



Cognitive abilities of students in the use of biology laboratory equipment: a study case at SMAN 1 Rasau Jaya, Kubu Raya District

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ARTICLE INFO	ABSTRACT
<p>Article history Received: 13 Februari 2025 Revised: 18 March 2025 Accepted: 25 March 2025</p> <p>Keywords: Cognitive Ability Knowledge Assessment Laboratory Practice Laboratory Equipment Proficiency Practical Experience</p>	<p>Laboratory activities enhance students' understanding of scientific concepts through hands-on experience and develop their scientific thinking. Proficiency in using key instruments like microscopes, pipettes, Bunsen burners, and thermometers is crucial for safe and successful experiments. This study at SMAN 1 Rasau Jaya aimed to assess students' understanding and proficiency in utilizing these six laboratory tools, with the goal of improving the quality of laboratory-based learning. The research employed a descriptive qualitative method to evaluate the cognitive abilities of 12th-grade students at SMA Negeri 1 Rasau Jaya in relation to the use of laboratory equipment, including microscopes, dropper pipettes, measuring cups, Bunsen burners, thermometers, and O'Haus balances. The sample consisted of a single study group with diverse student characteristics. Data were collected through a questionnaire consisting of yes/no questions designed to assess students' knowledge of proper tool usage. The questionnaire was completed manually within a limited time frame for each question. The findings showed that students generally had good to fairly good knowledge of laboratory equipment. Tools like microscopes, dropper pipettes, and Bunsen burners were better understood, while measuring cups, thermometers, and O'Haus balances required further instruction. The study emphasizes the importance of practical experience and familiarity with tools in developing proficiency. The study highlights the significant role of familiarity and practical experience in developing tool-use proficiency. These findings underscore the importance of achieving a balance between theoretical instruction, understanding of tool mechanisms, and hands-on laboratory practice.</p>

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INTRODUCTION

Laboratory activities help students to better understand material by experiencing experiments firsthand, facilitating their grasp of biological concepts and enabling simple research (Agustina, 2018). A key factor in successful biology practicums is students' proficiency with laboratory equipment. When learners use tools correctly and follow procedures, they not only become more skilled but also ensure safety and obtain accurate results. Laboratory work can be hazardous if students lack the knowledge of proper tool use (Adnyani et al., 2019). For instance, a test tube clamp should be used when heating substances to prevent splashing, and the tube's mouth must face away from people and chemicals (Hamidah et al., 2014).

Cognitive abilities, including problem-solving, decision-making, and intelligence, are crucial in practicum settings. Practical work fosters these skills by allowing learners to observe biological phenomena directly, enhancing their understanding and retention of concepts (Hasmiati et al., 2017). Knowledge of six essential tools—microscope, measuring cup, dropper pipette, Bunsen burner, thermometer, and O'Haus balance—is vital for science experiments, as these tools vary in function and complexity (Candra & Hidayati, 2020). Microscopes, pipettes, and Bunsen burners are more commonly used and easier to master, while measuring cups, thermometers, and balances require a deeper theoretical understanding for precise measurements.

Previous studies have shown that laboratory-based learning strengthens both conceptual understanding and cognitive abilities. For instance, Putri & Meilana (2023) found that experimental learning methods significantly enhance students' cognitive abilities in science learning. Similarly, Anjarsari et al. (2023) reported that hands-on practicum activities improve students' cognitive learning outcomes and science process skills. A solid understanding of lab safety, proper handling of equipment, calibration, and accurate measurement techniques is essential for conducting reliable experiments (Candra & Hidayati, 2020). These findings highlight the importance of practical experience in developing both procedural and cognitive competencies in science education.

However, several aspects remain underexplored. Most existing studies focus on the general benefits of laboratory practice or on individual tools in isolation, without thoroughly examining the direct relationship between students' proficiency with laboratory instruments—both procedural and conceptual—and their cognitive competence. For example, while studies like those by Mhlongo & Sedumedi (2023) explore the impact of teaching tools on knowledge representation, they do not specifically address the link between laboratory tool proficiency and cognitive skills. Moreover, most research has been conducted in well-resourced urban school settings. In contrast, schools in semi-rural areas like SMAN 1 Rasau Jaya may have adequate laboratory facilities, but the extent to which these tools are being effectively utilized to support students' cognitive development remains unclear. This represents a clear research gap that warrants further investigation. There is a lack of studies exploring this issue in rural or semi-rural school settings, where facilities may be sufficient but optimal utilization is uncertain.

This study aims to examine the relationship between students' proficiency in using laboratory equipment and their cognitive competence, with the specific goal of evaluating how well students apply scientific knowledge through practical tool use. Centered on SMAN 1 Rasau Jaya—a school with adequate laboratory infrastructure but located outside an urban area—this study seeks to assess whether available facilities are being effectively utilized to support meaningful and cognitively engaging learning experiences. In terms of novelty, this study adopts an integrated approach that not only measures students' practical skills in using laboratory tools but also evaluates their conceptual understanding of these instruments. Focusing on six core laboratory tools and examining their connection to students' cognitive performance, the study provides a new perspective in science education—particularly in semi-rural environments that are often overlooked in educational research. Evaluating the cognitive abilities of 12th-grade students in using key laboratory tools such as microscopes, pipettes, Bunsen burners, and others is beneficial for generating data to inform efforts toward improving biology education through more effective, skill-based practicum activities.

METHODS

Research Design

This research adopts a case study method using a descriptive qualitative approach to explore a phenomenon in depth, as described by Patnaik & Pandey (2019). Specifically, it examines students'

cognitive abilities related to the use of laboratory equipment, including microscopes, measuring cups, dropper pipettes, Bunsen burners, thermometers, and O'Haus balances. The study aims to provide a detailed understanding of the students' proficiency in using these tools.

Population and Samples

The research sample consisted of a single study group of 12th-grade students from SMA Negeri 1 Rasau Jaya, Kubu Raya Regency. The selection of this group was conducted using purposive sampling, a non-probability sampling technique chosen for its ability to intentionally select participants based on specific characteristics relevant to the research objectives. This group (rumble) was selected due to the diversity of the students' traits, particularly in terms of cognitive levels, to ensure that the sample would be representative of the broader student population in terms of cognitive variation and laboratory tool familiarity. This approach aimed to capture a range of perspectives and abilities within the group. The research sample consisted of a single group of 12th-grade students from SMAN 1 Rasau Jaya, located in Kubu Raya Regency. The total number of participants was 33 students, comprising 18 females and 15 males. All students in the selected class were taken as the sample to represent heterogeneity.

Instrument

Data collection was carried out through the administration of a questionnaire specifically designed to assess students' cognitive understanding of how to use various laboratory tools. Before being administered, the questionnaire was validated by two lecturers considered experts, using the Guttman scale (Yes/No). The aspects validated included clarity, content accuracy, relevance, and language appropriateness. The questionnaire was used only after both validators responded "Yes" to all items or confirmed that the criteria were met.

For each tool, the number of questions varied based on the specific information needed (Table 1). For instance, questions related to microscopes were divided into four categories: knowledge of microscope part names, how to carry and position the microscope, how to focus on an object, and how to use the objective lens magnification. Details for other tools are provided in Table 1.

Table 1

Questionnaire framework for assessing students' cognitive responses regarding the use of laboratory equipment

Tool	Knowledge Category	Number of Questions	Maximum Score
Microscope	1. Parts of the microscope	12	31
	2. How to carry and place it	8	
	3. How to obtain the focal point	7	
	4. How to use the objective lens	4	
Measuring cup	1. Parts of a measuring cylinder	4	10
	2. How to pour and read the results	6	
Dropper	1. Dropper part	3	11
	2. How to take the solution	4	
	3. How to dispense the solution	4	
Bunsen	1. Bunsen parts	2	10
	2. How to light and extinguish	4	
	3. How to heat with a test tube	4	
Thermometer	1. Parts of a thermometer	5	9
	2. How to use a thermometer	4	
O'Haus balance	1. Balance section	3	15
	2. How to clean	4	
	3. How to balance	4	
	4. How to set the result	4	

Data collection was conducted at the school, where students responded to a simple Yes or No format to ensure clear and straightforward answers. The questionnaire was administered manually on paper and completed within 25 minutes, with students spending 15-20 seconds on each question.

Procedure

The research procedures in this study were conducted in three sequential stages: preparation, data collection, and data analysis. The preparation stage encompassed the development of the research design, selection of the study site, formulation of a detailed timeline, identification of appropriate instruments, and the design of the data collection process. Additionally, formal approval was obtained from the selected school. During the data collection stage, research activities were carried out at the designated location, which included the administration of questionnaires, systematic recording of responses, and relevant documentation. In the final stage, data analysis was performed to interpret the findings in accordance with the stated research objectives. The results were subsequently examined in light of existing literature to provide a comprehensive understanding of the issues under investigation.

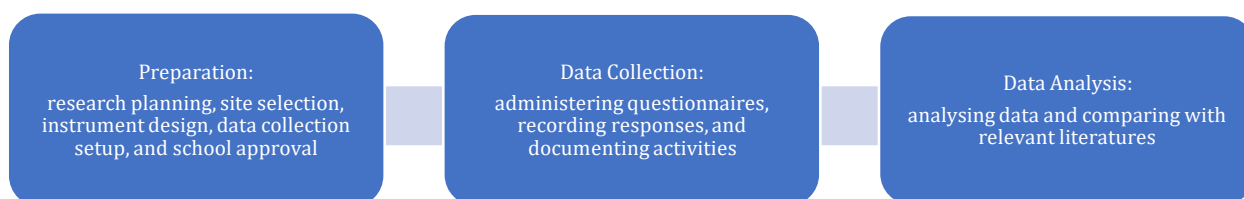


Figure 1. Research procedure comprising preparation, data collection, and analysis stages

Data Analysis

The results of the questionnaire were compiled for each tool and knowledge category. The calculation of the questionnaire results utilized the percentage formula (%) according to Sholikah & Pertiwi (2021). Students' knowledge within each category was classified into five levels, following Arikunto (2016) (Table 2).

Table 2

Categories of students' cognitive understanding of laboratorium equipment usage based on Arikunto (2016)

No	Range	Category
1	81%-100%	Excellent (E)
2	61%-80%	Good (G)
3	41%-60%	Fairly Good (FG)
4	21%-40%	Poor (P)
5	0%-20%	Very Poor (VP)

Next, the number of students in each cognitive understanding category was manually compared across different tools. The discussion focused on identifying tools where students demonstrated insufficient understanding that needs improvement, drawing insights from literature on similar previous studies.

RESULTS AND DISCUSSION

The questionnaire results for each category of students' knowledge are presented in percentage form (Table 3). Each category of knowledge has a varying percentage. In the microscope tool, there are four categories of knowledge. In mentioning the parts of the microscope, 58% of the subjects needed help to correctly mention the parts of the microscope. Only 18% and 3% of learners mastered the parts of the microscope with excellent and good categories. Regarding how to carry and place the microscope, 15% of learners were in the poor category. Most learners know how to carry and place the microscope well (61%) and very well (9%). For the category of knowledge on how to get the focal point, 73% and 21% of learners were in the excellent and good categories. No subjects were found in the poor categories regarding knowledge of how to get the focal point. Furthermore, most learners are in the excellent (52%) and good (30%) categories of knowledge about how to use an objective lens. Only students who were able to use an objective lens were found.

The results revealed distinct patterns in students' cognitive understanding across the six laboratory instruments evaluated. Students showed limited conceptual understanding of measuring cups, particularly in identifying their parts, with only a small percentage of students demonstrating

strong knowledge. However, procedural competence, such as the ability to pour and read measurements correctly, was relatively stronger, though not without deficiencies.

Table 3
Percentage per Knowledge Category

Tool	Knowledge Category	Knowledge Category (%)				
		E	G	FG	P	VP
Microscope	1. Parts of the microscope	18	3	12	9	58
	2. How to carry and place it	9	61	15	15	-
	3. How to obtain the focal point	73	21	6	-	-
	4. How to use the objective lens	52	30	12	6	-
Measuring cup	1. Parts of a measuring cylinder	6	9	37	33	15
	2. How to pour and read the results	30	49	18	3	-
Dropper	1. Dropper part	21	9	3	46	21
	2. How to take the solution	33	37	27	3	-
	3. How to dispense the solution	27	33	37	3	-
Bunsen	1. Bunsen parts	30	-	49	-	21
	2. How to light and extinguish	18	45	27	10	-
	3. How to heat with a test tube	45	30	21	-	3
Thermometer	1. Parts of a thermometer	3	-	-	9	88
	2. How to use a thermometer	52	27	18	3	-
O'Haus balance	1. Balance components	6	6	-	15	73
	2. How to clean	7	33	33	27	-
	3. How to balance	39	52	6	3	-
	4. How to set the result	18	46	21	15	-

Note: E = excellent; G = good; FG = fairly good; P = poor; VP = very poor

A similar trend emerged with dropper pipettes. Although many students struggled to accurately name the parts of the instrument, they performed better on procedural tasks such as drawing and releasing solutions. This suggests a greater emphasis on practical familiarity over conceptual clarity in their prior learning experiences (Restiana & Djukri, 2021). In contrast, students showed more balanced knowledge regarding the Bunsen burner. Most participants were able to correctly identify its parts and articulate the correct procedures for operation and extinguishing. Furthermore, a large proportion demonstrated a clear understanding of safe and proper heating techniques using test tubes, indicating a relatively high level of both conceptual and procedural proficiency with this tool.

For thermometers, the data revealed a significant discrepancy between theoretical and procedural knowledge. While a majority of students knew how to use the instrument appropriately, very few could accurately identify its parts. This gap reflects a broader pattern observed across multiple tools, where hands-on experience does not necessarily equate to comprehensive conceptual understanding (Bernhard, 2018). Findings related to the O'Haus balance reinforced this trend. Students generally exhibited strong practical skills in balancing and reading results, yet lacked understanding in areas such as identifying components and cleaning procedures. This pattern highlights the risk of functional proficiency developing in the absence of foundational knowledge.

Overall, students performed better with tools frequently used during school practicums—namely the microscope, dropper pipette, and Bunsen burner—placing their cognitive abilities in the “good” category. Conversely, instruments that demand greater conceptual precision, such as the measuring cup, thermometer, and O'Haus balance, were categorized as “fair.” Among all tools, the Bunsen burner demonstrated the most well-rounded and highest overall cognitive profile, suggesting more effective instructional delivery in that area. These findings point to the need for a more integrated approach in laboratory education that balances procedural training with deeper theoretical instruction.

The summary of students' basic knowledge in using laboratory tools—including microscopes, measuring cups, dropper pipettes, Bunsen burners, thermometers, and O'Haus balances—is presented in percentage form (Table 4). Cognitive abilities related to these six tools were categorized into two levels: *good* and *fair*. Students demonstrated good understanding in using microscopes, dropper pipettes, and Bunsen burners, while measuring cups, thermometers, and O'Haus balances fell into the fair category.

The recapitulation of the basic knowledge profile on the use of tools that include microscopes, measuring cups, drop pipettes, bunsen, thermometers, and O'Haus balance is presented in percentage form (Table 4). Cognitive abilities using six laboratory tools are in two categories, namely the good and pretty good categories. The good category used a microscope, dropper, and bunsen, while the fairly good category was found in measuring cups, thermometers, and O'Haus balance. Knowledge of the bunsen showed the highest percentage compared to the other five tools tested in this study although it was still in the good category. This finding reflects that students tend to understand better the tools that are often used in explicit and visual practicum activities, such as bunsen and microscope. This is supported by the findings of Ridwan et al. (2022) which show that the frequency of using laboratory equipment in practicum activities is positively correlated with the level of students' cognitive mastery of these tools. The more often a tool is used in the context of hands-on learning, the higher the level of students' conceptual and procedural understanding of the tool.

On the other hand, mastery of tools such as measuring cups, thermometers, and O'Haus balances that only fall into the "fairly good" category could be due to a lack of learning focus on the working principles and components of these tools. As stated in a study by Munawar & Jamil (2014), many teachers emphasize the procedures for using tools rather than understanding the components and working principles of the tools themselves. As a result, students only know how to use the tool in a limited context without really understanding its scientific function.

Table 4

Percentage Results of Cognitive Ability in the Use of Six Laboratory Tools at SMAN 1 Rasau Jaya

No	Laboratory Equipment	%	Knowledge Category
1.	Microscope	63	Good
2.	Measuring Cup	54	Fairly Good
3.	Dropper	63	Good
4.	Bunsen	67	Good
5.	Thermometer	45	Fairly Good
6.	O'Haus Balance	55	Fairly Good

Discussion

Students at SMA Negeri 1 Rasau Jaya demonstrated a good to fairly good understanding of the six laboratory tools analyzed. Microscopes, dropper pipettes, and Bunsen burners were well understood, whereas measuring cups, thermometers, and O'Haus balances showed only moderate comprehension. Familiarity played a crucial role in student proficiency, as frequently used tools such as dropper pipettes and Bunsen burners were more easily understood. This aligns with findings that frequent hands-on practice significantly enhances mastery of laboratory skills (Suryana et al., 2024).

Among the knowledge categories assessed, students exhibited a stronger understanding of tool usage compared to their knowledge of tool components. Practical skills tend to be more easily acquired through repeated experience in laboratory settings (Srianik, 2023). This pattern was particularly evident with microscopes, where students demonstrated competence in operational procedures but had limited knowledge of the individual components. Abdullah and Marvira (2014) observed a similar trend, noting that while students could effectively change objective lenses and maintain safe distances, their understanding of proper handling techniques remained weak. To address this, teachers should emphasize repeated instruction on correct microscope handling as part of laboratory safety protocols.

A comprehensive understanding of laboratory tools involves familiarity with their names, parts, functions, and proper usage techniques (Saputra & Kurniawati, 2021). Proper tool handling is essential for preventing accidents (Zuhra et al., 2021). For instance, understanding how to properly adjust a microscope's focus can prevent accidental damage to slides. In more severe cases, improper tool use can lead to health risks or equipment damage. Therefore, laboratory safety training and tool maintenance education should be integral to laboratory instruction (Haqi et al., 2019).

Despite students' relatively strong practical knowledge of microscopes, dropper pipettes, and Bunsen burners, their familiarity with the components of these tools remains limited. This may stem from a learning approach that prioritizes hands-on skill development over theoretical comprehension. Maknun (2015) suggested that students often focus on achieving experimental results rather than understanding the structural details of laboratory tools. To bridge this gap, educators should integrate

explanations of tool components alongside practical exercises.

Laboratory-based learning not only enhances technical skills but also fosters scientific thinking and problem-solving abilities (Hasmiati et al., 2017). However, students' cognitive understanding of tool components needs improvement. Research by Kurnianty and Nurita (2017) found that students often struggle with identifying microscope parts, emphasizing the need for educators to align teaching methods with student learning needs.

Introducing tool components in greater depth can significantly enhance students' operational proficiency. Padari, Muharini, and Hadi (2022) highlighted that a solid grasp of laboratory equipment functions contributes to successful practicum experiences. Students with prior knowledge of a tool's name, parts, and functions tend to perform laboratory tasks more efficiently and with greater confidence. Additionally, improved comprehension reduces errors and prevents accidents, reinforcing the importance of theoretical instruction alongside hands-on training.

Unlike the first three tools, students' knowledge of measuring cups, thermometers, and O'Haus balances fell into the moderate range. Kolil, Muthypalani, and Achuthan (2020) noted that difficulties in accurately measuring liquid volumes using a measuring cup stem from inadequate conceptual understanding and limited practice. Addressing this issue requires comprehensive introductory lessons and structured training sessions to develop students' proficiency (Eliyarti et al., 2020). Emphasizing practical exercises, such as precision dispensing techniques, can further improve accuracy and skill development (Adiningsih et al., 2019).

Among the three tools categorized as moderately understood, thermometer knowledge was the weakest, particularly in recognizing its components. This suggests the need for targeted instruction on thermometer structure and function. Despite this gap, over 75% of students demonstrated good to excellent proficiency in thermometer use, indicating a strong grasp of measurement techniques. These findings align with Dimyati, Triwidjaja, and Untari (2019), who reported that high school students generally understand thermometer operation but struggle with precise scale reading.

Similarly, students exhibited limited knowledge of O'Haus balance components, highlighting a need for improved instruction in this area. Few students achieved high proficiency in understanding the structure of the balance, likely due to insufficient hands-on exposure. In contrast, students displayed relatively strong competence in using and maintaining the balance, in line with findings from (Juvitasari, Melati, and Lestari (2019). Nurhayati (2022) emphasized that laboratory instruction should stress proper equipment maintenance, as well-maintained tools contribute to more accurate measurements. Additionally, integrating cleaning and calibration practices into laboratory routines can enhance students' awareness of experimental quality control (Jufriyah et al., 2019).

Regarding measurement interpretation, over 90% of students demonstrated proficiency in using the O'Haus balance, yet only 60% could accurately determine measurement results. This suggests that while students understand how to operate the tool, they struggle with data interpretation. The ability to analyze measurement results is critical for scientific learning (Artu, 2014; Khotimah et al., 2016). Similar findings by Putra, Ramlawati, and Rusli (2022) indicated that students could follow procedural steps but often failed to articulate calculations accurately.

Overall, students at SMA Negeri 1 Rasau Jaya demonstrated a good to fair understanding of the six laboratory tools analyzed. They exhibited strong operational knowledge of microscopes, dropper pipettes, and Bunsen burners, while their comprehension of measuring cups, thermometers, and O'Haus balances was moderate. These findings highlight the importance of balancing practical experience with theoretical instruction. A more integrated approach—incorporating structured theoretical explanations, targeted practice sessions, and laboratory safety training—can enhance students' laboratory proficiency (Iskandar et al., 2021). Strengthening students' understanding of laboratory equipment components and functions can enhance their analytical skills, reduce experimental errors, and improve accuracy in measurements and data interpretation. Additionally, increasing awareness of equipment maintenance and laboratory safety contributes to a safer learning environment. More broadly, these findings can drive improvements in curriculum design, teacher training, and the provision of better laboratory facilities, enabling students to develop stronger scientific competencies and better prepare for higher education or careers in science and technology.

This study revealed that students at SMA Negeri 1 Rasau Jaya demonstrated good to fair understanding of six laboratory tools, with stronger operational skills than conceptual knowledge. However, the study was limited to a single school, focused only on six tools, and relied on written tests

and observations without exploring students' reasoning through interviews or real-time monitoring. To build a more comprehensive understanding of students' laboratory competencies, future research should involve multiple schools, include a wider range of tools, and apply mixed methods that integrate both quantitative and qualitative approaches.

CONCLUSION

The study concludes that students at SMA Negeri 1 Rasau Jaya have a good to fair understanding of laboratory tools, with stronger proficiency in frequently used equipment but moderate comprehension of measuring tools. Their practical skills surpass their knowledge of tool components, highlighting the need for a balanced approach that integrates theoretical instruction with hands-on practice. Strengthening students' understanding of tool functions, safety, and maintenance can enhance analytical skills, reduce errors, and create a safer learning environment. These findings emphasize the need for improved curricula, teacher training, and laboratory facilities to better prepare students for scientific learning and careers.

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