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ORIGINAL ARTICLE

Organizing Activities for Chemistry Pedagogy Students to Research and Practice Extracting Cajeput Essential Oils from Melaleuca Leaves Using the CDIO Approach

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ABSTRACT

The philosophy in teacher training is geared towards students' excitement and passion for what the teacher will do in the role of the "Soul Engineer" in high schools. That philosophy in the CDIO approach is in the direction of developing the core competencies for graduates, Conceive - Design - Implement - Operate the teaching and educational process in the context of school educational innovation towards standardization, modernization, socialization, democratization and international integration. With the goal of researching the process of organizing the teaching of practical chemical experiments based on the CDIO standards to develop experimental competence for chemistry pedagogical students, the authors used an experimental method through instructing students to extract cajuput essential oil and implementing 14 teaching activities with this experiment. Drawing on the CDIO-based teaching standards, we have built a practical chemistry process to form and develop the competencies for students in chemistry pedagogy. Based on that process, we organized teaching activities and experimented with: (1) Extracting cajeput essential oil by the steam attraction method; (2) The process of preparing an antiseptic solution supplementing the extracted pure cajeput essential oil. The experimental data confirms that the CDIO teaching model applies effectively to chemistry practical exercises for pedagogical students.

1. INTRODUCTION

CDIO stands for "Conceive - Design - Implement - Operate". CDIO is an initiative of the engineering departments of the Massachusetts Institute of Technology (MIT), USA, in collaboration with Swedish universities. This is a solution to improve training quality to meet social requirements on the basis of determining output standards to design training programs and methods according to a scientific process (Crawley et al., 2007; Gunnarsson et al., 2007).

CDIO is logically constructed and has a generalized approach that can be used to develop standard procedures for a variety of training fields outside of engineering (with necessary modifications and additions), including the pedagogical sector.

Until now, the network of universities applying CDIO in the world has been steadily increasing, especially in the US. Up to this point, there have been more than 100 universities around the world applying CDIO to different subjects in Physics, Electronic Engineering and Machine Engineering (http://www.cdio.org/cdio-vision retrieved in May 2022).

In Asia, Singapore was the first country to implement CDIO. This country has successfully applied this model in 5 universities and 15 majors (diplomas) since 2007. In 2010, Singapore was awarded the Award for Excellent Training in Chemical Engineering by IchemE (S'pore) organization (Excellence in Education and Training in Chemical Engineering) thanks to the applying the CDIO process.

CDIO-based training in Vietnam has been effectively applied to technical training schools such as Ho Chi Minh City Polytechnic University, Hanoi University of Construction, Duy Tan University, etc. However, the application of CDIO in pedagogical training is still limited, with Vinh University among the universities that has successfully applied this model in pedagogical training.

The CDIO approach offers the following benefits:

(i) CDIO-based Training is associated with the needs of employers, thereby helping to bridge the gap between training provided by schools and requirements of human resource users;

(ii) CDIO-based Training helps learners develop comprehensively with "hard skills" and "soft skills" to quickly adapt to the ever-changing working environment;

(iii) CDIO-based Training helps training programs be built and designed according to a standardized process. The stages of the training process are interconnected and closely linked;

(iv) The CDIO approach is a development approach, linking program development with effective transmission and evaluation of higher education, contributing to raising the quality of higher education to a new level.

The process of performing chemical experiments in the laboratory using the CDIO model will effectively develop practical competence for students. The selection of testing the extraction of cajeput essential oil is in line with the content of organic chemistry practice in the 2018 general education curriculum of Chemistry in Vietnam.

2. LITERATURE REVIEW

In the training of chemistry pedagogical students, chemical experimental competence is an important output standard associated with the competence of teaching chemical theory in the classroom. Essential oil extraction is a basic chemical experiment for pedagogical students, through which students will be familiar with extraction and separation techniques to develop a chemistry lesson plan in high schools.

Melaleuca species include more than 100 species, some of which are known to be rich in essential oil. *Melaleuca cajuputi* is a species found in northern Australia, China, Indonesia, Thailand, and Vietnam (Doran, 1999). Its most important use is as a source of oil obtained by steam and hot water distillation of its leaves and terminal twigs. The major constituents of the essential oil of *M. cajuputi* are 1,8-cineole and α-terpineol (Doran & Turnbull, 1997). Commercial categorization of essential oil depends on the 1,8-cineole content. The essential oil of *M. cajuputi* has a camphor-like odor, is used as an insect repellent and as a painkiller for rheumatism, headache, toothache, and convulsions in the form of applied plaster (Ogata, 1969).

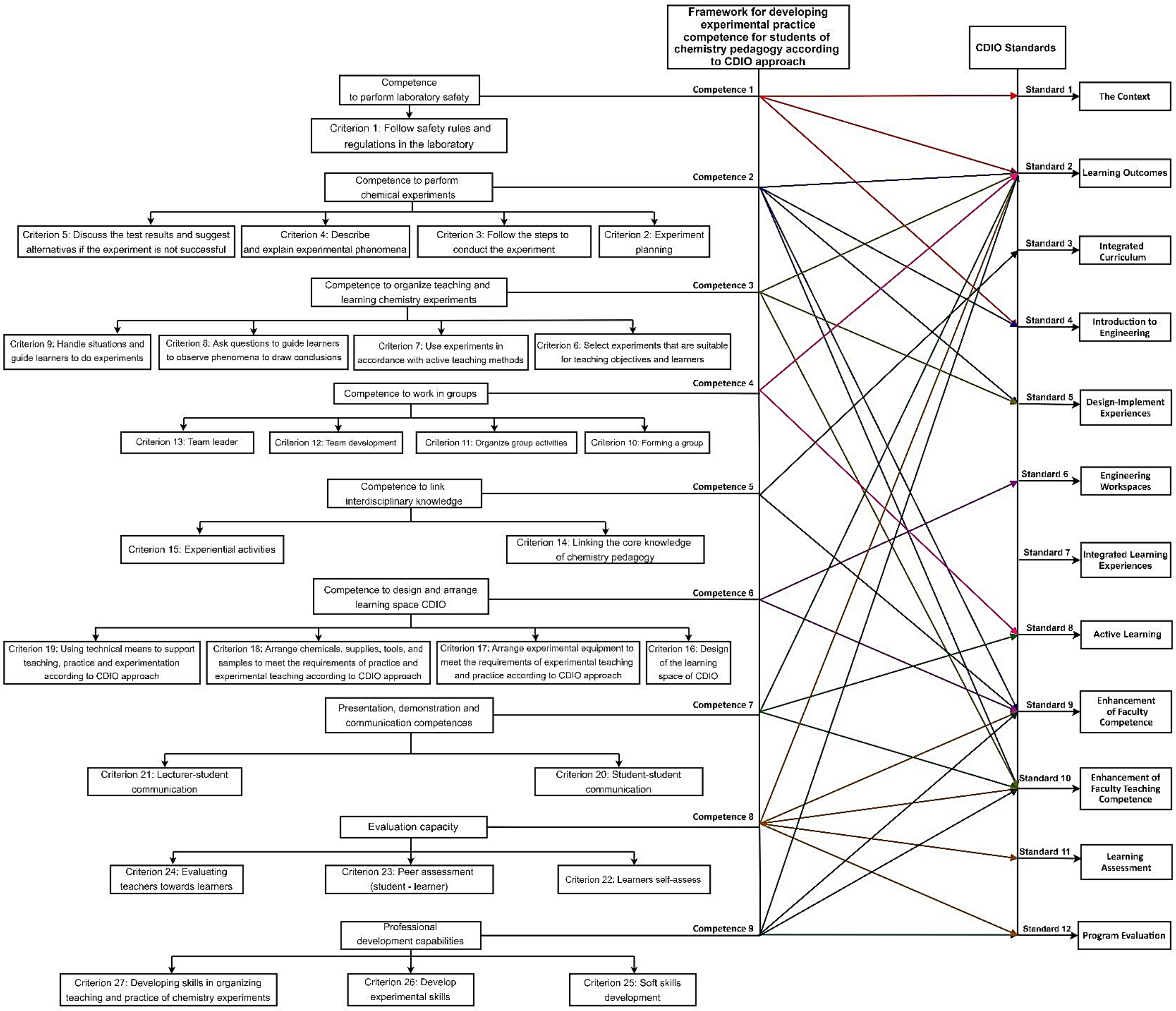
The Cajeput Essential Oil can have the antimicrobial effect (Jalilzadeh-Amin & Maham, 2014; An et al., 2020; Ukit, 2019; My et al., 2020; Pino et al., 2002; Idrus et al., 2020). The main chemical compositions of the Cajeput Essential Oil (*Melaleuca cajuputi*) include eucalyptol, γ-terpinene, terpinolene, β-eudesmene, α- selinene, α-terpineol, 1R-α-pinene, caryophyllene and α-caryophyllene (Pino et al., 2002; Idrus et al., 2020). Cajuput oil quality depends on the cineole which is also called by other names such as Eucalyptol, 1,8-cineol, 1,8-cineole, limonen oxide, cajeputol, 1,8-epoxy-p-menthan, 1,8-oxido-p-menthan, eucalyptole, 1,3,3-trimethyl-2-oxabicyclo[2,2,2]octane, cineole. The proportions of cineole in the oil produced in Cuba, Vietnam, and Indonesia are 27.512 %, 32.4%, and 70.22%, respectively (An et al., 2020; Pino et al., 2002; Idrus et al., 2020). Based on experimental theoretical studies, the Cajeput Essential Oil is considered as a valuable resource for preventing SARS-CoV-2 invasion into the human body (My et al., 2020). Therefore, the Cajeput Essential Oil is used to product the disinfectant solution.

In this study, we discussed the process of organizing experiments to extract cajeput essential oil according to the CDIO process to clarify the general process of chemical experimentation for chemistry pedagogy students.

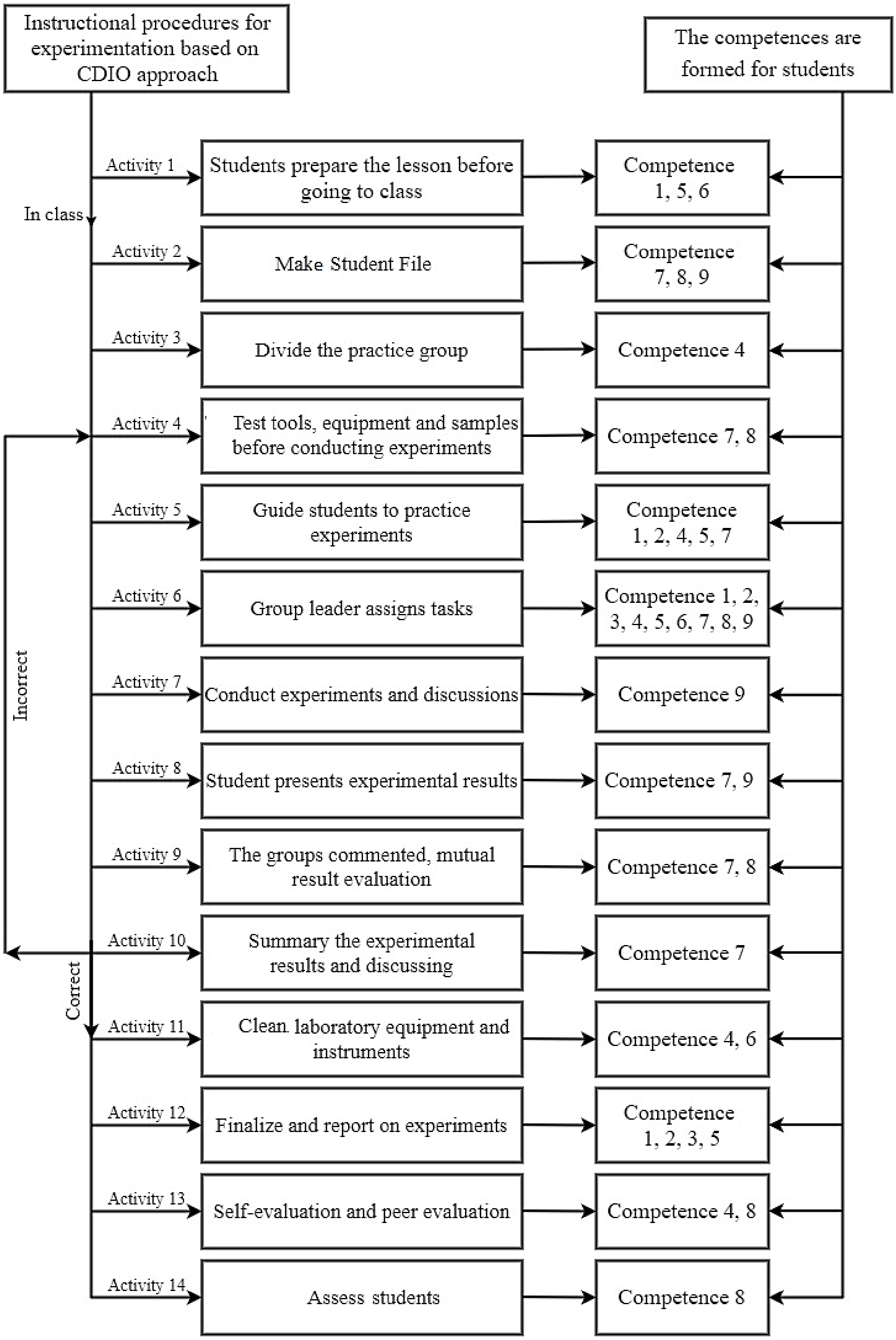
3. MATERIALS AND METHODS

3.1. Organizing teaching activities according to CDIO approach

In order to organize practical teaching activities according to the CDIO approach for chemistry pedagogical students, we analyzed 12 CDIO standards, then built a framework for experimental practice competency (Scheme 1) and proposed a process to guide experimental practice according to the CDIO approach (Scheme 2). On the basis of the experimental practice competence framework, we organized activities to develop experimental practice competence in teaching chemistry through the extraction of cajeput essential oil.



Scheme 1. Framework for developing experimental practice competence for third-year chemistry pedagogy students according to CDIO approach (Giac et al., 2024)



Scheme 2. Instructional procedures for experimentation based on CDIO approach

Activity 1. Students prepare lessons before coming to class

Activity 1 aims to develop students' competencies: 1, 5, 6. The detailed procedure for activity 1 is as follows:

Lecturer's activities	Students' activities
Ask students to define the objectives of the experiment.	Determine the experiment objectives: - Extracting essential oils by steam distillation. - Prepare an antiseptic solution with pure cajeput essential oil.
Ask students to identify the research object.	- Research object: Melaleuca leaves, grown in Ha Tinh province, Vietnam.
Instruct students to collect experiment materials (**Figure 1**).	- Pick fresh green leaves with small branches, no mold, reaching maturity, no pests. - Preserve in a cool place.
Ask students to prepare laboratory equipment and instruments	Prepare: - 100 kg (watch scale). - Ingredients stored in the refrigerator at 5-10 degrees Celsius. - Cutting machines. - Steam distillation system. - Pipettes, conical flasks, beakers, measuring tubes, glass funnels, glass rods, glass jars with lids, etc.
Ask students to identify common preparations for daily life products made from natural essential oils.	Implement and complete: - Production of cajeput oil. - Producing hand sanitizer solution.

Figure 1. Lecturers and students collected samples of Melaleuca leaves in Melaleuca forests in Ha Tinh province, Vietnam

Activity 2. Making a student profile

Activity 2 aims to develop students' competencies: 7, 8, 9. The procedure for activity 2 is as follows:

Lecturer's activities	Students' activities
- Create student profiles. - Attendance.	- Be on time, hard-working, serious, neat and have a scientific manner. - Demonstrate perseverance, ingenuity, creativity.

Activity 3. Dividing into experimental groups

Activity 3 aims to develop students' competencies: **4.** The procedure for activity 3 is as follows:

Lecturer's activities	Students' activities
- Divide into experimental groups equally in terms of experimental skills and gender. - Elect a group leader in charge of each group. - Elect a secretary to record the discussion and work results of the group. - Assign positions to the groups. - Add information to student records.	- Work in the assigned groups.

Activity 4. Checking tools, equipment, and samples before conducting experiments

Activity 4 aims to develop students' competencies: 1, 4, 6, 7. The procedure for activity 4 is as follows:

Lecturer's activities	Students' activities
Ask students to check tools, equipment, samples, etc.	Examine tools, equipment, samples (Figure 2), etc to get ready for the experiment.

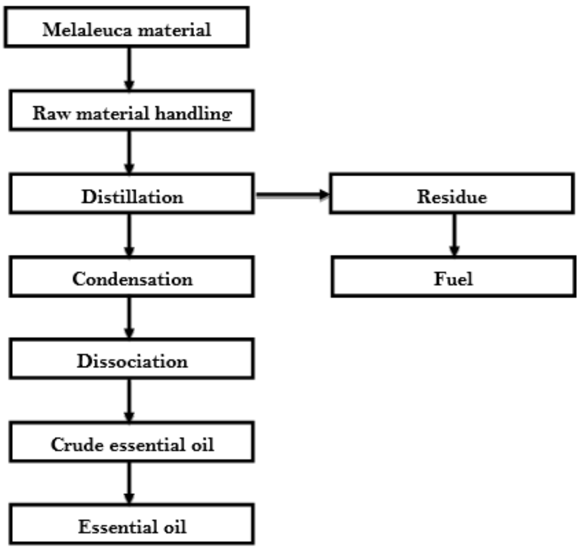
Figure 2. Fresh melaleuca samples

Activity 5. Guiding students to conduct experiments

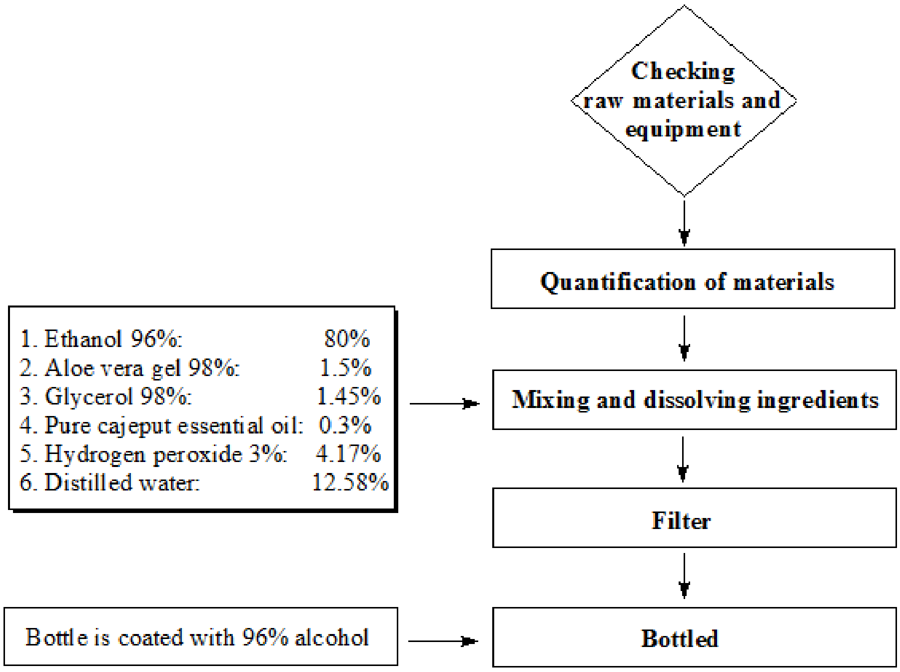
Activity 5 aims to develop students' competencies: 1, 2, 3, 4, 5, 6, 7, 8, 9. The procedure for activity 5 is as follows:

Lecturer's activities	Students' activities
- Guide students to handle samples.	- Choose fresh cajeput leaves, reaching maturity, and free from pests and diseases. - Rinse the sample, dry it. - Weigh 15 kg of sample. - Store raw materials at a temperature of 5-10 degrees Celsius.
- Guide students to draw a diagram of the steam distillation system. - Introduce steam distillation equipment in the laboratory.	- Students draw a diagram of the steam distillation system. - Students observe steam distillation equipment in the laboratory (**Figure 3**).
- Instruct students on the technological process of extracting cajeput essential oil (**Scheme 3**). - Guide students to prepare some products from pure cajeput essential oil (**Scheme 4**).	- Students master the technological process of extracting essential oils from cajeput leaves. - Students know how to prepare some products from pure cajeput essential oil.

Figure 3. Steam distillation equipment at the laboratory of Vinh University



Scheme 3. Technological process for extracting essential oil from cajeput leaves



Scheme 4. The process of preparing an antiseptic solution supplemented with pure cajeput essential oil

Activity 6. Team leader assigns tasks

Activity 6 aims to develop students' competencies: 1, 2, 4, 5, 7. The procedure for activity 6 is as follows:

Lecturer's activities	**Students' activities**
Instruct the team leader to assign tasks to team members.	The team leader assigns tasks to the team members.

Activity 7. Experimenting and discussing

Activity 7 aims to develop students' competencies: 1, 2, 3, 4, 5, 6, 7, 8, 9. The procedure for activity 7 is as follows:

Lecturers' activities	**Students' activities**
Assist students in conducting experiments and discussions.	Students conduct experiments and discuss (**Figure 4)**: - Experimental extraction of essential oils by steam method. - Experimenting with the process of preparing an antiseptic solution consisting of the extracted pure cajeput essential oil.

Figure 4. Students extract melaleuca essential oil and prepare an antiseptic solution supplemented with pure melaleuca oil

Activity 8: Students process data and present experimental results

Activity 8 aims to develop students' competencies: 7, 9. The procedure for activity 8 is as follows:

Lecturer's activities	Students' activities
Ask experimental groups to appoint student representatives to present experimental results and discuss.	Representatives of student groups present experimental results and discuss (**Figure 5)**.

Figure 5. Disinfectant solution supplemented with pure cajeput essential oil prepared by students

Activity 9. Experimental Groups comment and evaluate peer results

Activity 9 aims to develop students' competencies: 7, 8, 9. The procedure for activity 9 is as follows:

Lecturer's activities	Students' activities
Guide groups of students to discuss and evaluate others' results (if any).	The groups appoint student representatives to review the results of the other groups (if any).

Activity 10. Summary of experimental results and discussion

Activity 10 aims to develop students' competencies: *7, 8, 9.* The procedure for activity 10 is as follows:

Lecturer's activities	Students' activities
Ask students to summarize the experimental results and discuss (if any adjustments are made).	Summarise discussion results and experimental results (if any adjustments are made).

Activity 11. Cleaning equipment, tools, laboratory

Activity 11 aims to develop students' competencies: 4, 6. The procedure for activity 11 is as follows:

Lecturer's activities	Students' activities
Ask students to clean equipment, tools, laboratories, etc.	- Cleaning equipment. - Cleaning tools. - Laboratory cleaning, etc.

Activity 12. Completing the experimental report

Activity 12 aims to develop students' competencies: 1, 2, 3, 5. The procedure for activity 12 is as follows:

Lecturer's activities	Students' activities
Guide students to complete the experimental report.	Complete the lab report and return it to the instructor.

Activity 13. Self-assessment and peer assessment

Activity 13 aims to develop students' competencies: 4, 8. The procedure for activity 13 is as follows:

Lecturer's activities	Students' activities
Guide students to complete self-assessment and peer assessment (student - student).	Students conduct self-assessment and peer assessment (student - student).

Activity 14. Lecturers evaluate students

Activity 14 aims to develop students' competencies: 8. The procedure for activity 14 is as follows:

Lecturer activity	Student Activity
Lecturers organize student assessments.	Students answer some questions from the lecturer (if any).

3.2. Assessment of activities to develop chemical experimental competence for students in chemistry pedagogy according to CDIO approach

The assessment criteria, including students' quality and competence, are summarized in Table 1:

Table 1. Summary of assessment criteria, forms and tools for practical competences development activities for students in chemistry pedagogy according to CDIO approach

#	Criteria	Assessment form	Assessment tool	Guiding questions and implementation tasks	Applicable activities
1	Quality	Asking and answering, Observation	Questionnaire	Are students on time?	Activities 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
				Are students hard-working and serious in the learning process?	
				Are students persistent and skillful during the experiment?	
				Are students honest in the learning process?	
				Do learners self-assess their learning process objectively?	Activities 9, 13
				Do learners evaluate learners objectively?	

2	Self-study ability and self-control	Note-taking, observation, asking and answering	Learning products	Drawing a diagram of the steam distillation system.	Activity 5
				Pure cajeput essential oil.	Activity 7
				Antiseptic solution supplemented with pure cajeput essential oil.	
				Experiment report.	Activity 12
			Checklist	Prepare specimens and equipment to meet the requirements of the test: a) Yes; b) No	Activities 1, 4
				State the requirements and purposes of the experiment: a) Yes; b) No	Activity 1
				State the experimental hypothesis: a) Yes; b) No	Activity 1
				Design the experimental steps: a) Yes; b) No	Activity 1
			Rubric	Prepare equipment, tools, and specimens: a) Level 1: Prepare equipment, tools, and specimens, but are still insufficient.. b) Level 2: Prepare enough equipment, tools, and specimens for the experiment. c) Level 3: Prepare sufficient equipment, tools, and specimens, arranged in an order that is easy to find.	Activity 4
				Characteristics of the melaleuca sample: a) The melaleuca sample is difficult to find. b) The melaleuca sample is expensive. c) The sample of melaleuca is cheap, easy to buy and easy to find.	Activity 5
			Descriptive rating scale	The extent to which students adhere to the rules, safety rules and techniques of conducting experiments: a) Never; b) Rarely; c) Occasionally; d) Regularly; d) Very often.	Activities 3, 4, 5, 6, 7, 8, 9, 10, 11

3	Competence to communicate and cooperate	Observation, asking and answering	Rubric	Forming an experiment group: a) Level 1: The establishment of experiment groups is not rational in terms of group member number, gender, and proficiency. a) Level 2: Establishing an experiment group that is rational in group member number but not in terms of gender and learner proficiency. b) Level 3: Forming a practice group that is reasonable in terms of group member number, gender, and proficiency.	Activity 3
				Organizing group activities: a) Level 1: The group has elected a group leader and secretary but has not yet assigned specific tasks to the group members, and has not yet regulated the group's activities. b) Level 2: The group has elected its leader and secretary; assigned specific work to group members, but there is no regulation on group activities. c) Level 3: The group has elected its leader and secretary; assigned specific work to team members; Established rules for group activities.	Activity 3
			Descriptive rating scale	Level of teacher-student communication: a) Never; b) Rarely; c) Occasionally; d) Regularly; e) Very often.	Activities 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
				The extent to which students participate in commenting and evaluating the results of other groups: a) Never; b) Rarely; c) Occasionally; d) Regularly; e) Very often.	Activities 9, 13
4	Problem solving competence and creativity	Note-taking, observation	Checklist	Proficiently perform the experimental operations: a) Yes; b) No	Activity 7
				Record the full experimental process: a) Yes; b) No	Activities 7, 8, 9, 10, 12

		Explain the experimental results clearly: a) Yes; b) No	Activities 7, 8, 9, 10, 12
		Draw the correct conclusion: a) Yes; b) No	Activities 7, 8, 9, 10, 12
	Rubric	Coordinating experiments with teaching methods effectively: a) Level 1: Using a combination of experiments with active but less effective teaching methods. b) Level 2: Using a combination of experiments with active teaching methods which are quite effective. c) Level 3: Using a combination of proficiency in experiments with active teaching methods which are very effective.	Activity 5
		Handling situations and guiding learners to do experiments: a) Level 1: Handling situations when using experiments in teaching with little effect, guiding learners to do experiments. b) Level 2: Handling situations when using experiments in teaching quite effectively, guiding learners to do experiments. c) Level 3: Handling situations when using experiments in teaching very effectively, guiding learners to be creative in how to conduct experiments.	Activities 5, 7
		Developing hands-on experimental skills: a) Level 1: Choosing chemicals, supplies, tools and instruments suitable for the experiment to be conducted and laboratory conditions, but sometimes wrong. b) Level 2: Apply knowledge and practical skills learned to assemble experimental equipment and conduct experiments to meet requirements. c) Level 3: Capable of making and creating appropriate test kits for experimental practice.	Activity 7

5	Competence to apply learned knowledge and skills	Note taking, observation, asking and answering	Rubric	Applying theoretical knowledge, to conduct experiments: a) Applying theoretical knowledge, conducting experiments but sometimes inappropriately. b) Applying theoretical knowledge, conducting experiments competently, experimental phenomena are clear and easy to observe but have not been able to guide others to perform corresponding operations. c) Apply theoretical knowledge, conduct experiments competently, experimental phenomena are clear and easy to observe; instruct other students to perform corresponding operations.	Activity 7
			Rubric	Applying theoretical knowledge, to describe experimental phenomena: a) Applying theoretical knowledge, describing experimental phenomena in a lengthy and difficult way to understand. b) Apply theoretical knowledge, describe experimental phenomena clearly. c) Apply theoretical knowledge, describe experimental phenomena briefly, logically and attractively.	Activity 8

4. RESULTS AND DISCUSSION

In the school year 2023 - 2024, we organized an experiment for the third-year chemistry pedagogy students of Vinh University - Vietnam. The experimental process was conducted on the experimental group (EG, 36 students) and the control group (CG, 35 students). At the beginning, the samples were subjected to an input test (Table 2) and some statistical results were obtained (Table 3), the results being plotted as a cumulative curve (Figure 6).

Table 2. Pre-experiment test

x_i	Number of students scoring x_i		% number of students scoring x_i		% number of students who scored x_i or less	
	EG	CG	EG	CG	EG	CG
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	1	0	2.5	0	2.5
4	2	2	5	5	5	7.5
5	6	8	15	20	20	27.5
6	11	10	27.5	25	47.5	52.5

7	9	11	22.5	27.5	70	80
8	5	4	12.5	10	82.5	90
9	5	3	12.5	7.5	95	97.5
10	2	1	5	2.5	100	100

Table 3. Some statistical data when analyzing pre-experiment test

Data analysis	**Quantity**	**EG**	**CG**
Data description	Average value	6.35	6.5
	Median	6	6
	Mode	5	7
	Standard deviation	1.37	1.41
Data comparison	Value p	0.70	
	Efficiency scale ES	0.08	

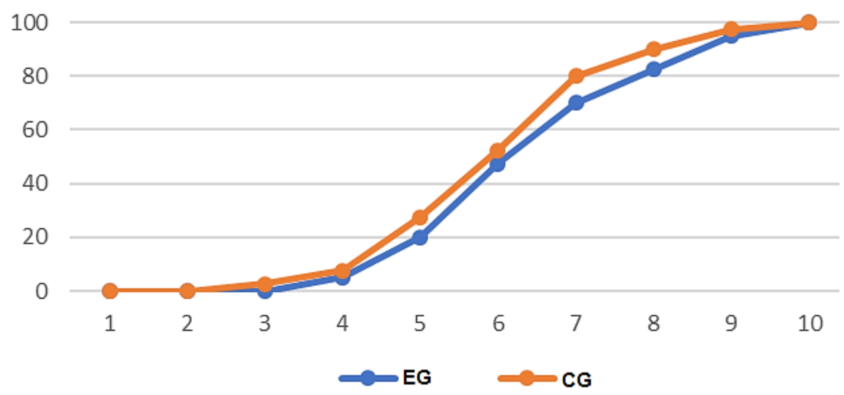


Figure 6. Pre-experiment test accumulation curve

The results can be interpreted as follows:

- The results of data processing before the experiment shows that the p value > 0.05, the ES influence level is 0.08, which means that the influence is very small.

- The mean score difference before the experiment is 0.15, the difference is not much. The two experimental and control groups were equivalent.

After confirming that the two groups are equivalent, we proceed to implement the intervention on the experimental group by organizing teaching activities (from activity 1 to activity 14). Following the treatment, we conducted the post-test on two experimental and control groups, the results were analyzed through Table 4, Table 5 and Figure 7.

Table 4. Post-experiment test results

x_i	**Number of students scoring x_i**		**% number of students scoring x_i**		**% number of students who scored x_i or less**	
	EG	**CG**	**EG**	**CG**	**EG**	**CG**
1	0	0	0	0	0	0

2	0	0	0	0	0	0
3	0	1	0	2.5	0	2.5
4	2	4	5	10	5	12.5
5	3	7	7.5	17.5	12.5	30
6	6	9	15	22.5	27.5	52.5
7	9	10	22.5	25	50	77.5
8	11	5	27.5	12.5	77.5	90
9	6	3	15	7.5	92.5	97.5
10	3	1	7.5	2.5	100	100

Table 5. Some statistical data when analyzing post-experimental test

Data analysis	Quantity	EG	CG
Data description	Average value	7.43	6.46
	Median	8	6
	Mode	8	7
	Standard deviation	1.41	1.52
Data comparison	Value p	0.0069	
	Efficiency scale ES	0.58	

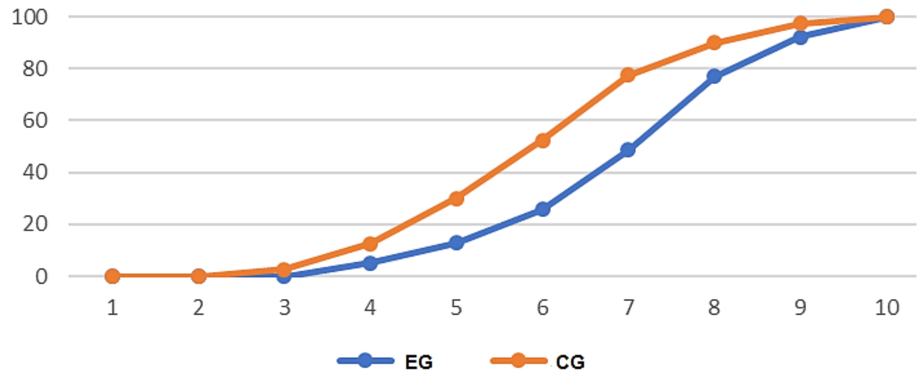


Figure 7. Post-experiment test cumulative curve

The results can be interpreted as follows:

- The mean score of the experimental group is higher than that of the control group, the standard deviation of the experimental group is lower than that of the control group, showing that the dispersion around the mean value of the experimental group's score is smaller than that of the control group.

- The cumulative line graph (Figure 7) shows that the experimental group is on the lower right and the control group is on the upper left, showing that the learning quality of the experimental group is higher than that of the control group.

- In Table 5, the p value between the experimental group and the control group is less than 0.05, which means that the test results are not random, but because the impact of teaching activities according to the CDIO approach has positively affected the scores of experimental group students.

5. CONCLUSION

From the above analysis results, it can be seen that the activities for chemical pedagogical students to study and experiment extracting Melaleuca essential oil from Melaleuca leaves according to the CDIO approach have had certain positive impact in developing experimental skills of chemical pedagogical students. As a result, students have certain practical professional skills, so that when they graduate from the University of Education, they can teach chemistry well in high schools.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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