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Research Article

Analyzing the Implementation of Practicum Organic Compound Separation and Purification in the Chemistry Education Study Program

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Abstract.
Students acquire various skills in the laboratory through scientific development practices such as demonstrations and experiments. The primary objective of this study is to gather empirical data regarding the implementation of organic compound separation and purification techniques at tertiary educational institutions to examine their efficacy as a proactive step to facilitate ongoing educational endeavors. The elements discussed include the practicum topics completed, the organic chemistry instruments and equipment possessed, how the practicum is conducted, and the problems and their resolutions. This study's respondents included course instructors, chemistry lab assistants, and students previously attending practicum content. This study used a qualitative research methodology to analyze multiple chemistry education study programs across various locations in Indonesia. Data collecting methods include open-closed surveys, observation, and documentation. The findings indicated that the separation and purification practicum topic incorporates concepts related to separation and purification, employing extraction, chromatography, distillation, sublimation, and recrystallization techniques. Some chemistry education programs needed adequate instrumentation for organic chemistry. In addition, the wet laboratory practicum for separating and purifying the studied organic compounds are yet to be completed as per the planned topics. Green chemistry and project-based learning have been largely implemented in the practicum, but the micro-scale concept, which can help reduce practicum waste, are yet to be implemented. Inadequate tools and materials for the practicum, as well as inadequate reference materials, are some of the obstacles that hinder the practicum's efficiency. Hence, there is a want for pragmatic instruments that can effectively cater to the demands of ongoing education. This practicum set should facilitate using green chemistry and micro-scale, focusing on minimizing pollution that can harm the environment.

Keywords: practicum organic, compound separation, purification, chemistry education

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1. INTRODUCTION

A different approach to obtaining abstract theories in science, especially chemistry, is through practicum [1]. Usually, the practicum is completed in the laboratory. Students develop their experimental knowledge and skills in the laboratory [2]. To optimize the chemistry learning process, laboratories at the tertiary level must be properly managed and have complete equipment and supplies. In addition, the laboratory at the college level should be a model for teaching students about environmental and occupational safety experiments. This shows that practicum can be more environmentally friendly, cost-effective, and attractive to students [3, 4]. However, the situation on the ground was not as smooth as expected.

Organic chemistry is a discipline within scientific inquiry that focuses on the comprehensive examination of chemical phenomena about the structure, characteristics, alterations, composition, reactions, and synthesis of various compounds [5]. The significance of organic chemistry concerning human existence lies in its involvement in producing several essential commodities utilized in everyday life. These commodities encompass a wide range of products, such as fuel sources, polymers, materials, food items, cosmetics, and numerous more, all of which prominently feature organic molecules [6]. Compound organic molecules serve as the fundamental building blocks of life on Earth and are the predominant constituents within the realm of chemistry. However, a significant aspect of complex chemical compounds is their inherent state of purity.

One of the educational settings in which organic chemistry is studied is through practical laboratory activities in chemical separation [7]. The separation and purification of a certain molecule hold significant importance in its practical utilization within everyday contexts [5]. The separation and purification of organic compounds can be achieved through diverse approaches. The choice of method is contingent upon the composition of the phase component composer substance, as each organic compound necessitates a specific solvent throughout the synthesis process. Therefore, it can separate itself from neighboring compounds [8].

The majority of organic chemistry experiments are conducted in laboratory settings, involving the utilization of scientific procedures. The successful execution of laboratory chemistry practicum is contingent upon sufficient equipment and materials. Implementing the practicum will likely yield favorable outcomes when the necessary tools and materials are readily available [9]. Efficient execution of practicum is essential, whereas effective administration is vital for conducting laboratory chemistry experiments. Practice is an educational endeavor to reinforce acquiring knowledge and skills about a certain subject matter [10]. The achievement of learning objectives in a comprehensive system maintenance practicum unit can be facilitated by effectively implementing independent activities, guidance, and the best exploitation of practice facilities and infrastructure [11].

Practicum activities can have an impact on student academic achievement in chemistry. This is because participating in activities allows students to see chemical phenomena or processes firsthand, which helps them build and improve their scientific thinking skills. In addition, being involved in practicum fosters the cultivation of a scientific mindset among students. Students are invited to participate to facilitate understanding of concepts and increase knowledge retention, serving as a valuable educational tool. To improve process skills and cultivate a scientific mentality, it is very important to engage in systematic development [12].

A laboratory serves as a designated space where students can engage in practical activities such as demonstrations, experiments, and applying theoretical information [1]. Nevertheless, the level of danger or safety in a work-in-progress practicum defines the ongoing activity in said practicum. The laboratory is a source of waste generated by material chemistry, including spillage and residue from unused initial forms, as well as new substances resulting from reactions with other chemicals and the cleaning of laboratory equipment during practical experiments [13]. The quantity and composition of chemical substances utilized in materials might vary, leading to varying amounts and types of chemical waste being released into the environment.

The principle of green chemistry can be observed in the context of learning chemistry, particularly in practical laboratory activities [14]. Green chemistry within laboratory practicum can be a highly effective conceptual framework and approach for reducing or substituting substances. The utilization of chemistry in reaction chemistry or synthesis poses inherent risks, as both the process and the resulting waste compounds can be highly hazardous to the environment [15]. The laboratory activity incorporates the principles of green chemistry, aiming to mitigate, eliminate, or substitute hazardous and toxic chemical components used in experiments. In order to mitigate the prevalence of contaminants and minimize the volume of waste [14].

Using chemical techniques and methodologies that reduce or eliminate the use of raw materials, products, by-products, solvents, reagents, and other substances harmful to the environment or human health is the simplest definition of green chemistry [16]. In other words, green chemistry can include laboratory-based micro-scale chemistry. Micro-scale techniques are an advantageous solution for chemical waste generation and subsequent disposal, leading to green chemistry that is more environmentally friendly [17]. For experiments in chemistry teaching laboratories, micro-scale techniques have been suggested because they can show several advantages, such as reducing the amount of substance (strengthening safety for human health and the environment), reaction time (minimizing the exposure of the practitioner to hazardous substances), and the amount of waste (minimizing the impact on the environment) [17–19]. The quantities of chemicals used in this micro scale method are relatively modest, ranging between 50 and 1000 mg (0.05 to 1.00 g), and the beaker is designed to hold less than 25 mL of liquid [20]. However, this simple equipment does not always carry micro-scale practicum [21]

The utilization of green chemistry at a micro-scale has the potential to create an optimal learning environment for gaining profound insights into the field of chemistry. The effective design of college-level chemistry education should incorporate sound learning theories and practical laboratory experiences that integrate the principles of green chemistry [22]. The principles of green chemistry in the context of space can be extended to encompass the attitudes and actions of individuals in order to mitigate potential environmental issues, as facilitated by green education [23]. As aspiring students, educators specializing in chemistry teaching must possess a comprehensive understanding, discernment, and proficiency in utilizing green chemistry concepts. Additionally, they should be capable of examining and evaluating the sustainability of educational practices through implementing micro-scale laboratory experiments.

2. research and MEthod

This research is a qualitative case study research. The research methodology used in this study includes documentation studies, observations, and semi-open questionnaires as a tool. The process of collecting research data includes several steps: 1) analyzing what topics are carried out in the separation and purification practicum of organic compounds, 2) evaluating the available organic chemical instrumentation equipment, and 3) how to implement the practicum of separating and purifying organic compounds based on chemical principles Green and project-based. The investigation started with a comprehensive literature review of advanced practical manuals for separating and purifying organic substances. In addition, laboratory observations were facilitated by assistants in the organic chemistry laboratory, followed by giving semi-open questionnaires to lecturers and students for further assistance. The study was conducted in various chemistry education programs in various locations in Indonesia. The research investigation deals with the practical applications of purification and refining of organic molecules. This topic is commonly explored in various chemistry courses through laboratory exercises which may differ in nomenclature.

3. RESULT AND DISCUSSION

In order to commence the research process, it is imperative to develop a comprehensive learning plan encompassing semester courses and relevant literature. Additionally, adjusting the practicum and refining the organic materials employed to enhance their quality is necessary. The present study conducted a documentation analysis of three chemistry education study programs in Indonesia. The primary objective was to examine the inclusion of practical themes about the purification and refining of organic compounds across different courses within these programs. This documentation study aims to analyze the underlying concepts encompassed within practical themes while also examining the interplay between micro-scale techniques and the principles of green chemistry. This study examines the fundamental elements of green chemistry. There are two primary concerns in this context: firstly, the challenge of optimizing the utilization of raw materials while avoiding waste, and secondly, the issues associated with the production, utilization, disposal, or reutilization of chemicals [17, 24]. Furthermore, micro-scale components are utilized. There are two key aspects to consider in this discussion: garbage disposal and its economic implications [17, 20]. Table 1 presents a comprehensive overview of a practical subject analysis focused on purifying and refining organic molecules. Additionally, the incorporation of green and micro-scale chemical principles is encompassed under this framework.

Based on the evaluations of the three Chemistry Education study programs, it was determined that each scheduled practicum was executed in adherence to the standards outlined in their respective practicum guidelines. However, practicum implementation varies throughout the three study programs, contingent upon factors such as preparedness, available resources, and the availability of practicum tools within each program. Study programs B and C have conducted practical exercises involving the purification and refinement of organic substances within a wet laboratory setting. This course involves a practical component in an organic chemistry laboratory setting. In contrast, Study Program A implements virtual learning to do practicum, providing students with practicum films. Study program A provided a rationale for its unpreparedness in the post-pandemic context, citing two primary factors: insufficient laboratory equipment and an absence of a practicum schedule. This inadequacy stems from the program's reliance on a common laboratory facility utilized by other science study programs within the University.

Analyzing the practicum documents from each learning program under investigation reveals the utilization of many concepts in the context of purification and refining practicum. As mentioned, the notions encompass embellishment and refinement practices by extraction, chromatography, distillation, sublimation, and re-crystallization practices.

One crucial component contributing to the successful execution of practicum activities is the availability of well-equipped laboratory facilities [1]. This includes providing complete and functional instruments and materials, particularly in practicum sessions focused on separating and purifying organic molecules. The successful completion of this practicum necessitates the availability of appropriate facilities, specifically instrumentation equipment that can support the comprehensive analysis and characterization of the organic compounds under investigation. Commonly employed techniques for the analysis and characterization of organic molecules encompass UV-Vis spectroscopy, atomic absorption spectroscopy (AAS), Fourier-transform infrared spectroscopy (FT-IR), and gas chromatography-mass spectrometry (GC-MS). This study aims to gather data regarding the four instrumentation tools and tool sets utilized in the separation and purification practicum within the three chemical education study programs under investigation in this research trial (as shown in Table 2).

The findings indicated that study program A needs more essential laboratory tools for organic chemistry, including reflux sets, simple distillation apparatus, fractional distillation equipment, and vacuum evaporation devices. This is one of the reasons why the practicum of separation and purification is carried out virtually in study program A, which is given to students via video. Separation and purification with simple tools have also become an alternative.

Furthermore, study program B has functional sets of reflux, distillation, and vacuum evaporation equipment. Nevertheless, the instructor of the separation and purification course under study program B asserted that despite the absence of fractional distillation apparatus, practical activities proceeded without interruption due to the diligent preparation of the practical instruction team, which ensured an adequate supply of equipment for basic distillation. Furthermore, the lecturer explained that the separation and purification practicum had been conducted sequentially as a viable solution to address the scarcity of available practicum equipment. The findings of study program C indicate that the instruments above, namely reflux set, simple distillation, fractional

Table 1: Numerous topics are available for practicum the separation and purification of organic compounds within various chemistry education study programs.

Research Subjects	Practicum Topics Planned in the Handbook	Learned Concepts, Integration of Green Chemistry and Micro-Scale Principles
Study Program A	Determination of Distribution Coefficient Determination of Anionic Surfactants by Extraction-Spectrophotometry Cation and Anion Exchange Resin Paper chromatography Thin layer chromatography	Extraction (liquid-liquid); the chosen solvent is non-flammable and non-toxic (applying the principles of Green Chemistry); use of a sample of more than 25 mL (not yet applying the principle of micro scale) Extraction; use of samples utilizing waste (applying the principle of green chemistry); use of less than 25 mL of solvent (applying the micro-scale principle) ion exchange chromatography; use of samples that utilize waste (applying the principle of green chemistry); use of a sample of more than 25 mL (not yet applying the principle of microscopy) Paper chromatography; samples derived from plants (the principle of green chemistry); use of samples exceeding 25 mL (not yet applying micro scale principles) Thin layer chromatography (TLC); use of samples originating from the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale)
Study Program B	Re-crystallization and Melting Point Determination Chloroform Synthesis Amyl Acetate Synthesis Synthesis of Phenyl Benzoate Synthesis of Benzyl Anilinia Identification of Organic Compounds	Re-crystallization; use of samples originating from the environment (applying the principle of green chemistry); use of samples of more than 1 gram (not yet applying the principle of micro scale) Simple distillation; use of samples that are relatively safe for the environment (applying the principle of green chemistry); the number of samples used was not detected Reflux and distillation; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); the number of samples used was not detected Distillation; use of relatively safe samples for the environment (applying green chemistry); the number of samples used was not detected Distillation and re-crystallization; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale) Identification/characterization of compounds by spectroscopy and chemical reactions; use of relatively safe samples for the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale)
Program Studi C	Distillation Benzoic Acid Re-crystallization Sublimation Chromatography Determination of Optical Rotation Concentration of Fructose Solution Elemental Qualitative Test	Simple distillation and fractionation; use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of samples exceeding 25 mL (not yet applying micro scale principles) Re-crystallization; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale) Sublimation; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale) Paper chromatography and thin layer chromatography; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale) Optical rotation of organic compounds; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of a sample of more than 25 mL (not yet applying the principle of micro scale) Element identification; the use of samples that are relatively safe for the environment (applying the principle of green chemistry); use of sample less than 25 mL (applying the principle of micro scale)

Table 2: Laboratory facilities for the separation and purification of organic compounds practicum.

Research Subjetcs	Available Instrumentation Tools	Current Conditions	Reflux Tool Set	Simple Distillation Tool Set	Fractional Distillation Tool Set	Vacuum Evaporator Tool Set
Study Program A	UV-Vis AAS	Optimally functioning	Do not have; condition: -	Do not have; condition: -	Do not have; condition: -	Do not have; condition: -
Study Program B	UV-Vis FT-IR	Optimally functioning	Have; optimally functioning	Have; optimally functioning	Don't have; condition: -	Have; optimally functioning
Study Program C	GC-MS FT-IR UV-Vis AAS	Optimally functioning	Have; optimally functioning	Have; optimally functioning	Have; optimally functioning	Have; optimally functioning

distillation, and vacuum evaporation, are possessed by the program and are in satisfactory condition. The separation and purification practicum within the study program has been conducted using sufficient resources and equipment.

In addition to possessing the requisite resources for facilitating the educational process, the laboratory must possess sufficient proficiency in utilizing the tools at its disposal. Using inappropriate tools and materials might impede the learning process and result in graduates failing to reach anticipated standards [25]. Hence, all three examined chemistry education study programs concur that, when conducting laboratory practicum, it is imperative to engage students as practicum assistants and enlist the participation of assisting lecturers. The responsibilities of practicum assistants encompass laboratory management, provision of instruments and materials, performing routine checks, and handling and storing chemicals [26–28].

Furthermore, an assessment is conducted on each practicum of separation and purification. This data investigation aims to assess the extent to which separation and purification techniques are implemented per the principles of green chemistry and micro-scale approaches. Based on the findings derived from the analysis of the semi-open-ended questionnaire, it has been determined by the supervisor that the laboratory associated with study program A currently lacks a designated receptacle for the disposal of chemical waste after the commencement of practical sessions. In contrast, the laboratory associated with study program B has demonstrated heightened attentiveness toward waste management matters. This is evident by their provision of multiple sizable containers, specifically jerricans, designated for storing acidic and alkaline waste materials within their organic laboratory setting. Furthermore, both study programs have indicated that they have yet to conduct a separation and purification laboratory exercise utilizing a micro-scale methodology. Nevertheless, a thorough examination of the documents reveals that certain practicum in their proposed curriculum have employed a micro-scale methodology.

While still, not optimal, project-based learning methodologies have implemented separation and purification practicum in wet laboratories. This practicum will likely be conducted in a collaborative setting, wherein groups will explore fundamental inquiries about the topic matter under investigation. Beforehand, students were instructed to engage with the modules provided by the assisting lecturers, produce initial journals, participate in practicum, complete final journals, and ultimately generate a practicum report. The practicum supervisor additionally emphasized the importance of using environmentally sustainable tools and resources in future practicum, particularly for students at the tertiary level. Figure 1 presented in this study illustrates students' responses in various chemistry education study programs to the practicum involving separating and purifying organic molecules.

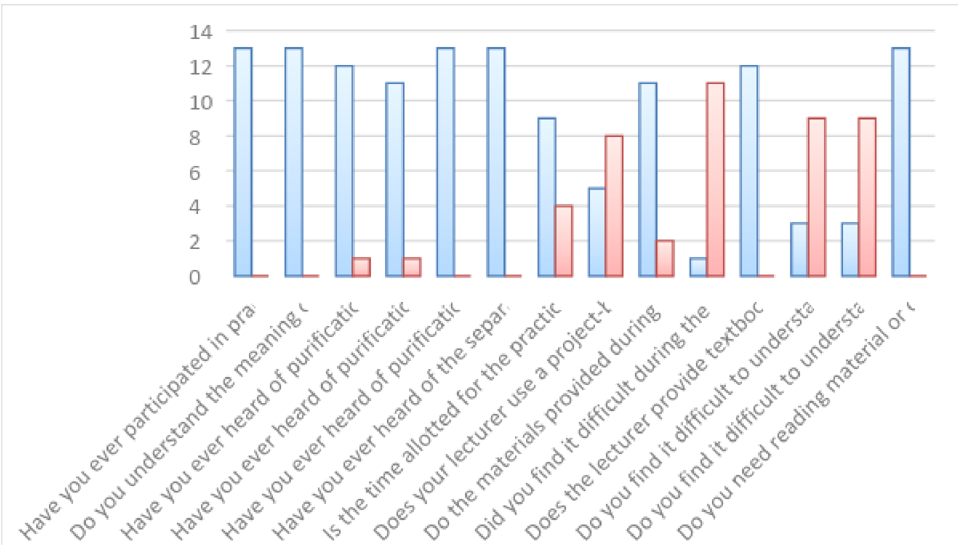

Figure 1: Students' response to the implementation of separation and purification of organic compounds practicum.

4. CONCLUSION

The present study examines the documentation, observations, and semi-open-ended questionnaires about three chemistry education study programs across various regions in Indonesia. The findings reveal that these programs' separation and purification practicum incorporates the principles of separation and purification by utilizing techniques such as extraction, chromatography, distillation, sublimation, and re-crystallization. Chemistry education study programs may need more organic chemistry instrumentation. Furthermore, the execution of wet lab experiments for separating and purifying organic compounds by the predetermined subjects has yet to be fully realized in the laboratory. In certain instances, virtual learning has been employed as a substitute for practical sessions. The examined separation and purification methodologies primarily employ the principles of Green Chemistry and project-based learning. However, they have yet to incorporate micro-scale concepts, which have the potential to mitigate waste generation during practical applications. One challenge that hinders the smooth execution of the practicum is the insufficiency of appropriate equipment, resources, and reference sources. Hence, it is imperative to utilize practicum resources, such as textbooks or practicum guidelines, that cater to ongoing education requirements by effectively incorporating the principles of green chemistry at a smaller scale, with a specific emphasis on mitigating harmful waste.

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