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Organizing activities for students of chemistry pedagogy to research according to the CDIO approach in Vietnam

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Abstract

A comprehensive educational framework is provided by the Conceive-Design-Implement-Operate (CDIO) which is particularly relevant to engineering and applied sciences. This paper investigates the application of the CDIO approach in the field of chemistry pedagogy in Vietnam focusing on its adaptability to the current educational demands and its potential to enhance the competency of future teachers. The CDIO approach develops training curricula and output standards based on input from teachers, students, alumni and recruitment firms. This study uses the CDIO approach extensively with professional knowledge, social awareness and creative tendencies. The study involved a survey of 240 chemistry teachers and 242 students from various universities across Vietnam. Data were collected through online surveys using Google Forms and processed using SPSS software for statistical analysis. The research analyzed the alignment of practical teaching activities with CDIO standards and developed a framework for experimental practice competency. Findings indicated a robust implementation of the CDIO approach in chemistry pedagogy. In laboratory safety, experimental planning, execution and competence were high. The study shows that the CDIO strategy enhances professional competence and practical abilities in Vietnamese chemistry pedagogy students. It promotes collaboration and personal growth to meet changing educational needs. The CDIO approach could transform chemistry pedagogy in Vietnam suggesting science education reforms and capacity building.

Keywords: CDIO approach, CDIO standards, Chemistry pedagogical students, Experimental practice competency.

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Contents

Contribution of this paper to the literature

This particular research embeds the CDIO (Conceive-Design-Implement-Operate) approach into chemistry pedagogy in Vietnam illustrating its flexibility and impact on enhancing educational capabilities. More precisely emphasizing experimental skills and problem-based learning, this research provides some viewpoints regarding the implementation of CDIO in chemistry education a new experience for Vietnamese students.

1. Introduction

This era of rapid technological advancement and growing global competitiveness is challenging and reshaping the traditional paradigms of educational pedagogy (Nehru, 2020). According to Griffin and Aubusson's (2020) research, a dynamic approach to teaching and learning is especially necessary in the fields of science and technology. This strategy needs to incorporate the real-world application of scientific concepts in addition to theoretical knowledge. The CDIO initiative has become a paradigm-shifting model for higher education particularly in the fields of engineering and applied sciences (Al-Obaidi, 2021). This can be attributed to the environment in which it has surfaced. This paper explores the use of the CDIO approach in the field of chemistry pedagogy in Vietnam. The aim of this study is to obtain a deeper comprehension of how this methodology fits in with today's educational demands and improves the competency of future teachers.

The four-staged educational framework that characterizes the CDIO approach has been a completely revolutionary concept in the field of engineering education. Tarasyan and Tarasyan (2020) pointed out the growing gap between engineers' academic training and the demands of their profession in the real world which led to the creation of the CDIO standards. They offer an all-encompassing framework that covers the whole educational spectrum from ideation to actual implementation. This model emphasises a skill set that extends beyond technical knowledge to encompass interpersonal and personal skills, system building and product and system lifecycle thinking (Forcael, Garcés, & Orozco, 2021). An integrated curriculum that promotes interdisciplinary teaching and active learning is emphasised in this model.

Vietnam has made significant improvements to its educational system in order to satisfy the demands of an expanding economy and a society that is becoming increasingly based on knowledge (Albright, 2022). Out of all the approaches being tested and used in Vietnam's universities for chemistry education, the CDIO approach has shown to have especially promising potential (Tieocharoen & Rimkeeratikul, 2019). The fundamental science of chemistry is vital to a wide range of disciplines including environmental science, materials science, pharmaceuticals and many more. Chemists who possess not only subject-matter expertise but also mastery of the art of teaching and applying chemical knowledge are in greater demand than in the past (Herdt, 2019).

Modern technology and global competition are challenging and reshaping educational pedagogy (Nehru, 2020). Science and technology require a dynamic approach to teaching and learning that goes beyond theory to include practical application (Griffin & Aubusson, 2020). The CDIO initiative has revolutionized higher education especially in the fields of applied sciences and engineering in this context (Al-Obaidi, 2021). This paper examines how the CDIO approach is applied to chemistry pedagogy in Vietnam to meet current educational needs and train future teachers.

The CDIO approach revolutionized engineering education with its four-stage framework. In response to the growing gap between engineers' academic training and their real-world demands, the CDIO standards provide a comprehensive structure that covers the entire educational spectrum from ideation to implementation (Tarasyan & Tarasyan, 2020). This model emphasises active learning, interdisciplinary teaching and a skill set that goes beyond technical knowledge to include personal and interpersonal skills, system building and product and system lifecycle thinking (Forcael et al., 2021).

Vietnam's educational sector is undergoing major reforms to meet the needs of a developing economy and a knowledge-based society (Albright, 2022). The CDIO approach is promising in chemistry pedagogy at Vietnamese universities (Tieocharoen & Rimkeeratikul, 2019). Chemical science is essential to pharmaceuticals, environmental science and materials technology. Chemistry pedagogues who are well-versed in their field and skilled at teaching and applying chemical knowledge are in high demand (Herdt, 2019).

2. Literature Review

The introduction of the CDIO framework into higher education has revolutionized engineering and technical teaching methodologies worldwide (http://www.cdio.org/about). As Vietnam embraces this global trend, it becomes crucial to understand its applicability and effectiveness within the context of chemistry pedagogy. This literature review examines the theoretical foundation of the CDIO approach, its global implementation, the peculiarities of its application in the field of chemistry and the specific challenges and opportunities it presents in the Vietnamese educational landscape.

The CDIO framework was conceptualized as an educational response to the growing need for engineers who are prepared to meet the challenges of modern technology (Gunnarsson & Swartz, 2022). The founding universities envisioned a system where students not only acquire technical knowledge but also develop a skill set encompassing design and systems thinking, teamwork and communication (Stevens, 2018). The CDIO approach's integrative nature makes it compatible with constructivist theories of education which support learning environments in which students create knowledge through experiences (Xu, 2022).

The spread of CDIO across more than 116 countries is a testament to its adaptability and global appeal (http://www.cdio.org/participate). Various studies have shown the effectiveness of CDIO in enhancing student engagement and outcomes in engineering education (Wang & Yuan, 2018). The approach has been praised for fostering creativity, critical thinking and the ability to tackle complex problems (Yue, 2018).

The CDIO framework's emphasis on experimentation and problem-solving is especially pertinent to chemistry education. Students studying chemistry benefit from a teaching strategy that reflects the discipline's emphasis on inquiry (Martseva, Movchan, Vakaliuk, & Antoniuk, 2021). Practical work is a vital component of chemical education and fits within the "implement" and "operate" phases of CDIO making it an appropriate match for pedagogical improvement in this field(Jambari, Ismail, Taman, Pairin, & Hamzah, 2023).

Considerable reforms have been made to meet the demands of a rapidly developing economy and to bring Vietnamese higher education into line with international standards (Tran & Marginson, 2018). The use of CDIO in Vietnam is a component of a larger plan to improve the calibre of university education especially in the area of chemistry pedagogy. Several challenges still exist including a lack of funding, the need for teacher preparation and integrating traditional teaching techniques with this new approach (Xu, 2022).

Language hurdles, cultural differences in schooling and customizing the framework to local circumstances are among the unique difficulties Vietnam faces when implementing CDIO (Gunnarsson & Swartz, 2022). However, the advantages it offers are strong including raising Vietnam's competitive advantage in science and technology and better preparing students for the workforce (Huy et al., 2021).

Recent studies on the CDIO approach in technical disciplines highlight a lack of contextual adaptation particularly in Vietnam (Nguyen & Tran, 2019). There is a call for more research on CDIO's interdisciplinary integration and its role in soft skills development (Smith & Lee, 2021) as well as understanding its real-world challenges and impacts on student learning in chemistry (Brown & Miller, 2020). Several studies conducted in recent years have demonstrated that the CDIO teaching paradigm is widely and extensively used by technical universities while teacher training universities are still stuck whether when establishing the CDIO model is consistent with the program's output standards (Garcia & Hernandez, 2018; Nguyen & Tran, 2019). This paper which focuses on helping students increase their capacity for chemical experiments, examines and overcomes these obstacles when using CDIO to build professional and career capacity. The scarcity of comparative and longitudinal studies further emphasizes the need for in-depth analysis of CDIO's long-term effectiveness in chemistry education (Garcia & Hernandez, 2018).

The present research seeks to build on the existing literature by focusing on the practical application of CDIO in chemistry pedagogy. Previous studies have seldom addressed how CDIO can be applied to such specific chemical processes within the Vietnamese context. This study seeks to close this gap by examining the opportunities and difficulties of integrating CDIO in chemistry education in Vietnam while taking into consideration the nation's distinct cultural and educational background. It will also shed light on how CDIO might strengthen students' chemical problem-solving and critical thinking skills which will ultimately help to raise the standard of STEM education in Vietnam.

In a nutshell, this research indicates that even though CDIO has significantly advanced engineering education across the globe, further research is needed to fully understand its use in chemistry education especially in Vietnam. It aims to contribute to a growing body of research that supports educational reform and capacity building in science education in Vietnam and beyond. This research will help identify potential challenges and opportunities for implementing CDIO principles in other STEM disciplines by examining the impact of CDIO on chemistry education in Vietnam. Additionally, it will clarify the precise methods and techniques that can be applied to successfully include CDIO in the chemistry curriculum promoting a more comprehensive and student-centered educational experience.

Therefore, the specific research questions were as follows:

1. How is the relationship between chemical experimental practice competencies and CDIO standards expressed?
2. What are the results of the survey of teachers and students regarding the performance criteria for each competency?
3. What are the suggestions to improve the criteria that still reveal limitations for students as well as teacher recommendations?

3. Methodology

The CDIO model is based on the philosophy of developing learners' core competencies to meet the principles of implementing the product life cycle. This model provides a scientific basis and a system of quality standards to ensure higher education institutions solve two central issues. It is important for students to acquire information, skills, and a well-rounded mindset before graduating from college. Additionally, what level of competency is attained? How can we do better at ensuring students acquire those skills?

Students will learn personal, communication, product, process and system building skills along with disciplinary knowledge in the context of professional practice following the CDIO approach to integrated learning. Integrated learning has the advantage of allowing students to use dual time to both learn knowledge and learn skills.

3.1. Research Goal

The study has created a procedure to direct experimental practice for students majoring in Chemistry education in accordance with the CDIO approach by investigating training practices and the role of experimental practice skills in the process of training current chemistry pedagogy students in Vietnam. They have also highlighted the applications of the CDIO teaching method to the development of standard procedures for many different training fields, including pedagogy. This study seeks to close this gap by examining the opportunities and difficulties of integrating CDIO in chemistry education in Vietnam while taking into consideration the nation's distinct cultural and educational background. It will also shed light on how CDIO might strengthen students' chemical problem-solving and critical thinking skills which will ultimately help to raise the standard of STEM (Science, Technology, Engineering and Maths) education in Vietnam.

The process developed and applied is the basis for lecturers' assessment of students and students' self-assessment of learning outcomes. Lecturers continue to have appropriate solutions for developing chemistry experimental practical competencies for students majoring in chemistry education according to the CDIO approach and students can also self-assess their limitations of these competencies to continue to consolidate and develop.

3.2. Sample and Data Collection

The research conducted a survey of the opinions of 240 chemistry teachers in high schools in the North, Central and South of Vietnam about "the level of agreement in implementing chemistry experimental practical competencies according to the CDIO approach". At the same time, a survey of 242 students at Hanoi University of Education, Vinh University, Hue University and Dong Thap University was conducted on the content "assessing the chemistry experimental practical competencies of students themselves". We distributed online surveys through Google Forms to gather data on the teachers' perceptions of implementing the CDIO approach in chemistry experiments and the students' self-assessment of their experimental competencies. Surveys were carried out at the beginning of the 2023–2024 academic years in order to optimize data completeness and relevance. This period aligns with the initiation of new educational programs providing a baseline for evaluating the implementation and impact of the CDIO approach in chemistry education.

3.3. Research Process

Our research process was designed to meticulously analyze the data from the surveys through statistical analysis focusing on key metrics such as correlation coefficients, Cronbach alpha and standard deviations. These metrics were applied to both the teachers' responses and the students' self-assessments regarding the application of the CDIO approach in chemistry experiments. This statistical approach enabled us to derive meaningful insights into the effectiveness of the CDIO approach in enhancing experimental competencies among chemistry students in Vietnamese educational settings.

3.4. Analyzing the Data

The survey data results were processed using SPSS software version 27.0 to statistically analyze parameters including total variable correlation coefficient, Cronbach alpha if item deleted value of observed variables, average score, standard deviation of the criteria for teachers' judgment on chemistry experimental practical competencies according to the CDIO approach (see Table 1) and assessment of students' own about these competences (see Table 2).

4. Results

We analyzed 12 CDIO standards and then made a framework for experimental practice competency in order to organize practical teaching activities according to the CDIO approach for chemical pedagogical students (see Figure 1).

The graphic shows a thorough schematic linking different competencies and requirements to the CDIO standards and a cutting-edge curriculum designed to develop the next generation of engineers. The framework's goal is to give students a thorough education so they can graduate from engineering school with the abilities and knowledge needed to meet the demands of contemporary engineering practice.

The two main sections of the diagram are as follows: the left side lists particular competencies associated with practicing and teaching chemistry experiments and the right-side links these competencies to the relevant CDIO standards.

As shown in Figure 1, there is a progression of competencies in the context of the CDIO approach to chemistry pedagogy, beginning with foundational skills such as ensuring laboratory safety and advancing to more complex capabilities like integrating interdisciplinary knowledge. This progression is detailed through specific criteria for each competency emphasizing the importance of a comprehensive skill set ranging from practical safety measures to collaborative and analytical abilities in a pedagogical setting. These competencies are decomposed into more precise criteria. For instance, the criteria for "competence to perform chemical experiments" go into detail about safety protocols, planning experiments and the capacity to discuss findings and offer alternatives in the event that an experiment is unsuccessful.

The diagram also emphasizes the significance of developing soft skills such as "competence to work in groups "which is broken down into criteria for group activities, team development and team leaders. It also highlights the importance of self-evaluation and evaluation skills along with highlighting the value of communication between students and lecturers.

The image's right side lists the CDIO standards. A network of colored lines connects the standards to the competencies showing which competency is in line with which standard. The CDIO standards address every facet of education ranging from "the context" and "learning outcomes" to "programme evaluation."

Each competency in the diagram has the potential to relate to more than one CDIO standard resulting in a complex web of connections. For instance, standard 5 design and implement experiences and standard 7 integrate learning experiences which are related to competence to design and arrange learning space CDIO.

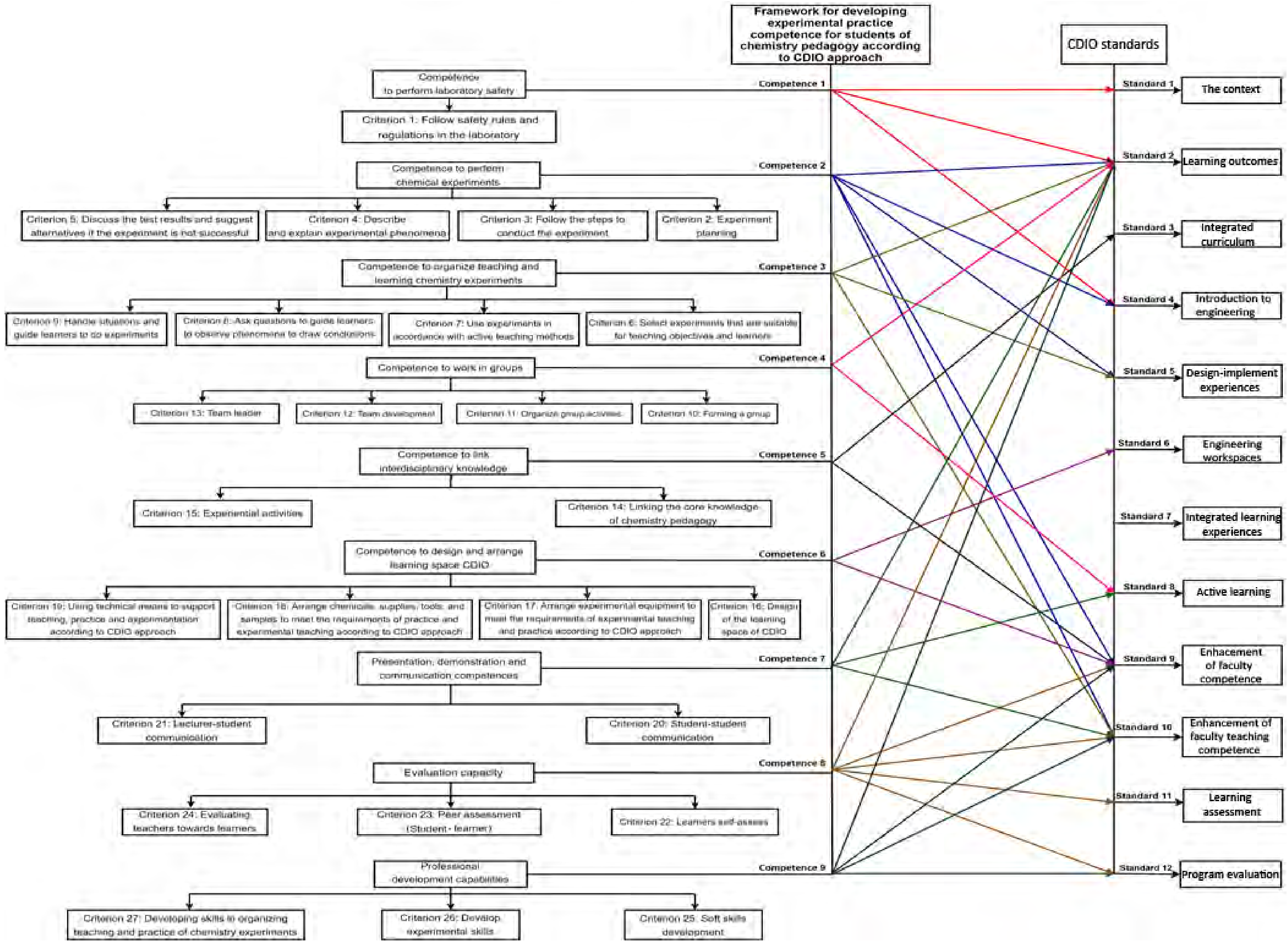

Figure 1. Framework for developing experimental practice competence for third-year pedagogical chemistry students according to the CDIO approach.

These relationships demonstrate the comprehensive approach of the CDIO framework which incorporates the acquisition of practical skills within a more comprehensive educational framework as opposed to developing them independently. In addition to technical proficiency, the goal is to guarantee that engineering graduates possess the critical thinking, creative problem-solving and effective communication skills that are essential in the field of professional engineering.

The diagram basically shows how a chemistry education program can be organized to be in line with the CDIO standards. It illustrates the complexity of engineering education which necessitates striking a balance between hard and soft skills as well as a thorough comprehension of the environment in which engineering is applied. This alignment guarantees that students can not only think through and create solutions for complex problems but can also carry out and manage these solutions in real-world settings which satisfy the main objective of the CDIO initiative.

Table 1. Item-total statistics of the level of agreement in implementing chemistry experimental practical competencies according to the CDIO approach.

No.	Names of competencies or criteria	Corrected item-total correlation	Cronbach's alpha if item deleted	Mean	Std. deviation
Criteria 1	I usually strictly and fully follow the rules and safety rules when working in the laboratory.	0.730	0.955	4.24	0.828
Criteria 2	I know how to make detailed plans before performing an experiment.	0.752	0.955	4.10	0.812
Criteria 3	I usually strictly follow the pre-determined steps in the experiment.	0.764	0.955	4.13	0.766
Criteria 4	I have the ability to describe and explain experimental phenomena accurately.	0.801	0.954	4.02	0.795
Criteria 5	I know how to propose and implement alternatives when an experiment fails.	0.776	0.954	3.90	0.862
Criteria 6	When teaching, I always choose experiments that suit the goals and subjects.	0.765	0.955	4.13	0.814
Criteria 7	I often apply active teaching methods when teaching experiments.	0.749	0.955	3.95	0.852
Criteria 8	During the teaching process, I often ask guiding questions for learners to observe and draw conclusion from the phenomenon.	0.799	0.954	4.11	0.746
Criteria 9	When situations arise, I know how to handle and guide learners appropriately.	0.826	0.953	3.99	0.795
Criteria 10	I have the ability to create and manage an effective group.	0.768	0.955	3.88	0.745
Criteria 11	I know how to organize and coordinate activities for my group.	0.772	0.954	3.94	0.760
Criteria 12	I often grasp and develop relationships within the group.	0.763	0.955	3.83	0.765
Criteria 13	I have the ability to lead groups, resolve conflicts and make appropriate decisions.	0.766	0.955	3.81	0.821
Criteria 14	I have the ability to connect and apply knowledge from other subjects to chemistry.	0.728	0.955	3.72	0.840
Criteria 15	I often participate in and organize experiential activities that help connect interdisciplinary knowledge.	0.646	0.957	3.53	0.919
Mean: 3.9508					
Std. deviation: 0.641					
Cronbach alpha: 0.958					

The results presented in Table 1 provide a comprehensive insight into the effectiveness of implementing chemistry experimental practical competencies based on the CDIO (Conceive-Design-Implement-Operate) approach. This table offers a detailed analysis of fifteen distinct competencies, each assessed through metrics like corrected item-total correlation, Cronbach alpha if an item is deleted, mean and standard deviation.

A critical observation from the table is the high level of agreement among participants on most competencies as indicated by the means ranging from 3.53 to 4.24 on a scale presumably ranging from 1 to 5. The highest mean score of 4.24 associated with criterion 1 ("I usually strictly and fully follow the rules and safety rules when working in the laboratory") suggests a strong adherence to laboratory safety and protocols among the participants. This is crucial in a practical chemistry setting emphasizing the importance of safety and procedure compliance in pedagogical practices.

Criterion 15 ("I often participate and organize experiential activities that help connect interdisciplinary knowledge") with the lowest mean score of 3.53 indicates a comparatively weaker engagement in interdisciplinary activities. This suggests potential areas for improvement emphasizing the need for educators to foster a more integrative approach that connects chemistry with other disciplines.

The corrected item-total correlation values ranging from 0.646 to 0.826 indicate a substantial correlation between individual competencies and the overall score. This suggests that each competency contributes meaningfully to the overarching skill set required in the CDIO approach. Notably, criterion 9 (when situations arise, I know how to handle and guide learners appropriately) shows the highest correlation (0.826) underscoring the importance of adaptability and guidance in the educational process.

Cronbach alpha values, consistently high and hovering around 0.955 reflect the reliability of the scale used for assessing these competencies. The only exception is criterion 15 where the alpha value marginally increases to

0.957 if removed indicating a slightly higher internal consistency of the scale without this item. However, this increase is not substantial enough to warrant significant concern.

The standard deviation values ranging from 0.745 to 0.919 demonstrate a moderate level of variance in responses. This variance is particularly noticeable in competencies involving more subjective and situational aspects such as criterion 15 suggesting diverse experiences and perceptions among the participants in these areas.

The results illustrate a robust implementation of the CDIO approach in chemistry pedagogy with a high level of competence demonstrated in key areas such as laboratory safety, planning and execution of experiments and the ability to adapt and guide learners. The somewhat lower scores in interdisciplinary activities and group dynamics suggest areas where further emphasis and development might be beneficial. These insights are vital for understanding the strengths and areas for growth in the current pedagogical approaches and can guide future improvements in chemistry education particularly in the context of the CDIO framework in Vietnam.

Table 2. Item-total statistics of assessment of students' own chemistry experimental practical competencies.

No.	Names of competencies or criteria	Corrected item-total correlation	Cronbach alpha if item deleted	Mean	Std. deviation
I. Competence to implement laboratory safety (Criteria: Implement safety rules and regulations in the laboratory)					
Q1	When doing experiments, be aware of the safety guidelines and requirements.	0.832	0.984	4.02	0.899
Q2	Understanding of potential risks and hazards in the laboratory.	0.853	0.984	3.99	0.888
Q3	Be aware of personal responsibility for ensuring safety in the laboratory.	0.804	0.985	4.19	0.899
II.1. Competence to perform chemical experiments (Criteria: planning to carry out experiments)					
Q4	Determine the goals and desired results of the experiment.	0.869	0.984	3.86	0.927
Q 5	Select and arrange the experimental steps appropriately.	0.880	0.984	3.82	0.910
Q 6	Know how to estimate and prepare enough of the necessary chemicals and supplies.	0.871	0.984	3.81	0.918
II.2. Ability to perform chemical experiments (Criteria: carry out experimental steps; criteria: describe, evaluate and explain experimental phenomena).					
Q 7	Follow the instructions or experiment plan exactly.	0.843	0.984	3.96	0.896
Q 8	Observe accurately and record the phenomenon that occurs.	0.871	0.984	3.91	0.905
Q 9	Describe, evaluate results and compare with expectations.	0.848	0.984	3.80	0.921
II.3. Competence to perform chemical experiments (Criteria: discuss experimental results and propose alternative solutions if the experiment is unsuccessful).					
Q 10	Discuss the experimental results and find out the cause of the phenomenon.	0.861	0.984	3.71	0.925
Q 11	Propose solutions when experiments do not meet the requirements.	0.846	0.984	3.68	0.953
III.1 Competence to organize the teaching and learning of chemical experiments (Criteria: choosing experiments suitable to teaching objectives and learners).					
Q 12	Select experiments that are appropriate to the experimental teaching objectives.	0.910	0.984	3.86	0.895
Q 13	Know how to combine theory and practice to create excitement for learners.	0.877	0.984	3.83	0.903
Q 14	Organize teaching time effectively.	0.867	0.984	3.78	0.923
III.2 Competence to organize the teaching and learning of chemical experiments (Criteria: use teaching methods suitable for experiments in the direction of active teaching).					
Q15	Use flexible and appropriate teaching methods.	0.886	0.984	3.76	0.941
III.3 Competence to organize and teach chemical experiments (Criteria: ask questions to guide learners in observing phenomena to draw conclusions).					
Q16	Ask interactive questions to stimulate thinking and observations for learners to draw conclusions.	0.864	0.984	3.76	0.930
III.4. Competence to organize the teaching and learning of chemical experiments (Criteria: handling situations and guiding learners to do experiments).					
Q17	Guide learners on how to approach and perform experiments confidently.	0.891	0.984	3.81	0.935
IV.1. Teamwork capacity (Criteria : forming a group)					
Q18	Divide into groups to practice evenly in terms of the number and capacity of group members.	0.883	0.984	3.90	0.913
IV.2. Teamwork capacity (Criteria : organizing group activities)					
Q19	Assign and divide work appropriately for each member.	0.879	0.984	3.90	0.931
IV.3. Teamwork capacity (Criteria : group development)					
Q20	Ensure effective interaction and cooperation among members.	0.855	0.984	3.92	0.950
IV.3. Teamwork capacity (Criteria : group leadership)					
Q21	Resolve conflicts and conflicts within the group effectively.	0.832	0.984	3.89	0.945
Mean: 3.8654					
Std. deviation: 0.806					
Cronbach alpha: 0.985					

Table 2 encompasses a range of competencies divided into four major categories: laboratory safety, performance of chemical experiments, organization of teaching and learning chemical experiments and teamwork capacity. Each competency is evaluated based on corrected-item-total correlation, Cronbach alpha if an item is deleted, mean and standard deviation.

Laboratory safety: The competencies under laboratory safety (Q1-Q3) show high corrected item-total correlation values (0.832 to 0.853) indicating a strong relationship between these items and the overall assessment. Notably, students exhibit high awareness of personal responsibility for ensuring safety (Q3, mean=4.19), underlining the emphasis placed on safety within the chemistry curriculum. The mean scores for these competencies (ranging from 3.99 to 4.19) reflect a substantial understanding and implementation of safety measures crucial for any practical chemistry setting.

Performance of chemical experiment: In the domain of performing chemical experiments (Q4-Q11), students demonstrate a solid grasp of planning and executing experiments with mean scores ranging from 3.68 to 3.96. The ability to follow instructions accurately (Q7, mean=3.96) and observe and record phenomena (Q8, mean=3.91) is particularly notable suggesting that students are well-trained in observing and documenting experimental results. However, the slightly lower scores in proposing solutions when experiments do not meet requirements (Q11, mean=3.68) suggest a potential area for enhanced focus in problem-solving and critical thinking.

Organization of teaching and learning: The competencies related to the organization of teaching and learning of chemical experiments (Q12-Q17) has mean scores ranging from 3.76 to 3.86. Students show proficiency in selecting appropriate experiments (Q12, mean=3.86) and combining theory with practice (Q13, mean=3.83) which are crucial for effective chemistry teaching. The slightly lower score for using flexible and appropriate teaching methods (Q15, mean=3.76) highlights an area where further improvement could be beneficial.

Teamwork capacity: Students scored consistently high (mean scores ranging from 3.89 to 3.92) indicating effective group dynamics and collaboration skills in terms of teamwork capacity (Q18-Q21). This is an essential aspect of modern pedagogy emphasizing the importance of teamwork in scientific research and education.

Overall analysis: The overall mean score across all competencies is 3.8654 with a standard deviation of 0.80597 indicating a moderate variation in student responses. The high Cronbach alpha value of 0.985 across the board signifies a high degree of internal consistency in the assessment tool used.

These results demonstrate a strong foundation in both theoretical knowledge and practical skills among the students. The emphasis on laboratory safety and effective execution of experiments reflects a curriculum that is not only focused on theoretical understanding but also on practical applicability. The slightly lower scores in certain areas such as problem-solving in unexpected experimental outcomes and flexibility in teaching methods suggest opportunities for curriculum enhancement. This can include integrating more problem-based learning and active teaching methods to further bolster students' critical thinking, problem-solving and adaptability skills.

The CDIO approach seems to be effectively cultivating essential competencies in students preparing them for the challenges of modern chemistry pedagogy. The assessment underscores the importance of continuous curriculum development to align with evolving educational needs and industry standards.

5. Discussion

Exploring the broader educational implications of this study necessitates a more thorough investigation into how it contributes to and expands upon current educational pedagogical practices. It emphasizes the contribution of this research to the existing literature on the practical implementation of the CDIO framework highlighting its particular relevance in the distinctive educational and cultural context of Vietnam as noted by Tran et al. (2021). The comparison of these findings with existing literature forms a key element of this discussion offering a comparative lens through which the study's contributions can be appreciated (Tran & Vu, 2020). It's essential to contrast how the CDIO approach has been applied in different cultural contexts or educational fields, thus positioning this study within the global conversation on educational methodologies. An important aspect of this discussion revolves around considering alternative explanations for the observed results. For instance, it delves into whether the improvements in competencies among students are solely attributable to the CDIO approach or if there are other contributing factors such as the specific educational environment in Vietnam (Hoang & Pham, 2019). This critical evaluation not only strengthens the study's conclusion but also ensures a balanced and comprehensive understanding of the observed phenomena. Recognizing the study's limitations is an essential aspect of this section ensuring a balanced and scientific approach. It includes recognizing the geographical and cultural specificity of the study, potential biases in data collection or constraints in the research design. This acknowledgment not only underscores the integrity of the research but also paves the way for future studies to build upon or address these limitations (Thanh & Anh, 2023). This study's findings are vital for guiding future research and improving educational practices. It explores how the CDIO approach could be adapted across various disciplines or more deeply integrated into Vietnam's educational system (Chunfang & Li, 2012). Furthermore, the study prompts an evaluation of the broader educational goals emphasizing the development of critical thinking, problem-solving skills and adaptability in students (Li & Gao, 2020). In connecting the findings to broader educational objectives, the discussion emphasizes the relevance and applicability of the CDIO framework beyond the immediate context of this study (Tran & Vu, 2020). It situates the findings within the larger goals of modern education highlighting their potential impact on shaping future educational practices and policies (Li & Gao, 2020). It encapsulates the importance of the findings in the context of educational pedagogy particularly in Vietnam and similar settings offering a comprehensive perspective on the role and potential of the CDIO approach in modern education.

6. Conclusion

This investigation meticulously scrutinized the Conceive-Design-Implement-Operate (CDIO) approach within Chemistry pedagogy in Vietnam focusing on its efficacy in enhancing critical thinking, problem-solving and adaptability among students. The research illuminated the multifaceted nature of CDIO portraying it as more than a teaching strategy for comprehensive educational transformation. Students engaged in CDIO exhibit not only heightened technical prowess and experimental acumen but also a profound development in holistic thinking and problem-solving capabilities. Such skills are indispensable in today's ever-evolving scientific and industrial landscapes. The CDIO's emphasis on innovative teaching methods ensures that the educational experience keeps pace with the rapid advancements and shifting paradigms in the professional world, preparing students to meet future challenges with resilience and ingenuity. However, the path to fully integrating CDIO in educational practice is nuanced with challenges such as resource limitations and the pressing need for extensive teacher training which are pivotal for the successful transition to innovative pedagogical models. The evidence strongly favors the continued exploration and integration of CDIO given its potential to revolutionize educational practices and outcomes despite these hurdles.

Although CDIO has many advantages, there are obstacles in the way of its complete adoption that need to be carefully considered. Resource constraints can hinder the application of CDIO standards, and there's a crucial need for comprehensive teacher training programs. Teachers stand at the forefront of this educational revolution, their ability to adapt to and proficiently deliver new teaching methodologies is vital for the fruitful adoption of CDIO principles. The study advocates for an unwavering commitment to overcoming these obstacles emphasizing that the long-term benefits far outweigh the immediate challenges. The research indicates various potential directions for future investigation. Conducting longitudinal studies would be beneficial to understand the lasting effects of the CDIO initiative on students' academic achievements and career development, thereby offering crucial data on the sustained effectiveness of this educational methodology. Additionally, investigating how CDIO can be tailored to fit Vietnam's unique cultural and educational context is crucial as is examining the cross-disciplinary potential of CDIO to revolutionize education beyond chemistry, potentially enhancing STEM fields and beyond.

In a nutshell, this study has not only substantiated the effectiveness of the CDIO approach in enriching chemistry education but has also set forth a compelling vision for its future application. The findings serve as a strong endorsement for the CDIO framework highlighting its capacity to transform students into innovative thinkers and adept problem-solvers ready to tackle the complexities of the modern world. It's a clarion call to educators, academic institutions and policymakers to heed these insights and collaboratively work towards integrating and refining the CDIO approach in Vietnam's educational system. Adopting this change is crucial for ensuring that future chemists are well-prepared. It equips them and all students with the skills needed to contribute effectively in a world that emphasizes innovation, adaptability and continuous learning. The adoption and implementation of the CDIO approach present an example of progress as Vietnam continues to forge its way across the global educational environment promising to raise the standard for both the relevance and quality of education.

7. Future Works Suggested

Additional research is needed to better understand the broader implications and potential enhancements of the CDIO approach in chemistry education. This includes investigating long-term impacts on students' competencies and readiness for professional careers and integrating interdisciplinary concepts from various scientific fields into chemistry pedagogy. Exploring the scalability and adaptability of the CDIO approach in diverse educational settings across Vietnam both in rural and urban contexts is crucial.

Further work is needed to develop reliable analytical methods for the integration of technology and digital tools into CDIO activities aligned with global educational trends. Comparative studies between Vietnam and other countries regarding the implementation of the CDIO approach offer valuable insights. Additionally, refining teacher training programs and assessing the impact of CDIO activities on curriculum development and educational policies in Vietnam would provide a deeper understanding of educational reforms.

Finally, a focus on collaborative projects and partnerships between educational institutions and the industry within the CDIO framework can bridge the gap between academia and the practical demands of the chemical industry, enhancing the relevance of chemistry education in Vietnam. The proposed research agenda, encompassing various aspects is designed to make a significant impact in the realm of chemistry pedagogy both from a scholarly perspective and in practical application.

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