00
Does the competency require expensive raw materials?	Yes/No	25%		0	0.00
Does the competency require equipments that involves high power consumption?	Yes/No	25%		0	0.00
Complexity of the Skill		**35%**			**0.00**
Does the competency involve complex procedures / operations ?	H/M/L	20%		0	0.00
Does the cognitive skill involved of higher order?	H/M/L	20%		0	0.00
Does the psychomotor skill involved of higher order?	H/M/L	20%		0	0.00
Does the competency take substantial time to complete compared to other competencies in the job role?	H/M/L	20%		0	0.00
Does the competency address the skill gaps for the job roles and future skills / employability skills?	Yes/No	20%		0	0.00
Sustainable Development		**5%**			**0.00**
Does the competency take into consideration sustainable development and re-use/proper disposal of waste?	Yes/No	100%		0	0

MODULE SELECTOR FOR SKILL-ELABS					
Module:					
SCORE (out of 100 Marks)					0.00
Factors	Data Range	Weight	Responses	Score	WeightedScore
Re-usability & Relevance		**25%**			**0.00**
Is the curriculum mapped to National Occupational Standards?	Yes/No	25%		0	0.00
Is the competency relevant to multiple job roles within the sector? (High = Over 7 job roles, Medium = Between 4 and 7, Low = Below 4)	H/M/L	25%		0	0.00
Does the competency lend itself for self employment?	H/M/L	25%		0	0.00
Does the competency form part of the key competencies for the job role?	Yes/No	25%		0	0.00
Work environment		**15%**			**0.00**
Does the competency need infrastructure that is difficult to setup?	H/M/L	33%		0	0.00
Does the competency involve utilizing human or animal subjects to practice the skill?	H/M/L	33%		0	0.00
Does the competency require high level of safety & health considerations?	H/M/L	33%		0	0.00
Equipment & Materials		**20%**			**0.00**
Does the competency require equipment this is costly to procure and/or maintain?	Yes/No	25%		0	0.00
Does the competency require equipment, that may be operated only by certified technicians?	Yes/No	25%		0	0.00
Does the competency require expensive raw materials?	Yes/No	25%		0	0.00
Does the competency require equipments that involves high power consumption?	Yes/No	25%		0	0.00
Complexity of the Skill		**35%**			**0.00**
Does the competency involve complex procedures / operations ?	H/M/L	20%		0	0.00
Does the cognitive skill involved of higher order?	H/M/L	20%		0	0.00
Does the psychomotor skill involved of higher order?	H/M/L	20%		0	0.00
Does the competency take substantial time to complete compared to other competencies in the job role?	H/M/L	20%		0	0.00
Does the competency address the skill gaps for the job roles and future skills / employability skills?	Yes/No	20%		0	0.00
Sustainable Development		**5%**			**0.00**
Does the competency take into consideration sustainable development and re-use/proper disposal of waste?	Yes/No	100%		0	0

Appendix F: Key Parameters for Selecting Learning Technologies for Skills

Key Parameters for Selecting 3D Simulations, AR, or VR Based on Skill to be Taught

In the ITI ecosystem, 3D simulations that are playable on mobile devices and computers are generally recommended as the primary technology for skill training. These simulations provide learners with a structured understanding of the structure, function, and procedures before hands-on practice. They are best suited for scenarios where learners need interactive practice but do not require full immersion.

However, Augmented Reality (AR) and Virtual Reality (VR) can be additionally be integrated based on the nature of the skill being taught:

- AR is ideal when the skill involves real-world interaction, where concepts can be best taught through visualization, overlays, or real-world operational guidance.
- VR is most effective when the skill is physically risky, costly, or difficult to practice in real life, as it provides full immersion and enhances spatial awareness, muscle memory, and decision-making.

A combination of these technologies enhances the learning experience, catering to different types of learners and improving overall training effectiveness. The selection of 3D Simulation, AR, VR, or a hybrid approach should be based on the skill's complexity, real-world application, safety considerations, and accessibility.

To determine the most suitable technology for a particular skill, the following parameters and criteria provide a structured framework for decision-making:

Parameter	**3D Simulations**	**Augmented Reality (AR)**	**Virtual Reality (VR)**
Skill Complexity	Moderate to High	Low to Moderate	Moderate to High
Type of Skill (Conceptual vs Procedural)	Procedural & Conceptual	Conceptual with Some Interaction	Highly Procedural & Immersive
Physical Environment Dependency	Low (self-contained in digital space)	Low (for teaching concepts) High (requires interaction with real-world elements)	High (replaces the real-world environment)
Spatial & Depth Understanding	Moderate	High (Overlay in real world)	High (Full immersion)
Safety Concerns	Can simulate hazards safely	Enhances awareness in real settings	Best for high-risk training
Complex Machinery (e.g., CNC machines, medical imaging devices)	Effective for interactive learning	Can provide real-time guidance on machine operation OR visualizing the machinery overlayed in real world to understand its functions	Best for full immersion & muscle memory training

Expensive Machinery (e.g., industrial robots, MRI scanners, jet engines)	Best suited (low-cost alternative for learning functionality)	Can assist in real-world maintenance & diagnostics OR visualizing the machinery overlayed in real world to understand its functions	Used for high-risk operation & full system understanding
Not Easily Available Machinery (e.g., nuclear power systems, aerospace engines)	Best suited (allows detailed digital exploration)	Limited unless physical setup exists OR visualizing the machinery overlayed in real world to understand its functions	Best when full hands-on training is needed
Learner Interaction Type	Mouse/keyboard-based, touchscreen, or gamified interactions	Hands-on interaction with real-world elements	Fully immersive using controllers/hand tracking
Hardware Requirements	Desktop/Mobile-friendly	Mobile/Tablet-based AR devices	VR Headset Required
Cost of Development	Moderate	Moderate to High	High
Portability & Accessibility	High (Can be accessed on standard devices)	High (Requires AR-enabled device)	Low (Requires VR headset)
Learning Retention & Engagement	High (Realistic practice)	High (Enhanced real-world application)	Very High (Complete immersion)
Best Suited For	Skill practice with controlled interactions	Enhancing real-world tasks with digital overlays , learning concepts, view objects in 3D from multiple angles, improving spatial awareness	Fully immersive, experiential learning

Appendix G: Two page article highlighting findings of Impact Evaluation

Digital Revolution in Vocational Training: India's Skill-eLabs Initiative Shows Promising Results

In an ambitious move to transform vocational education, India's Ministry of Skill Development and Entrepreneurship (MSDE) has successfully piloted Skill-eLabs – a pioneering digital learning program that could revolutionize technical education across the nation. This initiative aligns with MSDE's broader commitment to upgrading Industrial Training Institutes (ITIs) and National Skill Training Institutes (NSTIs) through evidence-based learning technologies informed by learning sciences, serving as an integral part of teaching and learning.

Addressing Critical Challenges in Technical Education

The landscape of vocational education in India presents both challenges and opportunities. With limited research on the impact of learning technologies as a catalyst to advance skill development in India, there's a pressing need for evidence-based insights to guide national-level adoption of effective digital learning solutions. "Technology acts as an amplifier of the quality of learning environments," explains a senior project advisor. Furthermore experts agree that "Strong foundations enhance impact, while weak foundations create inefficiencies."

The COVID-19 pandemic further exposed these gaps, highlighting the urgent need for resilient, digital learning solutions, especially for populations who are already vulnerable. This context shaped the vision of Skill-eLabs: to create a comprehensive roadmap and evidence-based strategy founded on solid research and expertise for implementing cost-effective learning technologies in vocational education and training (VET) institutions across India.

MSDE, in collaboration with the Directorate General of Training (DGT) and the National Instructional Media Institute (NIMI), launched the Skill-eLabs project under the SANKALP initiative in Dec, 2024 which was implemented by AMMACHI Labs, a research center at Amrita Vishwa Vidyapeetham. An expert committee composed of all these stakeholders, including experts from NSTIs, were formed to guide the project and review deliverables at each stage.

A Strategic Approach to Digital Integration

The project set clear objectives:

- Development of six comprehensive Skill-eLabs packages for two high-priority trades: Solar Technician and Electronics Mechanic.
- Skill-eLabs packages released in English and Hindi to ensure wider accessibility

- Impact evaluation through pilot implementation at four institutions: two ITIs and two NSTIs.
- Equipment provision including VR desktops and headsets to each pilot institution.
- Development of scalable standards, guidelines, and standard operating procedures for development and implementation of Skill-eLabs packages.

Revolutionary Learning Through Technology

The initiative introduces a sophisticated digital learning ecosystem featuring:

- Instructional Videos
- Interactive 3D simulations for practical exercises
- Virtual Reality (VR) modules for immersive learning
- Augmented Reality (AR) components for enhanced visualization

The modules were developed, and made available to the students and instructors through Amrita's AMPLE learning management system.

This pilot implementation involved 160 students and 17 instructors across four institutions - NSTI Dehradun, NSTI Mumbai, Govt. ITI, Jhajjar and Govt. ITI, Bicholim, providing a substantial sample for evaluating effectiveness across diverse contexts.

Impressive Results Show Promise

The impact assessment highlights the success of the Skill-eLabs programme. A study compared two student groups: the "control group," which received traditional classroom training, and the "experimental group," which used the Skill-eLabs package. After the first phase, assessments revealed that the experimental group significantly outperformed the control group in skill acquisition and practical performance.In the second phase, the control group also received Skill-eLabs training. Their performance improved markedly, becoming comparable to the experimental group.

Key findings include:

- Significant improvements in skills and practical performance.
- Enhanced engagement during training.
- Increased confidence and independence in completing tasks.
- Improved adherence to safety protocols.

> "Through Skill-eLabs exercises, I could learn many things within a short period. The virtual environment allowed me to practice without fear of damaging equipment," shares a student participant.

Perhaps most notably, instructor confidence in technology integration saw a dramatic increase, with median scores rising from 5.0 to 9.0 out of 10 after implementing the program.

Beyond Traditional Learning

The initiative's success lies in its comprehensive approach to skill development. Students benefit from:

- Risk-free practice environments with reduced need for consumable material and increased safety.
- Immediate feedback on performance.
- Self-paced learning opportunities with infinite repetition possible.
- Enhanced visualization of complex concepts.

The program also addresses resource constraints faced by many institutions, offering virtual alternatives to expensive equipment and consumables.

Building for the Future

Based on the pilot's success and observations from the pilot implementation the expert committee recommend:

1. **National Integration**: Implementing Skill-eLabs across all ITIs and NSTIs as a core component of practical training.
2. **Content Expansion**: Strategically expand to additional trades by evaluating skill requirements, selecting appropriate learning technologies (3D/AR/VR), and maximizing return on investment.
3. **Infrastructure Development**: Comprehensive evaluation of existing facilities, establishing robust technical support systems, and addressing connectivity challenges.
4. **Instructor Empowerment**: Create a comprehensive training program on technology-enabled teaching and learning, with mandatory certification for instructors and regular refreshers.
5. **Accessibility**: Design for mobile devices and integrate with mobile-supported Learning Management Systems to reach all students.
6. **Assessment Standards**: Develop technologies for standardized digital skill assessment to support instructor-based evaluation.
7. **AI Integration**: Provide AI-based solutions for personalized learning and adaptive feedback, especially targeting ITI students.

Looking Ahead

The Skill-eLabs initiative marks an important step forward in modernizing India's vocational education system. With 100% of participating instructors recommending the program for future training, the pilot demonstrates the clear potential for digital technology to enhance the accessibility and quality of vocational education.

As plans for nationwide implementation move forward, this innovative approach to technical education promises to better prepare India's workforce for an increasingly digital future. The successful integration of technology in vocational training through Skill-eLabs provides a strong foundation for expanding digital learning across India's vocational education system.

Submitted by:

AMMACHI LABS, AMRITA VISHWA VIDYAPEETHAM

24.10.2024