Enhancing Problem-Solving Proficiency through Industrial-Based Learning for Technical Workforce Advancement

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Abstract:- This research delves into the crucial need for improving problem-solving proficiency among technical workforce individuals through the strategic implementation of Industrial-Based Learning (IBL). The study meticulously follows a comprehensive cycle involving analysis, design, development, implementation, and evaluation of IBL, specifically focusing on students enrolled in the program at Phradabos. The identification of the population and sample is central to the study, employing purposeful data collection and analysis to draw conclusions from the implemented IBL program, tailored to augment problem-solving skills. The study reveals a noteworthy post-test performance in problem-solving skills, with participants achieving an average score of 72.67 (S.D. = 4.07), indicating a commendable level of competence. The research utilizes the ADDIE instructional design framework throughout the analysis, design, development, implementation, and evaluation phases of the IBL program. The efficiency of problem-based learning within the project course is remarkable, attaining a score of 90.75/86.53, surpassing the established criteria of 80/80. Moreover, students exhibit heightened abilities post-learning, showcasing a substantial increase in advanced skills. The Motivation, Information, Application, Progression (MIAP) teaching method is seamlessly integrated into the program, ensuring an engaging and participatory educational experience. The research highlights significant improvements in both knowledge and abilities among students, notably presenting a 53.33% increase in learning achievements (Q4/Q2). Additionally, the majority of project workpieces align with industrial requirements. In conclusion, this study underscores the efficacy of IBL as a potent means to foster problem-solving skills within the technical workforce.

Keywords*: industrial-based learning, problem-solving skills, technical workforce labor*.

1. Introduction

Thailand's technical and vocational diploma program employs a diverse curriculum encompassing industrial, commercial, agriculture, home economics, and fine arts. This comprehensive program offers a range of courses, including basic, specific, elective, experience training, and pivotal project courses [1]. Notably, the group-based project course stands out as indispensable for program completion. Despite its importance, a substantial challenge persists in the underdeveloped problem-solving skills of students, impacting their preparedness for future employment and compliance with competency standards [2-3]. This challenge is frequently attributed to conventional teaching methods, thereby negatively affecting the overall quality of vocational education.

In response to these challenges, collaborative initiatives have emerged between the educational and industrial sectors, aiming to enhance the project course by addressing real- world challenges. In Thailand, institutions have embraced innovative approaches, including cooperative learning, industrial-oriented education [4], industrial-based learning (IBL), hands-on models, learning factories, and active learning [5]. IBL, originating in Australia over 25 years ago, has evolved into a benchmark for work- integrated learning and has been adopted globally, including in New Zealand, the UK, the USA, and Indonesia. IBL offers placement opportunities for undergraduate students through a process that allows them to develop knowledge and skills for their future work. It increases critical appraisal, literature retrieval, encourages ongoing learning within a team environment, and reflects the outstanding quality of students [6]. IBL has been applied in teaching and learning and is suitable for the project course in the technical and vocational diploma program implemented for Phradabos students.

Phradabos school, operated by the Phradabos foundation under the Royal initiative of King Rama 9, was established in 1966. The first aim of Phradabos school is to help educationally disadvantaged individuals—those who are poor, unemployed, and lack basic knowledge to study at vocational institutes but express interest in learning and possess earnest perseverance. The second aim is to provide professional and moral training to enable them to pursue a career, develop their own position, contribute to family and society, and serve the country. Currently, many students are from border tribes, orphans, and youth who have undergone drug cessation treatment or have been released from prison. Phradabos school offers informal education, training students in auto mechanics, electronic technology, electricity, sufficiency agriculture technology, maintenance technology, construction and carpentry, welding, and nursing home services [7]. The Phradabos foundation established Lukphradabos school in 1998 to transfer agricultural technology and renewable energy knowledge. In 2010, the Southern Border Provinces Phradabos school was established to help the youth of the three southern border provinces affected by terrorism, training them in auto mechanics, motorcycle mechanics, and agricultural machinery technology. Currently, Phradabos school has implemented the dual vocational training project at the diploma level in collaboration with Nakornluang Polytechnic College, Donmuang Technical College (DMTC), Dusit Technical College (DTC), Samutprakan Polytechnic College, and Kanchanaphisek Nongchok Industrial and Community Education College (KNICE). However, students' learning achievement is low and does not meet industry requirements according to the report.

In recognizing the importance of prior research on teaching and learning in project- based subjects, the researcher aims to enhance practical skills and problem-solving abilities in the workplace through the implementation of IBL in project courses. The primary research question addresses the feasibility of integrating IBL into project-based learning (PBL). IBL within this context encompasses the ADDIE-MIAP-PBL-3 steps of the model, along with lesson plans, chalkboard layouts, question lists, teaching aids, exercises, keys, examinations, assessment forms from the Vocational Education Commission, and evaluation forms. The research's main objectives are outlined as follows:

- Develop IBL in vocational diploma programs with a focus on refining problem- solving skills and incorporating real workplace scenarios.
- Assess the current state of problem-solving skills among students within the vocational diploma program.
- Investigate the efficiency of the IBL approach in preparing students for real work in the workplace.
- Explore and analyze the advanced skills and abilities developed by students throughout the vocational diploma program.
- Examine the alignment between students' project workpieces and the actual requirements of the industrial landscape.
- Assess and measure the overall achievement of students in the context of enhanced problem-solving skills and industrial-based learning.

In light of the multifaceted challenges faced in Thailand's technical and vocational diploma program and the collaborative initiatives undertaken to enhance project courses, it becomes imperative to delve into existing scholarly works and educational methodologies. This literature review aims to provide a comprehensive exploration of key concepts crucial to our research, including IBL, problem-solving skills, PBL, the ADDIE model, the MIAP teaching method, and the Learning by Doing (LBD) theory. By examining these frameworks and methodologies, we seek to identify gaps, draw connections, and establish a solid foundation for our research endeavors. In the following section, we will conduct an in-depth exploration of the existing body of knowledge, presenting a comprehensive understanding of these concepts and their interconnectedness within the realm of vocational and technical education.

1.1 Industrial-based learning

Industrial-Based Learning (IBL) stands as a cornerstone in fostering active learning methodologies, particularly within the realms of computer programming and information technology education. Originating over two decades ago in Australia and subsequently adopted globally, including in New Zealand, the UK, the USA, Indonesia, and Kenya, IBL has been a transformative force. Notably, Australia's implementation has been documented over the past 25 years [8-15], marking its enduring impact. IBL's role is pivotal in sculpting a workforce equipped with the knowledge, skills, and attitudes essential for navigating the challenges of the 21st century.

The outcomes of IBL extend beyond the academic realm, preparing students to graduate not only with theoretical knowledge but also with practical skills and hands-on experience [16]. This multifaceted preparation positions them for success in further learning, work environments, and life. The effectiveness of IBL is underscored by the fact that many graduating students receive multiple job offers in their final year, solidifying IBL's status as the gold standard in work-integrated learning for the industry.

The IBL process is a catalyst for students to cultivate knowledge and skills that will shape their future careers. It goes beyond traditional education by enhancing critical appraisal, literature retrieval, and fostering ongoing learning within a collaborative team environment. Moreover, the impact of IBL extends to the development of educators, reflecting the outstanding quality of students who undergo this transformative learning approach.

Structured around three main steps—admission, industrial placement, and assessment and credit—the IBL framework not only facilitates the development of critical appraisal, literature retrieval, and ongoing learning within a team environment but also sets a precedent for excellence in experiential education [17].

1.2 Problem-solving skill

Problem-solving skill is a complex skill and considered one of the key skills in the UK, Scotland, and other countries in the United Kingdom. The national qualification framework (NVQs) was divided in 7 levels in UK which the competency in NVQs comprise of basic skill, common skill and key skill [18] but basic skills of AQF in Australia are referred to as key competencies that comprise of collecting, analysing and organsing ideals, communication ideals and information, planning and organizing activities, working with other and in teams, using mathematical ideals and techniques, solving problem and using technology [19]. In Thailand, it was called national qualification framework (NQF) that was divided in 7 levels same UK and the competency in NQF comprise of core skill and occupational skill which both skills were consist of knowledge, psychomotor skill or ability and attitude. The core skill consists of communication, calculation, using information technology, analytic thinking and Problem-solving and working in teams [20]. The key skill is a range of essential generic skills that underpin success in education, employment, lifelong learning and personal development. People in the UK will often develop these skills through other subjects or main programs, but many will also study them in their own right [21]. Problem-solving skill involves with critical thinking, analytic thinking, decision making, creative thinking and information processing [22-24]. The three basic steps for common job and life problem-solving comprise identifying the problem, generating a list of possible solutions, and implementing the solution [25]. Additionally, the five primary steps in careers involving problem-solving include analyzing causes, generating alternative interventions, evaluating solutions, implementing a plan, and assessing effectiveness [26].

1.3 Problem-based learning

Problem-Based Learning (PBL) stands as a widely embraced pedagogical approach, recognized for its child-centered focus. Rooted in experiential learning, PBL encourages students to delve into subjects, honing skills through analytical, systematic, problem-solving, critical, and creative thinking. This method involves tackling open-ended problems presented in materials crafted by instructors. Initially developed for medical and nursing education,PBL has evolved into a versatile tool applicable across diverse learning, teaching, and training programs [27-28].

PBL transcends mere problem-solving; it cultivates valuable skills, attitudes, and attributes such as knowledge acquisition, collaborative abilities, numerical thinking, and proficiency in information and communication technology (ICT). The process includes stages like clarifying terms, defining the problem, brainstorming, analyzing, formulating learning issues, engaging in self-study, and reporting [29].

Noteworthy aspects of the PBL process involve driving questions, inquiry and innovation, the incorporation of 21st-century skills, student autonomy, feedback mechanisms, revision cycles, and the creation of publicly presented products. It shares similarities with project-based learning (PjBL), both serving as student-driven, teacher-facilitated approaches. In these methods, students work extensively to explore and respond to authentic, engaging, and complex questions, problems, or challenges. These learning approaches are particularly applied in vocational, technical, and engineering education, aiming to enhance students' skills for the 21st century, equipping them for the challenges of the future [30-33].

1.4 Problem-based learning

The ADDIE Model, a framework for instructional systems design, serves as a guide for instructional designers and training developers across five key phases: Analysis, Design, Development, Implementation, and Evaluation [34]. In the Analysis phase, designers identify the learning needs, goals, and constraints of the target audience. Subsequently, in the Design phase, a comprehensive blueprint is developed, detailing learning objectives, content, instructional strategies, and assessment methods. Moving to the Development phase, the actual creation of instructional materials occurs, encompassing diverse resources such as supplementary materials, visual aids, and interactive tools. Implementation marks the presentation of the course to learners, with a close monitoring of the effectiveness of both instructional materials and methods deployed during delivery. The final phase, Evaluation, involves assessing the course's success, gathering feedback, and making necessary revisions for continuous improvement. To illustrate the application of the ADDIE model, consider a case study in a technical training program. In the Analysis phase, designers pinpoint the specific learning needs and constraints of the technical audience. The ensuing Design phase sees the creation of a blueprint outlining learning objectives, content, instructional strategies, and assessment methods. During the Development phase, instructional materials tailored to technical subject matter are crafted, and in the Implementation phase, the course is delivered. In conclusion, the Evaluation phase critically assesses the course's effectiveness by soliciting feedback, paving the way for continuous improvement.

1.5 MIAP teaching method

The MIAP teaching method, extensively employed in the Department of Teacher Training in Mechanical Engineering, Electrical Engineering, and Civil Engineering at King Mongkut's University of Technology North Bangkok, utilizes a questioning technique in four steps: Motivation, Information, Application, and Progression. Integrated with the 7 steps of PBL and the ADDIE model, MIAP enhances its effectiveness in guiding learners through a comprehensive learning experience [34-35].

1.5.1 Motivation

This stage aims to engage students' interest and curiosity, making them eager to learn. Students are motivated through engaging questions, aiming to capture their interest and curiosity, creating a sense of eagerness to learn. The use of thought-provoking questions is crucial in setting the tone for the learning experience.

1.5.2 Information

Relevant information is provided, necessary for understanding the subject matter. This step ensures that students have access to the foundational knowledge required for the topics being covered in the engineering program. Relevant information is delivered to students, providing the necessary content for understanding the subject matter. This step ensures that students have access to the foundational knowledge required for the topics being covered in the engineering program.

1.5.3 Application

Encouraging students to apply the acquired knowledge through practical exercises, problem-solving, or hands-on experiences. This step is vital for reinforcing theoretical concepts and developing practical skills. After receiving information, students are encouraged to apply their knowledge through hands-on projects, practical exercises, and problem-solving activities. This application phase is vital for reinforcing theoretical concepts and developing practical skills.

1.5.4 Progression

Ensuring continuous and structured advancement in learning, building on previous knowledge and skills. The learning experience is designed to align with scaffolding, where each stage builds upon the foundation laid in the previous ones. The learning experience is structured to ensure continuous advancement. Students build on their previous knowledge and skills, creating a cohesive and progressive educational journey. This step aligns with the idea of scaffolding, where each stage builds upon the foundation laid in the previous ones.

In Thai-German vocational and technical colleges, the MIAP teaching method is applied through questioning, motivation, information delivery, application exercises, and structured progression. For instance, in an engineering program, students might be motivated through engaging questions, receive relevant information, apply their knowledge through hands-on projects, and progress in a structured manner, building on their skills. This integration with PBL and the ADDIE Model further enhances its effectiveness in guiding learners through a comprehensive learning experience.

The integration of the MIAP teaching method with the 7 steps of PBL and the ADDIE model further enriches the learning experience. PBL encourages students to actively engage with real-world problems, fostering critical thinking, while the ADDIE model provides a systematic approach to instructional design.

This comprehensive approach, tailored to engineering programs, emphasizes not only theoretical understanding but also practical application and continuous advancement, aligning with the multifaceted demands of technical education.

1.6 Learning by doing

Learning by Doing (LBD), introduced by the American philosopher John Dewey, focuses on active student engagement through hands-on experiences. This theory underscores the significance of learners interacting with their environment to adapt and learn actively. Originating from Dewey's innovative approach, the University of Chicago Laboratory School became a practical embodiment of his ideals, contributing to the establishment of progressive education practices. Notably, Richard Dufour applied the LBD theory to elucidate professional learning, emphasizing its role in enhancing educators' and professionals' skills through practical experiences [36-38]. Key tenets of the LBD theory encompass:

- Hands-on learning: LBD advocates for active participation and practical experiences, enabling students to apply theoretical knowledge in real-world scenarios.
- Adaptation and learning: This theory posits that students learn optimally when actively engaging with their surroundings, adapting to challenges, and learning through direct experiences.
- Professional learning: Richard Dufour's contributions highlight the application of LBD in professional development, fostering skill enhancement for educators and professionals.

The theory underscores the significance of experiential learning, emphasizing its positive impact on knowledge retention and skill development.

1.6.1 Connection to vocational and technical education

The LBD theory holds particular relevance in vocational and technical education by placing emphasis on hands-on learning. In a technical college setting, this theory is applied through practical experiences, enabling students to actively engage with their chosen fields. For example, in an electrical engineering program, students may participate actively in building circuits, troubleshooting electrical systems, and adapting to real-world challenges.

1.6.2 Connection to vocational and technical education

The LBD theory aligns seamlessly with the broader goals of vocational and technical education, prioritizing the preparation of students for real-world applications. By actively engaging with their environment, students not only gain theoretical knowledge but also develop practical skills essential for their future careers. This alignment resonates with the core mission of vocational and technical education, aiming to produce graduates who are not only knowledgeable but also adept at applying their skills in professional settings.

The subsequent sections will delineate our materials and methodology, present study results, and draw conclusions, contributing to the discourse on improving technical education and workforce preparedness. Within the conclusions, we will synthesize key findings from our study, specifically highlighting the impact of IBL on problem-solving skills in vocational diploma programs. The integrated discussion will delve into the implications of our results, drawing comparisons with existing literature and emphasizing the broader significance for the field. Additionally, we will provide recommendations for future research and improvements. These recommendations include exploring specific components of IBL, assessing its long-term impact on careers, advocating for continuous program evaluation, suggesting expansion to other core competencies, proposing technology integration, and endorsing global comparative studies. This comprehensive approach not only presents our study's outcomes but also guides future research endeavors and enhancements in technical education practices.

2. Material and methodology

This section provides a comprehensive overview of the research design, the structure of the IBL program, analysis of student background and behavior, determination of the population and sampling group, competency creation, topic analysis, and the creation of research tools. The methodology aims to develop and implement an effective IBL program, assess its impact on students' problem-solving skills, and evaluate its efficiency in preparing them for real-world workplace challenges.

2.1 Research design and model

The chosen experimental research design, as depicted in Figure 1, underscores the meticulous planning and structured approach taken in this study. By integrating IBL with the ADDIE framework, we aim to create a symbiotic relationship between theoretical learning and practical application. The MIAP teaching method, along with a questioning teaching method, is incorporated to ensure an engaging and participatory educational experience. Additionally, the utilization of the 7 steps of PBL adds layers of complexity and critical thinking to the learning process. This integrative model is not merely a theoretical construct; it serves as a dynamic roadmap for the entire research endeavor, guiding the development, implementation, and evaluation of the IBL program.

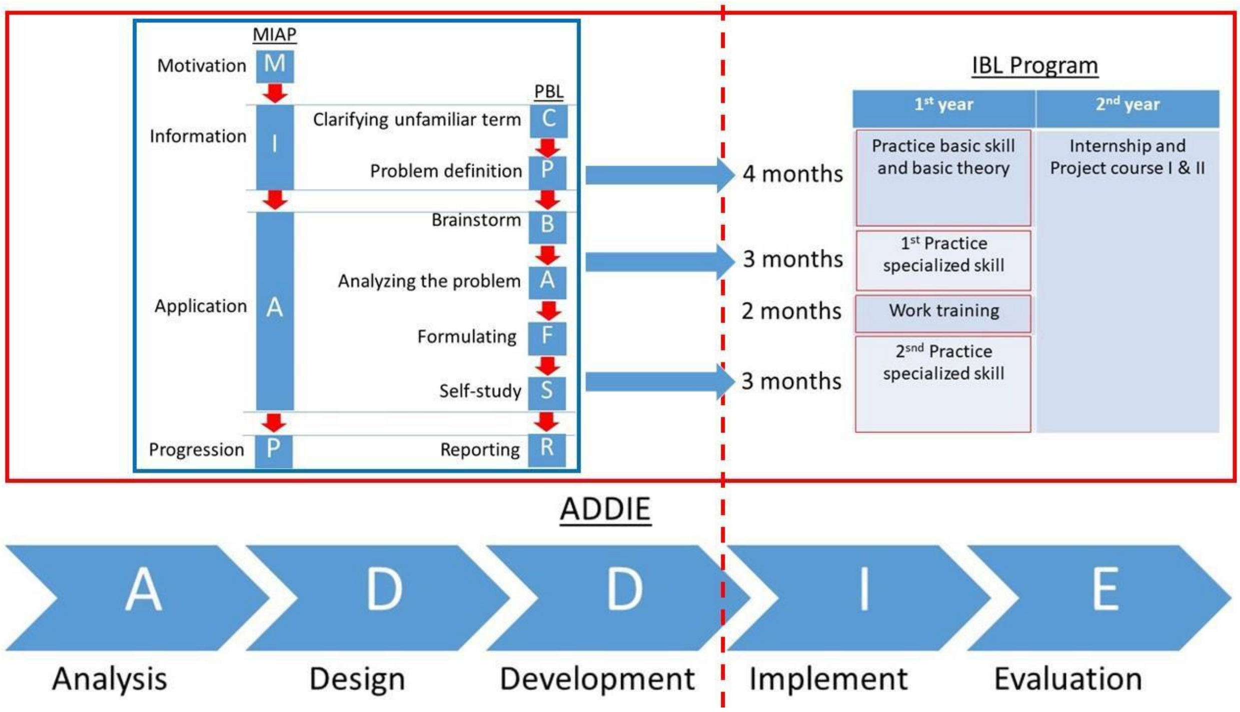

Figure 1. Experimental research model - IBL-ADDIE-MIAP-7 steps in conjunction with questioning teaching method and PBL.

2.2 IBL program structure

The structural composition of the IBL program is carefully designed to maximize the educational impact on students. The two distinct phases, starting with the foundational 1st year at Phradabos school and progressing to the immersive 2nd-year internship within industry placements, create a holistic learning journey. The MIAP teaching method, known for its success in Thai-German vocational and technical colleges, is seamlessly woven into the fabric of the program. This child-centered pedagogy ensures that each phase—motivation, information, application, and progression—builds upon the previous one, fostering a continuous and structured advancement in learning. The inclusion of the questioning teaching method and the 7 steps of PBL further enriches the program, encouraging critical inquiry, problem-solving, and collaborative learning.

2.3 Analysis of student background and behavior

The analysis of student background and behavior transcends conventional assessments, delving into the intricacies of individual experiences, socio-economic challenges, and personal motivations. Understanding that Phradabos students come from tribal, disadvantaged, and economically challenged backgrounds with limited basic knowledge necessitates a tailored approach. This comprehensive analysis extends to various facets, including IBL, problem- solving skills, and the specifics of project courses I and II. By delving into these aspects, we not only design an IBL program that addresses academic needs but also one that is culturally sensitive, inclusive, and supportive. This nuanced understanding of students' backgrounds serves as a foundational cornerstone for the design and development of the IBL program.

2.4 Determination of population and sampling group

The targeted population, comprising workforce labor engaged in the 2nd-year internship of the IBL program, is more than a demographic—it represents active contributors to the workforce. These individuals, enrolled at a diploma certificate level, bring practical experience and real-world insights to the learning environment. The sampling group, carefully selected from the 43rd Phradabos student cohort, is diverse in specializations, reflecting the varied landscape of vocational education. The inclusion of students specializing in industrial technology, furniture and interior design, metal technology, Automotive Technology, and electrical technology ensures a representative and comprehensive study. This intentional selection process enriches the study's findings, providing insights applicable across diverse vocational domains.

2.5 Competency creation and topic analysis

The creation of problem-solving skill competencies is not a mere academic exercise but a strategic alignment with national frameworks and industry needs. By deriving these competencies from the core skills of the Thailand National Qualifications Framework (NQF) and the basic skills of the National Vocational Qualifications (NVQs), the IBL program ensures a cohesive integration of academic and vocational skills. The analysis of topics in project course II (3104-8503) goes beyond surface-level categorization. Coral analysis, a meticulous technique, dissects the course content into sub-topics, main elements, and course expected learning outcomes (CLOs). This detailed breakdown guarantees that the IBL program is finely tuned to meet not only academic standards but also the practical expectations of the industry.

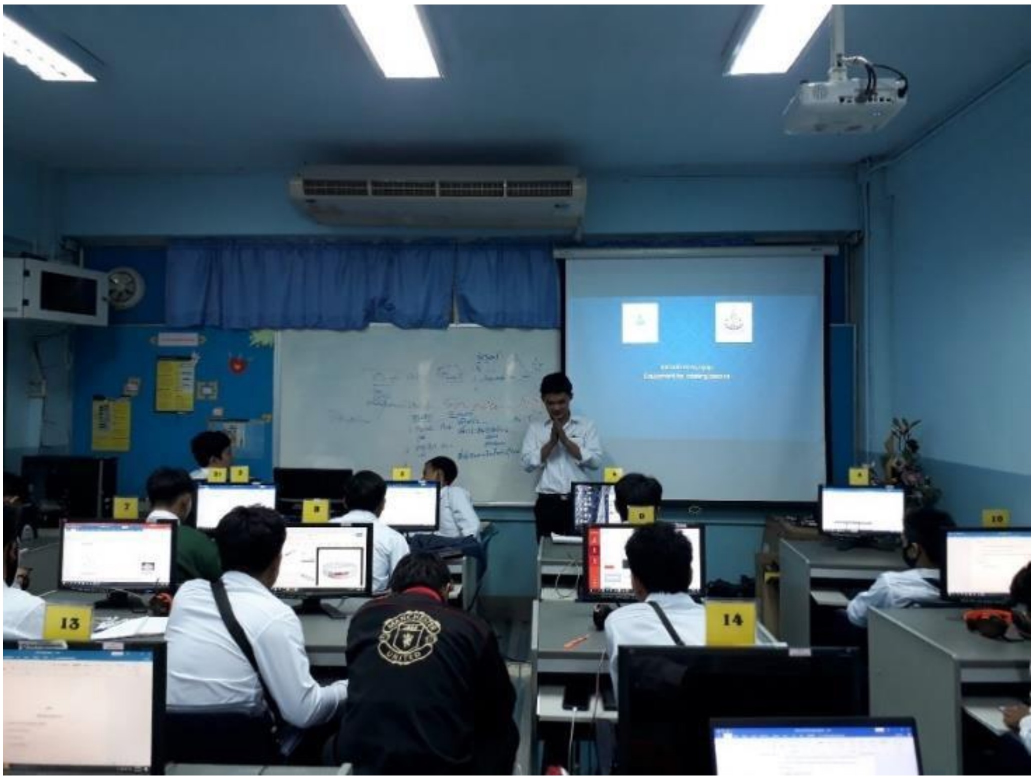

Figure 2. Presentation of Phradabos student projects in the computer room.

2.6 Competency creation and topic analysis

Figure 2 serves as more than just a visual aid; it is a testament to the dynamic and multifaceted nature of the research tools employed throughout the study. The presentation of Phradabos student projects in the computer room offers a tangible glimpse into the real-world application of these tools. The comprehensive toolkit, ranging from traditional lesson plans to digital platforms like LINE groups and Google classroom, is not an arbitrary collection but a strategic ensemble. Each tool plays a specific role in facilitating the implementation and evaluation of the IBL program. For instance, assessment forms, Vocational Education Commission forms, and evaluation forms provide a structured mechanism to gauge student achievements and industry relevance. Laboratories and computer facilities extend beyond physical spaces; they are arenas for active learning and practical application. The interconnectedness of these tools ensures a holistic and thorough evaluation of the IBL program's impact on student learning outcomes.

3. Results and Discussion

This section presents a detailed assessment of the IBL program's impact on the problem-solving abilities of technical workforce labor in a diploma certificate level program. The evaluation encompasses various facets, including pre-test and post-test assessments, efficiency of IBL, analysis of advanced abilities, assessment of project workpieces, student learning achievement during the COVID-19 pandemic, and overall satisfaction levels among participants.

Table 1. Assessment of IBL impact on problem-solving abilities of diploma certificate level students

Competency	Pre- test	Post- test	Averg. (Pre)	Stdev. (Pre)	Averg. (Post)	Stdev. (Post)
PS 2.1	42.58	74.46	39.13	6.49	72.67	4.07
PS 2.2	37.79	72.33		6.51		4.23
PS 2.3	37.00	71.21		6.15		4.00
Averg.	39.13	72.67		6.49		4.07

Competency Key: PS 2.1 - Collaborate with an appropriate individual to identify a problem and explore various approaches to address it. PS 2.2 - Strategize and implement at least one solution to the identified problem. PS 2.3- Evaluate the resolution of the problem and discern ways to enhance problem-solving skills.

A total of 24 participants underwent the IBL program, with competencies assessed across three units: PS 2.1, PS 2.2, and PS 2.3, as detailed in Table 1. Pre-test results indicated a moderate level of problem-solving skills, with an average score of 39.13 (S.D. = 6.49). Post- test assessments, post-implementation of IBL, exhibited a significant improvement, reachinga good level with an average score of 72.67 (S.D. = 4.07). The positive shift suggests that IBL effectively enhances participants' problem-solving skills.

3.1 Analysis of competencies

Evaluating key competencies, including collaboration (PS 2.1), strategy implementation (PS 2.2), and problem resolution evaluation (PS 2.3), revealed significant advancements following the implementation of IBL. The average scores increased substantially, showcasing the efficacy of collaborative problem identification, strategic implementation, and problem resolution evaluation.

3.1.1 Collaborative problem identification (PS 2.1)

The structured group activities within the IBL program facilitated a remarkable improvement in collaborative problem identification (PS 2.1). Students actively engaged in identifying and exploring real-world problems, contributing to the substantial advancement observed in this competency.

3.1.2 Strategic implementation (PS 2.2)

The learning modules focused on strategic planning and execution, including real- world case studies and practical exercises, contributed to a noteworthy progress in the strategic implementation competency (PS 2.2).

3.1.3 Problem resolution evaluation (PS 2.3)

The IBL program effectively developed students' skills in assessing the outcomes of their implemented solutions, as reflected in the positive trend observed in the problem resolution evaluation competency (PS 2.3).
In summary, the results affirm that IBL significantly improves the problem-solving skills of technical workforce labor at the diploma certificate level, with specific competencies showing marked advancements.

Table 2. Efficiency of IBL in enhancing problem-solving skills for technical workforce: A comparison of process (E1) and output (E2) efficiency

Evaluation	Total Score	Average	Efficiency
E1	50	45.38	90.75
E2	30	25.96	86.53

3.2 Assessment of efficiency

Detailed in Table 2, the evaluation of IBL's efficiency in developing problem-solving skills for technical workforce labor encompasses both process efficiency (E1) and output efficiency (E2).

3.2.1 Process efficiency (E1)

Participants attained a total score of 50, averaging 45.38, resulting in a high process efficiency of 90.75%. This score highlights IBL's effectiveness in nurturing skills throughout the learning process, offering valuable insights into the educational journey.

3.2.2 Output efficiency (E2)

The evaluation of output efficiency resulted in a total score of 30, with an average of 25.96, yielding an efficiency score of 86.53%. This aspect assesses the practical outcomesand application of problem-solving skills acquired during the IBL program, emphasizing their real- world applicability.

3.2.3 Combined efficiency ratio (E1/E2)

Analyzing both process efficiency (E1) and output efficiency (E2) reveals a balanced approach to the effectiveness of IBL in enhancing problem-solving skills. The combined efficiency ratio (E1/E2) exceeds the set criteria of

80/80, indicating significant contributions from both the learning process and tangible outcomes in improving these skills. This balanced approach underscores the holistic impact of IBL, not just in theoretical understanding but in the application of acquired skills to real-world scenarios.

Table 3. Comparative analysis of advanced abilities: Impact of IBL on student learning outcomes

	N	ΣX	ΣD	$ΣD^2$	t
Pre-test	24	9.25	401	6771	40.60
Post-test	24	25.96			

3.3 Assessment of efficiency

Presented in Table 3, a comparative analysis delves into advanced abilities, highlighting the impact of IBL on student learning outcomes using a statistical t-test for dependence (significance level set at 0.01).

3.3.1 Pre-test (Before studying)

The baseline measurement of advanced abilities, reflected in the pre-test mean score of 9.25, is supported by a substantial sum of deviations (ΣD = 401) and squared deviations ($ΣD^2$ = 6771), resulting in a high t-value of 40.60.

3.3.2 Post-test (After studying)

After participating in IBL, students demonstrated a considerable increase in advanced abilities, as indicated by the post-test mean score of 25.96. A detailed comparison of deviations, squared deviations, and the t-value provides a comprehensive understanding of the progress made.

In conclusion, the comparative analysis underscores the effectiveness of IBL in enhancing student abilities, providing a solid foundation for improved problem-solving skills and overall knowledge acquisition. The statistical approach adds rigor to the assessment, emphasizing the program's impact on advancing students' skills and abilities.

Table 4. Assessment of project workpieces and their alignment with industrial requirements.

	DMTC	DTC	KNICE	Average	S.D.
Appropriated design	4.00	5.00	4.57	4.42	0.51
Drawing & specification	3.75	5.00	4.57	4.25	0.67
Production	4.25	5.00	5.00	4.71	0.45
Valuation	3.50	4.00	4.43	4.08	0.67
Presentation	3.55	4.00	4.29	4.00	0.60
Supported document	4.00	5.00	4.71	4.50	0.52
Ethic & code of conduct	3.89	4.71	4.61	4.40	0.58

The assessment of project workpieces and their alignment with industrial requirements, as presented in Table 4, involves students from various diploma programs, including 73 persons from Phradabos studying IBL, 24 persons from Donmuang Technical College (DMTC) in industrial technology, 4 persons from Dusit Technical College (DTC) in furniture and interior design, and 45 persons from Kanchanaphisek Nongchok Industrial and Community Education College (KNICE) in Metal Technology, Automotive Technology, Electrical Technology, and Electronics.

3.4 Assessment of project workpieces and alignment with industrial requirements

Project workpieces, assessed for alignment with industrial standards and requirements (Table 4), reflect the practical relevance of the IBL program in meeting industry expectations.

3.4.1 Detailed evaluation of project workpieces

Meticulous evaluation across categories (Appropriated design, drawing & specification, production, valuation, presentation, supported document, ethic & code of conduct) yielded a strong performance (average score: 4.38, S.D. = 0.58).

3.4.2 Student learning achievement

Positive assessment results demonstrate the effectiveness of IBL in enhancing problem- solving skills and applying knowledge.

3.4.3 Overall alignment and exceedance of industrial requirements

Majority of project workpieces align with or surpass industrial requirements, indicating students' proficiency in meeting industry expectations.

These findings not only affirm the efficacy of IBL in improving problem-solvingskills but also highlight students' ability to produce workpieces meeting industry standards. This adaptability is evident across diverse diploma programs, reinforcing the effectiveness of IBL in enhancing both student achievement and practical skills in real-world scenarios.

Table 5. Analysis of student learning achievement amidst the impact of the COVID-19 pandemic on internship programs.

	Q1 (May-Jul)	**Q2 (Aug-Oct)**	**Q3 (Nov-Jan)**	**Q4 (Feb-Apr)**
Ind. Technology	24	18	7	7
Furniture & Interior Design	4	4	2	2
Metal Technology	6	2	2	2
Automotive Technology	16	9	7	7
Electrical Technology	15	9	6	6
Electronics	8	3	3	0
Total of Admission	73 (100%)	45 (60%)	27	24
Achievement Percentage (Q4/Q1)				32.88%
Achievement Percentage (Q4/Q2)				53.33%

3.5 Impact of COVID-19 on student learning

Amidst the unprecedented challenges introduced by the COVID-19 pandemic, the impact on student learning was profound. The presented data in Table 5 outlines the distribution of students across various technical fields during four quarters (Q1 to Q4), shedding light on the evolving landscape of student enrollment and achievement.

3.5.1 Enrollment trends

Table 5 illustrates fluctuations in student enrollment across different quarters, starting from Q1 (May-Jul) and extending through Q4 (Feb-Apr). In Q1, the total admission was 73 persons, representing the initial stage of the academic year. Subsequent quarters saw variations in enrollment, with implications for internship programs and learning experiences.

3.5.2 Impact on learning achievement

The percentage of achievement (Q4/Q1) reflects the overall learning accomplishment during the academic year. The calculated percentage of 32.88% indicates a considerable decline, attributing the challenges to disruptions caused by lockdowns, quarantine measures, and other consequences of the pandemic. Reduced working hours and suspended programs further contributed to this decline.

3.5.3 Resilience of diligent students

Intriguingly, when considering the achievement percentage of diligent students actively navigating challenges (Q4/Q2), a notable increase to 53.33% emerges. This suggests that despite the adversities brought about by the pandemic, a significant portion of diligent students demonstrated resilience and adaptability, succeeding in their educational endeavors.

3.5.4 Nuanced analysis

The nuanced analysis of enrollment trends, overall learning achievement, and the resilience of diligent students provides a comprehensive understanding of the intricate dynamics influenced by the COVID-19 pandemic. While the overall learning achievement was affected, the determination and efforts of diligent students stand out, showcasing their ability to overcome adversities and succeed in their educational pursuits.

The COVID-19 pandemic significantly impacted the educational landscape, introducing challenges to internship programs. The subsequent decline in total admissions reflects the widespread disruptions experienced by students. The lower achievement percentage in Q4/Q1 highlights the initial hardships during the pandemic. However, a positive note arises when considering diligent students' achievement in Q4/Q2, indicating their resilience and adaptability in seeking solutions amid challenges. In conclusion, although overall learning achievement was affected, the determination and efforts of diligent students demonstrate their ability to overcome adversities and succeed in their educational pursuits. This nuanced analysis offers a comprehensive understanding of the intricate dynamics influenced by the COVID-19 pandemic.

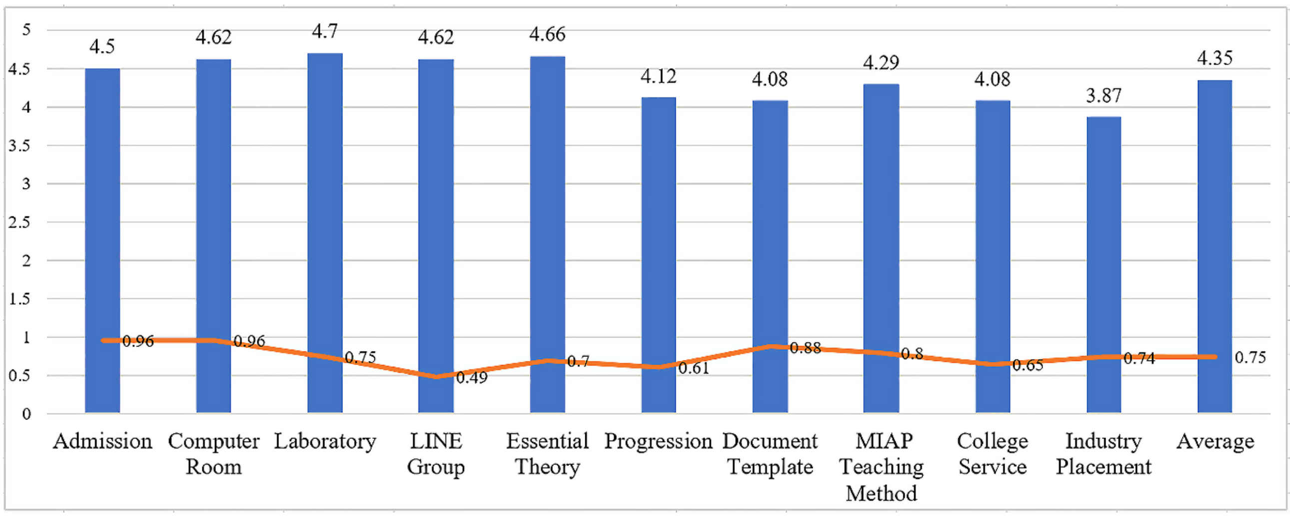

Figure 3. Integrated assessment of IBL impact on problem-solving skills in technical workforce labor environments.

3.6 Satisfaction levels and future implementation

Evaluating satisfaction levels across different aspects of IBL aimed at enhancing problem-solving skills in technical workforce labor environments. The data presented in Figure 3 reflects the perceptions of students across key components of the IBL program.

3.6.1 Components assessment

- Admission: The initial stage of admission into the IBL program received a favorable average satisfaction score of 4.5 (S.D. = 0.96), indicating positive feedback from students at the onset of their learning journey.
- Computer room: The facilities provided in the computer room garnered a high average satisfaction score of 4.62 (S.D. = 0.96), highlighting the effectiveness of the learning environment in facilitating problem-solving skill development.
- Laboratory: The laboratory facilities received a commendable average satisfaction score of 4.7 (S.D. = 0.75), indicating positive experiences and effective utilization of the laboratory setting in enhancing problem-solving skills.
- LINE group: The collaborative learning platform, represented by the LINE group, achieved a solid average satisfaction score of 4.62 (S.D. = 0.49), showcasing the positive impact of group interactions on skill development.
- Essential theory: The theoretical aspects integral to the program received positive feedback, with an average satisfaction score of 4.66 (S.D. = 0.7), indicating the effectiveness of theoretical knowledge in problem-solving skill enhancement.
- Progression: The progression of learning activities within the program demonstrated a robust average satisfaction score of 4.12 (S.D. = 0.61), signifying a well-structured and engaging

curriculum.

- Document template: The tools and resources provided, such as document templates, received positive reviews, with an average satisfaction score of 4.08 (S.D. = 0.88), suggesting effective support for project-based learning.
- MIAP teaching method: The MIAP teaching method, a key pedagogical approach, achieved a commendable average satisfaction score of 4.29 (S.D. = 0.8), indicating its effectiveness in facilitating learning and skill development.
- College service: Support services offered by the college received positive feedback, with an average satisfaction score of 4.08 (S.D. = 0.65), emphasizing the importance of comprehensive support for student success.
- Industry placement: The practical exposure gained through industry placement received positive evaluations, with an average satisfaction score of 3.87 (S.D. = 0.74), highlighting the real-world applicability of the program.

3.6.2 Components assessment

The aggregated average satisfaction score across all components of IBL was 4.35 out of 5 (S.D. = 0.75), indicating a high level of satisfaction among participating students. This comprehensive assessment underscores the success of IBL in creating a positive and effective learning environment for enhancing problem-solving skills within the technical workforce context.

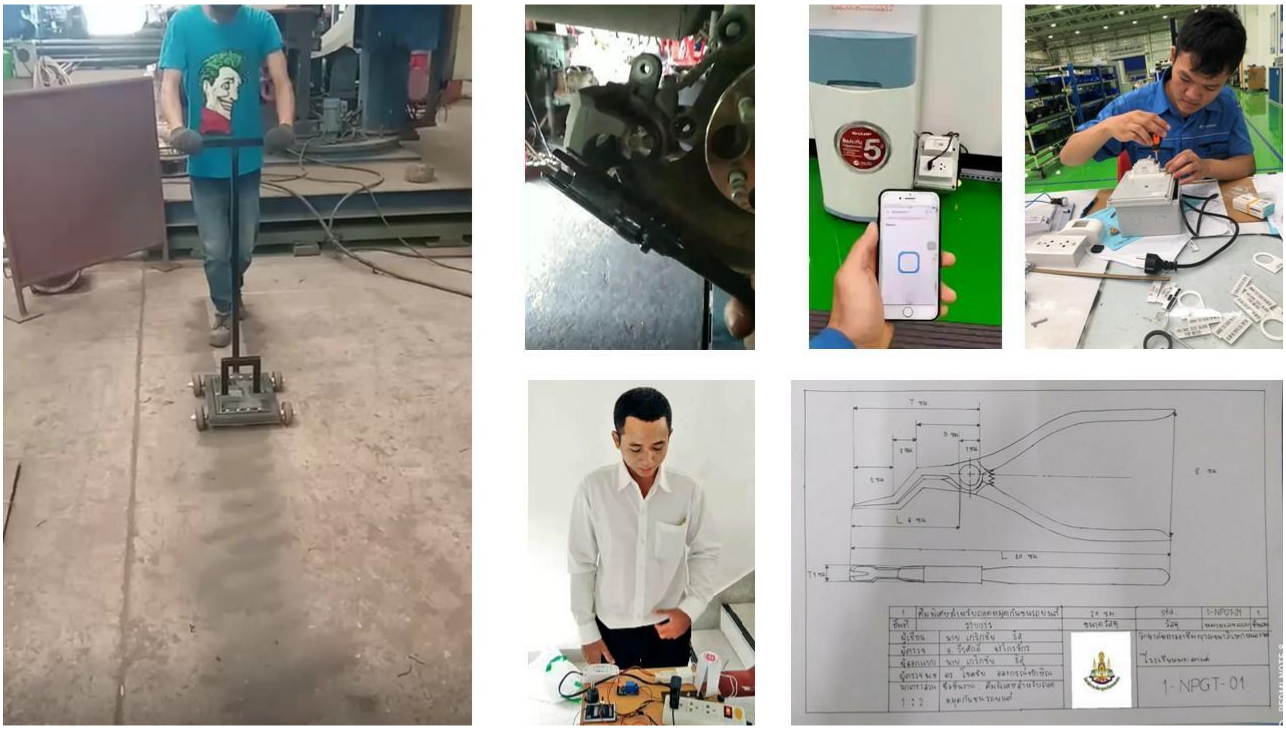

Figure 4. Exemplary student's projects enhancing problem-solving skills in real-world industrial settings.

The cumulative findings strongly support the effectiveness of the IBL program, offering valuable insights for continuous enhancement and enriching the discourse on innovative pedagogical approaches in technical education. Figure 4 serves as additional validation, showcasing the impact of IBL through student projects aimed at enhancing problem-solving skills and tackling real-world industrial challenges. These projects stand as tangible evidence of the program's triumph in translating theoretical knowledge into practical solutions.

3.7 Discussions

After thoroughly reviewing the implementation and completion of the IBL program, it is beneficial to provide a brief preview or summary of the key insights before delving into each point for enhanced reader guidance. Numerous key insights and discussions have come to light, highlighting significant aspects of the IBL initiative.

3.7.1 Advancements in problem-solving skills

Notable enhancement in problem-solving skills has been observed, marking the success of the IBL initiative. The shift from a modest pre-test average score (39.13, S.D. = 6.49) to a commendable post-test average score (72.67, S.D. = 4.07) underscores the program's effectiveness in nurturing advanced problem-solving capabilities among students.

3.7.2 Effective assessment of problem-solving skills

The utilization of pre-test and post-test assessments has proven to be effective in evaluating the progression and improvement of problem-solving skills within the vocational diploma program. This methodological approach offers a clear understanding of the impact of IBL on students' practical abilities.

3.7.3 Efficiency in real-world problem-solving

Efficiency assessment, both in process (E1) and output (E2), exceeding the established criteria (90.75/86.53), highlights the program's efficacy in preparing students for real-world problem-solving challenges. This underscores the practical applicability of skills acquired during the learning process.

3.7.4 Development of advanced abilities

The substantial growth in advanced abilities affirms the positive impact of IBL on students' overall capabilities. This aligns with the program's objective of not only enhancing problem-solving skills but also cultivating a broader skill set essential for professional success.

3.7.5 Quality alignment with industrial requirements

The assessment of project workpieces reveals a commendable level of quality, as the majority align well with industrial requirements (average score 4.38, S.D. = 0.58). This indicates that IBL not only improves skills but also enables the practical application of knowledge, meeting or exceeding industry standards.

3.7.6 Student achievement amidst COVID-19 impact

The COVID-19 pandemic presented challenges that impacted the overall learning achievement of students, leading to a decline in the percentage (32.88%). Notably, students who actively confronted these challenges demonstrated a substantially higher achievement percentage (53.33%). This underscores the resilience and determination of these students in navigating and overcoming disruptions.

3.8 Limitations of the study

The current study provides valuable insights into the impact of the IBL program on problem-solving skills in technical vocational education. However, it is important to acknowledge and address certain limitations that may influence the interpretation of the findings.

Firstly, the study's sample size is relatively modest. Despite efforts to ensure diversity within this group, the generalizability of the results to a broader population may be constrained. Moreover, the sample composition predominantly consists of participants from specific diploma programs, potentially limiting the broader applicability of the findings to other technical fields.

Secondly, the study was conducted over a specific timeframe, raising the possibility that the observed outcomes may have been influenced by the duration of the IBL program. A more extended study period could offer insights into the sustainability and long-term effects of the IBL approach on problem-solving skills.

Thirdly, external factors pose potential influences on the study outcomes. Individual learning styles, participants' prior educational experiences, and personal circumstances may have introduced variability in responses and outcomes. Understanding and accounting for these external factors is essential for a comprehensive interpretation of the study's results.

In light of these limitations, it is crucial to approach the findings with a recognition of the contextual constraints and to consider these aspects when generalizing the results or applying them to different educational settings.

4. Broader discussion and conclusions

The broader discussion and conclusions section explores the implications of the results, compares them with existing literature, highlights the significance for the field, and addresses challenges faced during the COVID-19 pandemic. It emphasizes the positive alignment of IBL with broader educational goals, contributing to skill development and the preparation of adaptable professionals.

4.1 Discussions Implications of results

The enhancement of problem-solving skills aligns seamlessly with overarching educational objectives, underscoring a practical emphasis. IBL emerges as a robust strategy, adept at fostering the competencies crucial for success in real-world workplace scenarios.

4.2 Comparison with existing literature

The findings align with established literature, affirming the positive influence of IBL on skill development in technical and vocational education. This contribution adds to the expanding body of evidence reinforcing IBL as a highly effective pedagogical approach.

4.3 Broader significance for the field

The success of IBL holds profound implications for technical education, empowering students for employment and nurturing adaptable professionals. The alignment of project workpieces with industry requirements not only amplifies the program's practical relevance but also emphasizes its real-world applicability. Amid the challenges presented by COVID-19, the discernible impact on overall achievement and the resilience demonstrated by diligent students vividly showcase IBL's adeptness in navigating disruptions, providing valuable insights into the adaptability of IBL programs in challenging circumstances. Emphasizing the broader significance of IBL, the ensuing key conclusions underscore its substantial impact on vocational diploma programs:

4.3.1 Success in developing IBL in vocational diploma programs

The IBL initiative has successfully elevated problem-solving capabilities among students, evidenced by the transition from a fair pre-test average score (39.13, S.D. = 6.49) to a noteworthy post-test average score (72.67, S.D. = 4.07).

4.3.2 Impactful assessment of problem-solving skills

The use of pre-test and post-test assessments has effectively evaluated the progression and improvement of problem-solving skills within the vocational diploma program.

4.3.3 Efficiency of IBL in preparing for real-world challenges

IBL demonstrated efficiency in improving problem-solving skills, surpassing established criteria (90.75/86.53). This underscores the program's effectiveness in preparing students for real-world challenges.

4.3.4 Nurturing advanced abilities

Students exhibited substantial growth in advanced abilities, affirming the positive impact of IBL on their overall capabilities.

4.3.5 Alignment of project workpieces with industrial requirements

Project workpieces demonstrated a good level of quality (average score 4.38, S.D. = 0.58), aligning well with industrial requirements.

4.3.6 Resilience amidst COVID-19 challenges

The challenges posed by the COVID-19 pandemic impacted overall student learning achievement (32.88%), but diligent students actively addressing challenges exhibited a significantly higher achievement percentage (53.33%).

4.3.7 Satisfaction and future implementation

The evaluation of satisfaction with the problem-based learning in the project course garnered positive feedback, with an average score of 4.35 (S.D. = 0.75). This underscores the success of the implemented pedagogical approach.

The recommendations put forth strategic pathways for future research and improvements in the IBL program. These include a detailed exploration of specific components within IBL to facilitate targeted enhancements, investigating the long-term impact on students' careers, promoting ongoing program evaluation, extending IBL to encompass additional core competencies, integrating cutting-edge technological advancements, and undertaking global comparative studies.

4.4 Specific components of IBL

Future research could delve deeper into specific components contributing most significantly to skill development for targeted improvements.

4.5 Long-term impact on careers

Exploring the long-term impact of IBL on students' careers will enrich the literature and inform program refinements.

4.6 Continuous program evaluation

Regular assessments and adjustments, incorporating feedback, are crucial for ensuring sustained efficacy of IBL in vocational diploma programs.

4.7 Expansion to other core competencies

Expanding IBL to address other core competencies beyond problem-solving will contribute to a well-rounded technical education.

4.8 Technology integration

Integrating technological advancements into the IBL framework, such as virtual simulations, can enhance its relevance and effectiveness.

4.9 Global comparative studies

Comparative studies across global contexts will offer a broader perspective on IBL's effectiveness, contributing to a comprehensive understanding.

In conclusion, the positive outcomes affirm the efficacy of the IBL program in enhancing problem-solving skills, overall abilities, and project outcomes. These findings contribute valuable insights to the ongoing dialogue on innovative pedagogical approaches in technical education. Furthermore, the recommendations delineate avenues for further research and the ongoing refinement of IBL programs.

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