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Analysis of Undergraduate Students' Awareness of Chemical Laboratory Extraction Methods

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Abstract

Laboratory education is a key part of undergraduate chemistry programs, linking theoretical concepts with hands-on practice. In this practical context, separation science remains vital; in fact, extraction methods are crucial for various purposes, including pharmaceutical analysis and environmental surveillance. This study presents an academic and professional analysis of questionnaire data collected from undergraduate students regarding their awareness of chemical laboratory extraction methods. The analysis focuses on interpreting responses to each question, identifying potential correlations among students' understanding of different concepts, and supporting these interpretations with relevant academic references.

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INTRODUCTION

Laboratory education is widely recognized as a supporting component of the undergraduate chemistry curriculum, bridging theoretical knowledge and practical application (Harwood & Moody, 1989). Joining these two domains is a bridge, suggesting the crucial educational link that lets students to convert abstract concepts into hands-on skills. Floating higher up this entire structure is the "Helix of Knowledge", which represents learning is not as a linear path, however, as an evolving, cyclical process where the relationship between theory and practice shapes a deeper, more robust and high-level level of expertise.

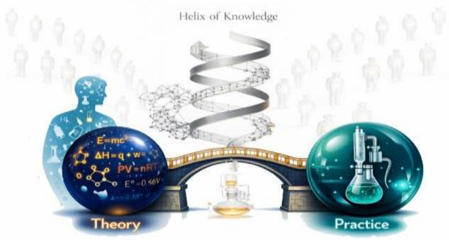

Figure 1. Represent synthesis of theoretical knowledge and practical application

Within this practical framework, separation science remains a crucial field; indeed, extraction techniques are essential across a range of applications, from pharmaceutical analysis to environmental monitoring (Pavia, et al., 2011). Mastering these techniques is essential for students to develop the problem-solving skills required in professional research and in industrial settings (Skoog, et al., 2014). Specifically, this entails the ability to distinguish between batch methods such as liquid-liquid extraction and continuous methods such as Soxhlet extraction These methods occupy a central position in standard syllabi; nevertheless, recent educational research suggests that students often perform laboratory procedures algorithmically, lacking a deep conceptual awareness of the underlying physicochemical principles (Christian, Dasgupta & Schug, 2014). For instance students may demonstrate proficiency in assembling a Soxhlet apparatus; however, their understanding of the solvent cycling mechanism or the specific advantages of this method over modern alternatives like ultrasonic-assisted extraction often remains superficial (McMurry, 2016). Assessing this awareness gap is crucial; such deficiencies directly influence a student's ability to select and optimize appropriate extraction methods in independent research. Awareness gap detected in undergraduate chemistry laboratory education, highlighting the difference among algorithmic performance and conceptual understanding. On one side, students are showed as successfully following experimental techniques and protocols, indicating procedural or algorithmic competence. On the other side, core theoretical elements for example molecular structures, thermodynamic relations, and reaction energetics are indicated, symbolizing deeper conceptual comprehension.

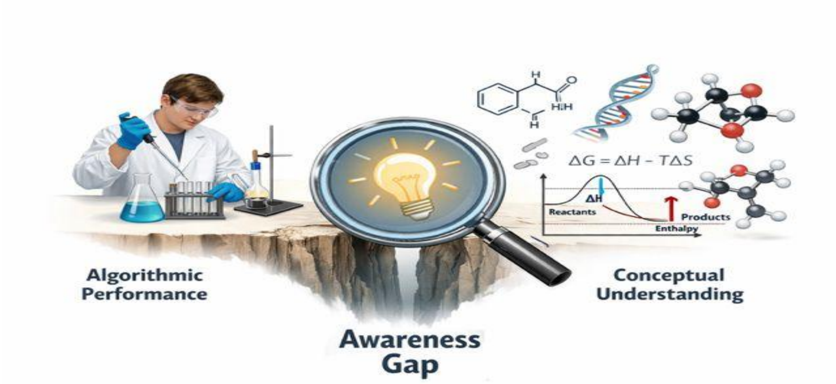

Figure 2. Awareness gap observed in undergraduate chemistry laboratory

This study presents an academic and professional analysis of questionnaire data collected from 43 third-year undergraduate students regarding their awareness of chemical laboratory extraction methods. By interpreting student responses to technical questions ranging from basic definitions to the operational mechanics of specific equipment such as the Soxhlet extractor, this research aims to identify correlations between theoretical instruction and practical understanding. Ultimately, the findings are intended to inform pedagogical strategies that enhance students' competency in essential chemical separation techniques.

METHODS

The data were obtained from a questionnaire administered to 43 third-year undergraduate students, focusing on various aspects of chemical extraction techniques. Figure 3 presents the major extraction techniques examined in this study, namely liquid–liquid extraction, Soxhlet extraction and ultrasonic-assisted extraction, which representing both conventional and modern approaches in separation science. These techniques were chosen due to their essential role in undergraduate laboratory courses and their general application in chemical analysis. By visually connecting the experimental methods with the student cohort.

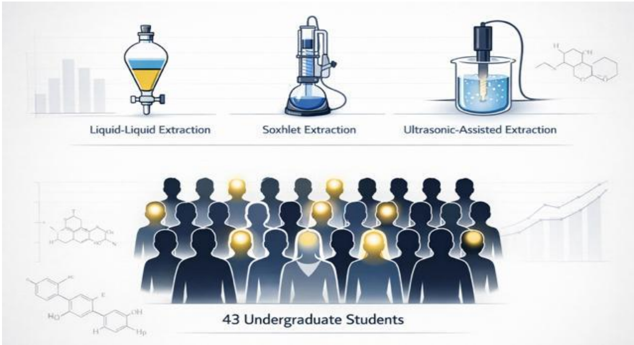

Figure 3. Presents the principal extraction techniques examined in this study.

RESULS AND DISCUSSION

With particular emphasis on Soxhlet extraction methods, this study investigates questionnaire data from 43 third-year undergraduate students on their understanding of extraction methods in chemical laboratory activities. The evaluation shows varying degrees of conceptual understanding across several facets of extraction techniques.

The students' responses to the first question, which was Student perception of Soxhlet extraction, are revealed in Table 1.

Table 1. Student responses to the question regarding the primary function of a Soxhlet extractor

Students' responses	Percentage (%)
is used for liquid-solid extractions when the compound to be extracted has limited solubility in the chosen solvent, and the impurities are insoluble	95.3
is used for solid-solid extractions.	0
is used for gas-liquid extraction	0
not all above	4.7

These data indicate a strong understanding among students of the primary application of a Soxhlet extractor. A significant majority (95.3%) correctly identified its use for liquid-solid extractions, particularly when the target compound has limited solubility and impurities are insoluble. This suggests that students grasp the fundamental principle of Soxhlet extraction, which involves continuous solvent cycling to efficiently extract sparingly soluble compounds from solid matrices (Harwood & Moody, 1989). The negligible responses for incorrect options further indicate a clear conceptual understanding of this specialized laboratory technique. This high level of awareness is crucial for students undertaking practical organic chemistry, where efficient separation techniques are paramount (Pavia, et al, 2011).

The second question was: What method is used for the separation of an organic compound from a mixture of compounds?

Table 2. Student responses identified extraction as the method for separating organic compounds from mixtures

Students' responses	Percentage (%)
Distillation	0
Extraction	100
Sieving	0
Boiling	0

Table 2 shows that all surveyed students (100%) understand that extraction is the method used to separate organic compounds from a mixture. This result is expected among third-year chemistry undergraduates, as extraction is a foundational separation technique taught early in organic chemistry curricula (Skoog, et al., 2014). The complete absence of responses for distillation, sieving, or boiling indicates that students clearly distinguish extraction from other separation methods based on their underlying principles and applications. This strong consensus suggests that the basic concept of extraction as a separation tool is well established in their knowledge base.

On the other hand, the third question was: Solvent extraction is based on the relative _____ of two liquids. The answers were displayed in Table 3.

Table 3. Student responses identified extraction as the method for separating organic compounds from mixtures

Students' responses	Percentage (%)
Distillation	0
Extraction	100
Sieving	0
Boiling	0

Table 3 shows that all students (100%) correctly identified that solvent extraction is based on the relative solubilities of two liquids. This indicates a strong understanding of the physicochemical principle underlying liquid-liquid extraction, which relies on the differential partitioning of a solute between two immiscible phases (Christian, Dasgupta & Schug, 2014). The complete rejection of irrelevant physical properties, such as odor, texture, or color, as the basis for solvent extraction underscores a solid grasp of the chemical principles involved. This fundamental understanding is critical for selecting appropriate solvents and designing effective laboratory extraction protocols.

These results indicate that all students understand that solvent extraction is based on the relative solubilities of two liquids. This strong positive correlation suggests a cohesive understanding of the fundamental concept of extraction: students not only know what extraction is used for (separation) but also why it works (differential solubility). This foundational knowledge is crucial for any further advanced study in chemical separations (Skoog, et al., 2014; Christian, Dasgupta & Schug, 2014).

The next question asked of the students was: Usually, one of the solvents used in solvent extraction is a(n) _____ solvent. The responses were summarized as follows:

Table 4. Student responses regarding the typical type of solvent used in solvent extraction

Students' responses	Percentage (%)
glue	0
viscous	0
inorganic	2.3
organic	97.7

Table 4 show that an overwhelming majority of students (97.7%) correctly identified that an organic solvent is typically used in solvent extraction. This reflects a practical understanding of the technique, as organic compounds are generally extracted into organic solvents due to the principle of 'like dissolves like' (McMurry, 2016). The small percentage of students who selected 'inorganic' might be considering aqueous solutions, which are often one of the two immiscible phases, but the question specifically asks about one of the solvents, implying the extracting solvent. This result suggests a good practical understanding of solvent selection in extraction processes.

Another related question was asked of the student: ---------- Is a continuous extraction procedure. The responses were displayed in Table 5 as follows.

Table 5. Student responses identifying continuous extraction procedures.

Students' responses	Percentage (%)
Soxhlet extraction	48.8
Maceration	0
Percolation	0
Infusion	48.8

While Table 1 shows a high level of understanding (95.3%) regarding the specific application of a Soxhlet extractor for liquid-solid extractions, Table 2 reveals a notable discrepancy. Only 48.8% of students correctly identified Soxhlet extraction as a continuous extraction procedure. This suggests that while students are aware of the purpose and output of a Soxhlet extractor, their understanding of its operational classification within extraction methodologies might be less robust. The term 'continuous extraction' might not be as clearly defined or emphasized in their curriculum as the Soxhlet apparatus's specific function. This gap indicates that while students can identify the equipment and its general use, the nuanced classification of extraction processes requires further reinforcement (Vogel, 1989; Ghasemi & Ghasemi, 2011)

On the other hand, the next question was about the nature of the solvent extraction analytical technique. The question was: Solvent extraction is a _______ analytical technique. The responses were shown in Table 6.

Table 6. Student responses classifying solvent extraction as an analytical technique

Students' responses	Percentage (%)
Separating	74.4
Qualitative	18.6
Quantitative	7
Identification	0

Table 6 shows that the majority of students (74.4%) correctly perceive solvent extraction primarily as a 'Separating' analytical technique. This aligns with its fundamental role in isolating target compounds from complex mixtures (Skoog, et al., 2014). However, a notable portion of students (18.6% and 7%) incorrectly classified it as 'Qualitative' or 'Quantitative', respectively. While extraction can be a preparatory step for both qualitative and quantitative analyses, it is not inherently either; rather, it is a separation method that precedes such analyses Christian, Dasgupta & Schug, 2014). This suggests that while students understand its function in isolation, they may struggle to classify it precisely within the broader spectrum of analytical chemistry techniques. This highlights a potential area for reinforcing the distinction between separation techniques and analytical methods that provide qualitative or quantitative information.

Next, the students were asked about the application of laboratory extraction. The authors wanted to determine whether students were aware of which of the selected materials they used during an extraction in the laboratory. The students' answers were displayed in Table 7.

Table 7. Student responses classifying solvent extraction as an analytical technique

Students' responses	Percentage (%)
Tea	100
Paper	0
Plant paper	0
Cacao	0

Table 7 shows a complete consensus (100%) among students that 'tea' is extracted in the laboratory. This likely refers to a common undergraduate experiment in which caffeine is extracted from tea leaves, serving as a practical introduction to liquid-liquid extraction (Williamson & Masters, 2017). The unanimous response indicates that this specific laboratory exercise is highly memorable and effectively conveys the practical application of extraction methods. This practical experience likely reinforces the theoretical concepts learned in lectures.

Students' responses to the question asked about the importance of the Soxhlet extractor, which are revealed in Table 8.

Table 8. Student responses classifying solvent extraction as an analytical technique.

Students' responses	Percentage (%)
green chemistry	32.6
photo chemistry	0
electrochemistry	0
biochemistry	67.4

Table 8 reveals that a majority of students (67.4%) associate the Soxhlet extractor with 'biochemistry', while a significant portion (32.6%) links it to 'green chemistry'. The association with biochemistry is plausible, as Soxhlet extraction is widely used in natural product chemistry and the extraction of biomolecules from plant or animal tissues (National Research Council, 2006). The connection to green chemistry is also relevant, as the continuous and efficient nature of Soxhlet extraction can reduce solvent consumption compared to other methods, aligning with principles of waste minimization (Sahu, 2018). However, the fact that 'biochemistry' received a higher percentage suggests that students primarily associate its application with biological samples rather than its broader implications for sustainable practices. This could indicate a need to emphasize the green chemistry aspects of traditional laboratory techniques.

The last question asked of the student was about the function of the Thimble in the Soxhlet Extractor. The data are presented in Table 9.

Table 9. Student responses classifying solvent extraction as an analytical technique

Students' responses	Percentage (%)
ensures that the rapid motion of the solvent does not transport any solid material to the still pot.	27.9
Put solvent in it	0
collected the extracted	69.8
not at the above	2.3

Table 9 shows that a majority of students (69.8%) believe the thimble 'collected the extracted' material, while a smaller but still substantial portion (27.9%) correctly identified its role in preventing solid material from being transported to the still pot. The thimble's primary function is to hold the solid sample and allow solvent to percolate through it, ensuring that only the dissolved extract flows back to the boiling flask and preventing contamination of the main solvent reservoir with solid particles (Vogel, 1989). The misconception that it 'collected the extracted' material suggests a misunderstanding of the continuous nature of the extraction process, where the extracted compound accumulates in the boiling flask, not the thimble. This indicates a lack of understanding of the detailed operational mechanism of the Soxhlet apparatus.

Table 8 indicates that students primarily associate the Soxhlet extractor with biochemistry (67.4%) and green chemistry (32.6%). However, Table 9 reveals a significant misunderstanding of the Soxhlet thimble's specific function, with only 27.9% correctly identifying its role in preventing the transport of solid material. This discrepancy suggests that while students understand the broader application areas or significance of the Soxhlet apparatus, their detailed understanding of its internal mechanics and the function of its components is weaker. A robust understanding of equipment mechanics is vital for effective and safe laboratory practice (Vogel, 1989; Chemat & Cravotto, 2013).

CONCLUSION

The questionnaire results indicate a generally strong foundational understanding among third-year undergraduate students of chemical extraction methods, particularly the basic principles of solvent extraction and the identification of common laboratory equipment, such as the Soxhlet extractor. However, there are specific areas, such as the classification of continuous extraction procedures and the detailed operational understanding of equipment components (e.g., the Soxhlet thimble), where student comprehension could be improved. Reinforcing these nuanced aspects through targeted instruction and practical demonstrations would further enhance their awareness and proficiency in chemical laboratory extraction methods.

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