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Needs Assessment for Interactive Digital SOP Development in Vocational Culinary Education

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Abstract

Background: Vocational education requires students to master practical and industry-relevant skills, particularly in laboratory-based fields such as culinary science and food technology. However, many Indonesian vocational programs still rely on instructor-led demonstrations and provide limited access to structured or digital Standard Operating Procedures (SOPs), which may reduce students' confidence, independence, and accuracy in operating advanced instruments.
Objective: This study aims to identify students' needs for interactive digital SOPs to support self-directed learning and improve competence in operating laboratory instruments, particularly the Texture Profile Analyzer (TPA) and VolScan Profiler.
Methods: A mixed-methods needs assessment was conducted involving 40 culinary students. Data were collected through structured questionnaires and open-ended responses to explore laboratory experience, instrument familiarity, perceived barriers, and preferred learning media.
Results: The findings showed 75% of students rarely participated in laboratory activities, and 88% relied entirely on instructor guidance. Only 45% had experience using the TPA, while only 5% had used the VolScan Profiler. In addition, 50% reported the absence of written SOPs. The main barriers were equipment-related technical issues (42%), limited operational knowledge (30%), and unclear instructions (15%). Most students preferred video tutorials (83%), supported by simplified language, contextual explanations, QR code-linked manuals, and digital integration.
Conclusion: The study highlights the need to transform static SOPs into interactive, learner-centered digital formats aligned with Outcome-Based Education (OBE), digital literacy development, and the Merdeka Belajar Kampus Merdeka (MBKM) framework. These findings provide a foundation for developing digital SOPs that improve procedural understanding, independent learning, and laboratory competence among vocational culinary students.

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INTRODUCTION

Vocational education plays a pivotal role in developing industry-relevant competencies, particularly in laboratory-based disciplines such as culinary and food technology. In these environments, mastery of laboratory instruments is essential not only for ensuring safety and accuracy but also for cultivating students' procedural autonomy and critical thinking. However, many vocational and applied higher education institutions in Indonesia, including those offering

Culinary Arts and Food Service Management programs, continue to rely heavily on instructor-led demonstrations with limited exposure to standardized written guidelines or operational procedures (Alsalem, 2023; Hortin, 2024). This situation often results in inconsistent laboratory practices, reduced learning independence, and higher rates of operational error.

A fundamental challenge lies in the inherent mismatch between the predominantly artistic and practical orientation of culinary students and the highly analytical, technical nature of laboratory instruments such as the Texture Profile Analyzer (TPA) and VolScan Profiler. The TPA requires students to configure compression parameters, interpret force-deformation curves, and understand mechanical properties of food matrices, while the VolScan Profiler employs laser displacement technology to measure volumetric and dimensional attributes concepts that are largely foreign to students trained primarily in culinary technique and sensory evaluation. This gap between student characteristics and instrument demands creates significant technical anxiety, particularly when students must navigate analytical software interfaces requiring systematic data input and interpretation beyond their disciplinary training (Alhashem & Alfailakawi, 2023). Importantly, in vocational culinary laboratories, procedural errors in operating analytical equipment carry a dual impact: they compromise the precision of objective food quality data and simultaneously lead to failure in replicating edible culinary products that meet industry standards. This dual consequence distinguishes culinary laboratory instruction from conventional science laboratories where errors primarily affect only data accuracy. Digital SOPs incorporating video demonstrations and QR code access provide a just-in-time learning solution that is inherently mobile-friendly, enabling students to watch visual demonstrations instantly at their workstations without leaving their working areas or consulting printed documents (Robertson & Kobylianskii, 2025; Thompson et al., 2024).

Standard Operating Procedures (SOPs) serve as a cornerstone of laboratory management and are widely acknowledged as essential for maintaining accuracy, safety, and reproducibility in both educational and industrial contexts (Hollmann, 2020; Peres, 2022). Properly designed SOPs not only minimize human error but also foster a structured learning environment that enhances students' confidence in using analytical instruments (Systems, 2025). Yet, despite their importance, many vocational culinary laboratories still lack accessible or student-centered SOPs, especially for advanced analytical tools such as the Texture Profile Analyzer (TPA) and VolScan Profiler, which are used to assess the textural and volumetric properties of food products (Ibanez et al., 2022; Selga et al., 2024). The absence of these resources has led to significant learning barriers students often misinterpret operational steps, experience technical difficulties, or avoid using the equipment altogether.

Recent studies have explored the potential of digital and multimedia-based SOPs to improve procedural learning in science and engineering education. For instance, Wu (Sagit et al., 2025; Wu, 2024) demonstrated that integrating multimedia and interactive formats enhances learner satisfaction and engagement, particularly among digital-native students. Similarly, Peres (Hollmann, 2020; Ibanez et al., 2022; Peres, 2022; Selga et al., 2024) emphasized that clear, interactive procedural documents can significantly reduce cognitive load and operational errors during complex laboratory tasks. These findings align with the principles of Mayer's Cognitive Theory of Multimedia Learning, which advocates that combining visual and auditory elements improves comprehension and long-term retention compared to text-only materials (Mayer, 2009; Sun & Nembhard, 2025). In vocational education contexts, integrating such digital instructional materials aligns with the broader shift toward flexible and technology-driven learning environments (Sagit et al., 2025; Wu, 2024).

In Indonesia, the Merdeka Belajar–Kampus Merdeka (MBKM) initiative emphasizes learner autonomy, digital literacy, and innovation-oriented practices within vocational education (Aditomo, 2024; Education, 2024). To support this policy, instructional resources including laboratory SOPs must evolve from static documents to interactive digital tools that enable self-directed learning (SDL) and reflect the realities of Industry 4.0. Several studies have validated the effectiveness of such tools in engineering and medical training (Rahyasih et al., 2023; Torras et al., 2024), yet their implementation in culinary laboratories remains largely unexplored. Existing literature tends to focus on science, chemistry, or healthcare laboratories, overlooking the specific operational and pedagogical challenges faced in culinary education settings where practical precision and safety are equally critical (Anwar et al., 2024; Habibi et al., 2023).

The novelty of this research lies in its specific focus on needs assessment for interactive digital SOPs within vocational culinary education a context systematically overlooked in existing literature. Unlike previous studies examining digital learning tools in science, engineering, or healthcare laboratories, this study specifically addresses the intersection of analytical instrument operation and culinary vocational pedagogy. By investigating the unique challenges faced by predominantly artistic and practically oriented culinary students when engaging with technical instruments, this research contributes a context-specific empirical foundation absent from the current body of knowledge. Furthermore, this study integrates Mayer's (2009) Cognitive Theory of Multimedia Learning and the UTAUT framework within the specific operational realities of a culinary laboratory, providing a theoretically grounded and contextually relevant basis for future SOP development (Mayer, 2009; Sun & Nembhard, 2025).

While prior studies have demonstrated the effectiveness of digital SOPs in science and engineering contexts, critical examination reveals significant limitations in their applicability to culinary education. Rahyasih et al. (2023) validated digital learning resources for vocational high schools but focused exclusively on theoretical content delivery rather than hands-on instrument operation. Similarly, Torras et al. (2024) designed digital platforms for professional training in clinical settings where learners already possess analytical foundations a condition absent among culinary students. Habibi et al. (2023) examined digital technology access in vocational education broadly but did not address the specific cognitive demands of analytical laboratory instruments. Furthermore, Anwar et al. (2024) investigated technology self-efficacy among vocational teachers rather than students, leaving the learner perspective largely unexplored. These gaps indicate that existing research neither accounts for the unique characteristics of culinary students nor addresses the pedagogical challenges of teaching analytical instrument operation in food technology laboratories.

This gap highlights the need for an empirical needs assessment to determine the current accessibility, usability, and relevance of SOPs in culinary laboratory instruction. Without this foundational understanding, digital innovation efforts risk misalignment with actual student needs and contextual constraints Specifically, no study has yet investigated the needs, challenges, and preferences of culinary education students regarding interactive digital SOPs for analytical instruments such as the TPA and VolScan Profiler. The absence of this foundational evidence represents a critical research gap that must be addressed before effective digital interventions can be designed for this unique educational context (Sagit et al., 2025; Torras et al., 2024). Therefore, this study aims to identify the existing challenges and learning preferences of students regarding laboratory SOP use in the Culinary Engineering Laboratory at Universitas Negeri Jakarta. The findings from this preliminary phase will inform the design of interactive digital SOPs that promote self-learning, procedural accuracy, and operational independence directly supporting MBKM principles and the transformation of vocational education toward digital competence The benefits of this research extend to curriculum designers, laboratory instructors, and policy makers who seek evidence-based recommendations for integrating digital instructional tools into vocational education. The practical implications include the development of a prototype interactive digital SOP system that can serve as a model for other vocational disciplines, while the theoretical implications contribute to expanding the application of multimedia learning theory in non-traditional laboratory contexts.

METHOD

Research Design

This study adopted a Research and Development (R&D) approach based on the Borg and Gall model, which systematically guides the design, development, and evaluation of educational products. The present article reports on Phase I: Needs Assessment, which serves as the foundational stage in the iterative development of an interactive digital Standard Operating Procedure (SOP) for culinary laboratory instruments. The purpose of this phase was to explore students' experiences, operational challenges, and expectations regarding the use of two essential laboratory devices the Texture Profile Analyzer (TPA) and VolScan Profiler in the Culinary

Engineering Laboratory. Insights from this phase will inform the next stages of prototype design and formative evaluation. The Borg and Gall R&D model comprises ten systematic stages: (1) research and information collection, (2) planning, (3) developing a preliminary product form, (4) preliminary field testing, (5) main product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. The present study specifically addresses Stage 1 (research and information collection), which involves conducting a needs assessment through literature review and field surveys to establish the empirical basis for product development.

Participants

The study involved 40 undergraduate students enrolled in the Culinary Education Program at Universitas Negeri Jakarta (UNJ). Participants were selected through purposive sampling, focusing on students who had prior experience or exposure to laboratory activities involving the Texture Profile Analyzer (TPA) and VolScan Profiler. The inclusion criteria required that participants (1) had completed at least one laboratory-based course and (2) had operated or observed the use of the specified instruments during their studies. The 40 participants represented approximately 67% of the total population of 60 upper-level students (semesters 5–7) who regularly utilize the Culinary Engineering Laboratory, providing substantial representation of the target population. Purposive sampling was deliberately selected over random sampling because the research objectives required participants with direct experiential knowledge of the TPA and VolScan Profiler instruments not encountered by all students in the program. This criterion-based approach ensured that collected data reflected genuine user experiences rather than uninformed opinions, enhancing the ecological validity of the findings (Creswell & Creswell, 2018; Rosidi et al., 2026). While purposive sampling may introduce selection bias, this limitation was mitigated by including all eligible students who met the inclusion criteria, effectively constituting a census of the qualified population.

The sample consisted of 32 female students (80%) and 8 male students (20%), with an age range of 22 to 25 years. Participation in the study was voluntary, and all participants were informed about the research objectives and procedures prior to data collection. They were assured that their responses would remain confidential and anonymous and would be used solely for academic research purposes.

Data Collection Instrument

Data were collected using a structured questionnaire that included both closed- and open-ended items. The instrument was designed by the research team based on a review of relevant literature on educational technology design and laboratory instruction, ensuring that each item aligned with the objectives of the study. The questionnaire was organized into five key domains showed on Table 1.

Table 1. Five Key Domains

Domain	Purpose
Demographic Information	To collect background data such as age, gender, and academic level.
Laboratory SOP Experience	To assess familiarity with existing SOPs and the level of access.
Operational Challenges	To identify obstacles faced by students in independently using TPA and VolScan Profiler.
Learning Preferences	To explore preferred formats for SOP delivery (e.g., video, text, QR-based).
SOP Feature Expectations	To capture desired characteristics of a digital SOP (e.g., step-by-step visuals, interactive elements).

The questionnaire was reviewed by two lecturers with expertise in educational technology and culinary science to ensure clarity, relevance, and alignment with the study's objectives before distribution to participants. Content validity was established through expert judgment, in which both reviewers assessed each questionnaire item for relevance, clarity, and alignment with the five key domains. Items that received inconsistent evaluations were revised based on expert feedback before final administration. For the closed-ended items, internal consistency reliability was assessed using Cronbach's alpha, yielding a coefficient of 0.82, which exceeds the commonly accepted threshold of 0.70 and indicates good reliability (Mahmood & Badrinarayanan, 2026; Taber, 2018). The closed-ended items were measured using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), enabling the calculation of mean scores and standard deviations for quantitative analysis.

Data Collection Procedure

The questionnaire was administered online via Google Forms during the second semester of the 2024–2025 academic year. Participants were given one week to complete the survey, and reminders were sent via institutional email to maximize response rates. Completion time averaged 15–20 minutes.

Data Analysis

Data collected from the questionnaire were analyzed using a mixed-method descriptive approach. Quantitative responses were processed using descriptive statistics, including frequencies, percentages, and mean values, to identify patterns related to students' experiences, familiarity with SOPs, operational challenges, and preferred learning formats. The results were organized and visualized using Microsoft Excel through tables, bar charts, and pie charts to illustrate trends across each domain.

Open-ended responses were analyzed qualitatively following Braun and Clarke's (Braun & Clarke, 2006; Jungert et al., 2026) thematic analysis framework. The process involved six iterative steps: (1) familiarizing with the data by reading all responses multiple times, (2) generating initial codes to capture key ideas, (3) grouping codes into broader themes, (4) reviewing and refining themes to ensure consistency and relevance, (5) defining and naming the final themes, and (6) producing a narrative synthesis of the findings. This approach allowed the identification of recurring patterns and deeper insights into students' expectations, perceived barriers, and learning needs related to laboratory SOP usage.

Finally, triangulation was employed to integrate quantitative and qualitative findings. This was achieved by comparing statistical trends with emergent themes to provide a more comprehensive understanding of the context and to validate the results from multiple perspectives. The combined analysis enabled the development of user-centered recommendations for designing an interactive digital SOP tailored to students' needs and learning preferences.

RESULTS AND DISCUSSION

Results

This section presents and interprets the findings of the needs assessment conducted among students enrolled in the Culinary Education Program at Universitas Negeri Jakarta. The aim of the analysis was to explore students' current experiences, challenges, and expectations in using laboratory instruments particularly the Texture Profile Analyzer (TPA) and VolScan Profiler and to identify their preferences for the development of an interactive digital Standard Operating Procedure (SOP). A total of 40 student responses were collected through a structured questionnaire, comprising both closed-ended and open-ended items.

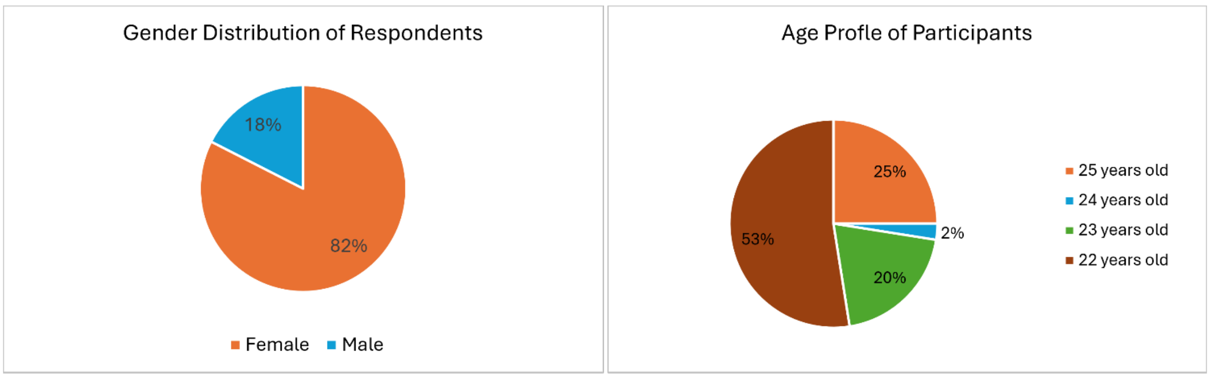
The results are organized into four key areas: (1) demographic characteristics and laboratory participation patterns, (2) experience and familiarity with existing SOPs and laboratory instruments, (3) operational challenges and barriers to independent tool usage, and (4) learning preferences and expectations for future SOP formats. Quantitative data were analyzed descriptively to identify dominant trends, while qualitative responses were examined using Braun and Clarke's thematic analysis to reveal deeper insights into students' perceptions and needs. A triangulation approach was then applied to integrate both types of findings, offering a comprehensive understanding of how procedural resources are currently used and how they can be improved to support self-directed learning and align with the goals of the Merdeka Belajar–Kampus Merdeka (MBKM) framework.

The discussion that follows not only summarizes these findings but also contextualizes them within existing literature on instructional design, educational technology, and laboratory pedagogy. It highlights critical gaps between current practice and desired outcomes, which serve as the empirical foundation for the next stage of this research: the design and development of interactive, student-centered digital SOPs.

Demographic Characteristics and Laboratory Participation Patterns

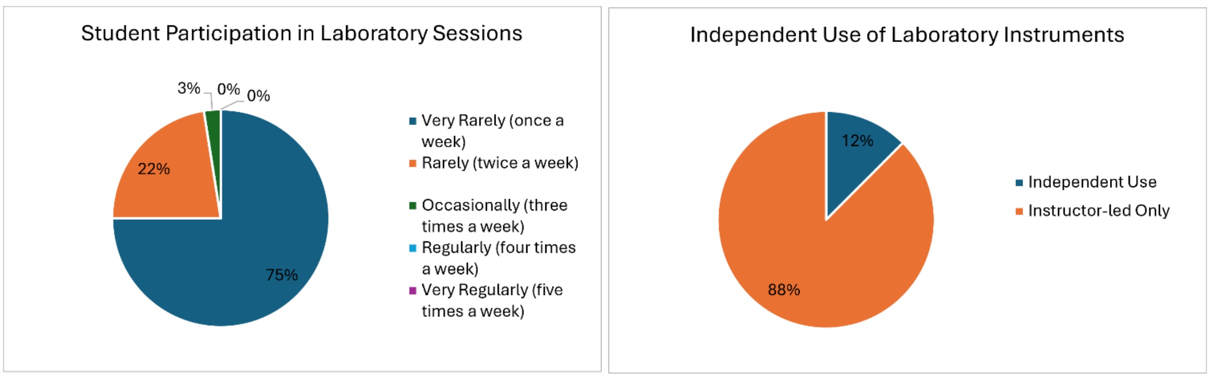
The demographic profile of respondents described previously in Section 3.2 reflects the typical structure of vocational culinary education cohorts, characterized by a predominance of female students and a narrow age range of 22–25 years (Fig 1). Panel (a) shows the gender distribution of respondents, with a predominance of female students (82%). Panel (b) illustrates the age profile, indicating that the majority were between 22 and 25 years old. These demographics provide essential context for interpreting participation patterns and learning preferences in vocational culinary laboratory settings (N = 40). This demographic context is relevant because research shows that gendered career perceptions and age-related digital familiarity significantly shape learning engagement, technology adoption, and participation in vocational contexts [18].

Most participants reported having attended at least one laboratory-based course and being introduced to analytical instruments such as the Texture Profile Analyzer (TPA) and VolScan Profiler (Fig. 2). However, participation patterns reveal that this exposure has not translated into meaningful hands-on learning experiences. As shown in Figure 2(a), the majority of students reported engaging in laboratory activities very rarely (75%) or rarely (22%), indicating that opportunities for regular, practice-based learning remain limited. Even more strikingly, Figure 2(b) illustrates that only 12% of respondents had ever operated laboratory instruments independently, while 88% relied exclusively on instructor guidance.



(a) (b)

Figure 1. Demographic characteristics of students participating in the needs assessment survey



(a) (b)

Figure 2. Laboratory engagement and operational autonomy among students

These findings underscore a significant gap between exposure and procedural mastery: students are present in laboratory environments but lack sufficient opportunities to develop operational competence through active experimentation. Similar challenges have been documented in engineering and technical education contexts, where limited practice opportunities often result in shallow learning and reduced procedural confidence (Basu & Lohani, 2023; May et al., 2023). This pattern reflects a broader issue in vocational and technical education, where teacher-centered pedagogical models while effective for ensuring procedural safety and accuracy frequently fail to cultivate autonomy, self-regulation, and transferable technical skills (Basu & Lohani, 2023). Addressing these limitations requires structured learning strategies, such as scaffolding approaches, which gradually transition students from observation to independent operation and significantly enhance procedural learning outcomes (Richardson et al., 2022). Integrating such strategies with accessible instructional resources including interactive digital SOPs can play a critical role in bridging the gap between exposure and mastery.

To better understand how these instructional gaps manifest and how they might be addressed through digital interventions, it is essential to examine students' current experiences, familiarity, and interactions with existing SOPs. The following section (4.2) explores these dimensions in depth, providing insights into how students perceive current SOP practices and identifying specific areas for improvement in designing more effective, user-centered instructional resources.

Laboratory SOP Experience

Figure 3, presents findings on students' experience and interaction with standard operating procedures (SOPs) and analytical equipment in the Culinary Engineering Laboratory. The analysis covers three main dimensions: the types of instruments used, the parameters most frequently measured, and the availability of written SOPs. Results indicate that 45% of students reported using the Texture Profile Analyzer (TPA), while only 5% had experience with the VolScan Profiler. A substantial 37% had not used either instrument, and 13% reported using other laboratory tools. None of the respondents had operated both devices. These results highlight a clear bias toward single-instrument exposure, particularly the TPA, which is commonly used for analyzing food texture and structural properties. The limited engagement with multiple analytical instruments suggests instructional gaps and a lack of procedural support that discourage students from exploring the full range of laboratory technologies. Prior research confirms that the absence of structured guidance often reduces students' confidence and willingness to engage with unfamiliar tools, ultimately leading to underutilization of laboratory infrastructure (Hollmann, 2020; Thompson et al., 2024).

In terms of analytical focus, 43% of students reported measuring texture profile, followed by 35% who measured product density and 20% who measured volume. Only 2% had measured surface profile, and none reported measuring product dimensions. This concentration on texture and density analysis correlates with the dominance of TPA use and reveals a narrow procedural engagement. The minimal use of dimensional or surface measurements points to insufficient training, a lack of awareness, or inadequate procedural documentation for these analytical functions. Similar patterns have been observed in laboratory education more broadly, where students' procedural choices are strongly influenced by the accessibility and clarity of available instructional resources such as SOPs (Hollmann, 2020; Robertson & Kobylianskii, 2025).

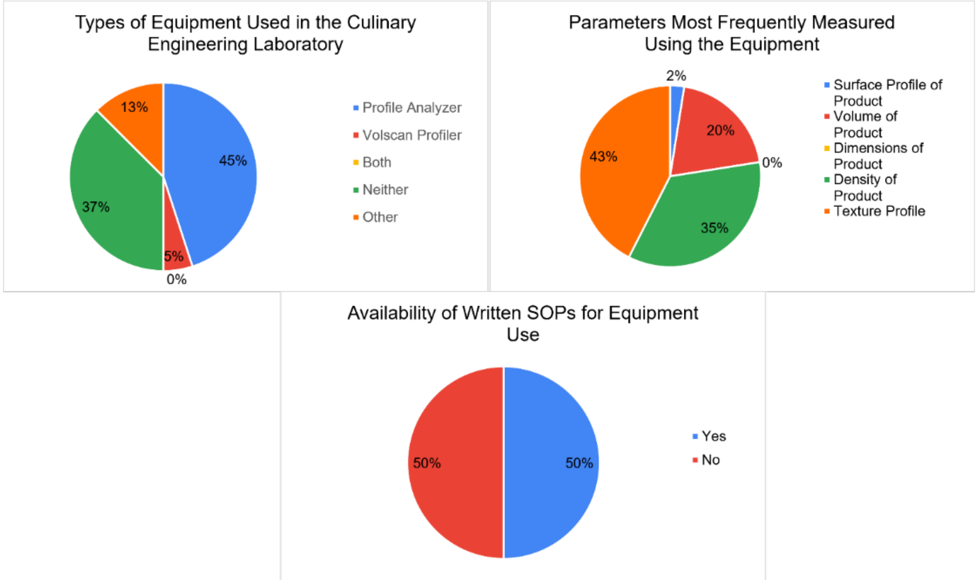


Figure 3. Laboratory SOP Experience of Students in the Culinary Engineering Laboratory

Responses regarding the availability of written SOPs showed that 50% of students reported their absence, while the remaining 50% confirmed their existence. This division reflects a significant barrier to the standardization of laboratory practices and the development of independent learning competencies. Well-structured SOPs are essential for building procedural confidence, ensuring safety, and enabling students to operate laboratory instruments autonomously (Alhashem & Alfailakawi, 2023; Mayer, 2009; Sun & Nembhard, 2025). Their absence not only increases the risk of misuse but also undermines competency-based curricular objectives, such as those promoted by the *Merdeka Belajar–Kampus Merdeka (MBKM)* framework, which emphasizes learner autonomy, self-regulation, and practical competence development (Education, 2024).

Overall, the findings underscore the urgent need for comprehensive SOP development that encompasses all key laboratory instruments, particularly the underutilized VolScan Profiler. Additionally, SOPs should include guidance on a broader range of measurement parameters to encourage deeper engagement with laboratory tools. To maximize their pedagogical impact, these SOPs should be designed in multiple digital formats including video tutorials, QR-code manuals, and interactive PDFs that accommodate diverse learning preferences and support independent, self-paced learning. Previous studies have demonstrated that multimedia-based SOPs significantly enhance procedural understanding, student engagement, and operational autonomy in laboratory contexts (Mayer, 2009; Thompson et al., 2024). Such an approach aligns with contemporary vocational education reforms and directly contributes to the development of 21st-century competencies within the MBKM and Outcome-Based Education (OBE) frameworks (Education, 2024).

Operational Challenges

The survey results revealed several significant operational challenges experienced by students in the Culinary Engineering Laboratory, underscoring the urgent need for more robust procedural support systems and well-designed SOP resources. As illustrated in Figure 4, one-third of respondents (33%) reported that they *sometimes* encountered difficulties while conducting laboratory activities, followed by 23% who faced challenges *rarely* and 22% who experienced them *often*. A smaller fraction (2%) reported facing such issues *very often*, whereas 20% stated they had *never* encountered operational obstacles. This distribution suggests that most students face difficulties at least occasionally, highlighting the importance of targeted interventions to improve laboratory support. Previous research indicates that recurring operational difficulties in technical laboratory environments can negatively affect learning outcomes, engagement, and procedural accuracy if not addressed through structured instructional support (Alhashem & Alfailakawi, 2023; Hollmann, 2020; Mayer, 2009).

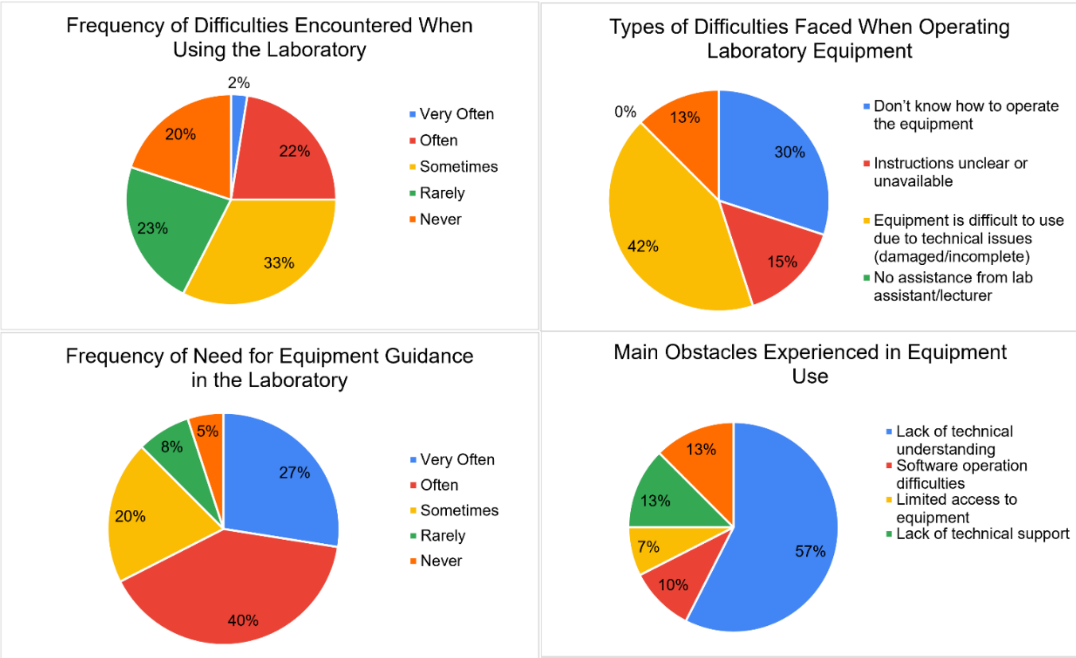


Figure 4. Operational Challenges in Using Equipment in the Culinary Engineering Laboratory

The types of challenges reported provide deeper insight into the nature of these obstacles. The most frequently cited difficulty was technical-related issues such as incomplete, damaged, or malfunctioning equipment reported by 42% of students. This was followed by insufficient knowledge on how to operate the tools (30%), unclear or unavailable instructions (15%), and lack of assistance from laboratory personnel (13%). These findings align with the literature on laboratory-based learning, which consistently identifies the absence of accessible procedural guidance and inadequate technical readiness as key barriers to independent practice (Basu & Lohani, 2023; Hollmann, 2020). Furthermore, the absence of reliable technical infrastructure often leads to reduced equipment utilization and limits students' opportunities for hands-on learning/

Another critical finding relates to the persistent need for external guidance. A substantial proportion of students indicated that they *often* (40%) or *very often* (27%) required assistance during laboratory sessions, while only 5% reported that they *never* needed help. Such reliance on instructor support reveals a gap between curricular goals such as developing autonomous operational competencies and actual student experiences. This dependency reflects broader challenges identified in technology adoption literature, where the lack of "facilitating conditions" (e.g., clear guidance, accessible instructions, and institutional support) significantly reduces users' willingness and ability to engage with technological tools. According to the Unified Theory of Acceptance and Use of Technology (UTAUT), facilitating conditions strongly influence behavioral intention and performance expectancy, which are critical determinants of technology adoption in educational settings (Kumagai, 2026; Venkatesh et al., 2003).

Students also identified specific barriers that further limit their ability to work independently. The most frequently reported obstacle was a lack of technical understanding (57%), followed by software-related issues (10%), limited access to laboratory equipment (7%), and insufficient technical support (13%). These factors are closely related to self-efficacy constraints, which have been shown to significantly restrict hands-on learning outcomes in technical and vocational education environments (Alhashem & Alfailakawi, 2023). When procedural knowledge is limited and technical support is inconsistent, students are less likely to experiment with laboratory tools, reducing opportunities for experiential learning and skill mastery. Notably, the dominance of technical understanding deficits (57%) among culinary students reflects a deeper structural issue: as predominantly non-pure-science vocational learners, these students experience heightened technical anxiety when confronted with analytical software interfaces and data interpretation tasks requiring scientific reasoning outside their primary disciplinary training. This technical anxiety is compounded by the unfamiliarity of measurement concepts involved while TPA data on hardness and cohesiveness bear some intuitive connection to culinary experience with food texture, the VolScan Profiler's laser-based volumetric measurements remain conceptually abstract and disconnected from students' practical culinary knowledge (Alhashem & Alfailakawi, 2023).

Collectively, these findings indicate that operational independence among students remains in the *low to medium* category, with fewer than 40% demonstrating the ability to operate laboratory equipment without external support. Such conditions not only hinder students' confidence and competence but also reduce their motivation to engage with laboratory activities. Addressing these issues requires a comprehensive strategy that includes developing interactive SOPs, improving equipment reliability, and strengthening support systems. By enhancing procedural clarity, integrating multimedia-based guidance, and ensuring consistent technical support, vocational education programs can foster greater operational autonomy and improve the overall effectiveness of laboratory learning environments.

Learning Preferences

The survey results revealed clear patterns in students' learning preferences for laboratory equipment usage, highlighting an urgent need to redesign instructional support in ways that align with the learning styles of Generation Z students. As shown in Figure 5, a dominant 72% of students reported relying on lecturer guidance as their primary reference when operating laboratory tools. This heavy dependence on instructor support far exceeds the proportion of students who reported using online resources (18%), participating in training sessions (5%), or consulting printed manuals (2%), while 3% reported "other" sources. Such reliance reflects a strong instructor-dependent learning culture that conflicts with the objectives of the From a pedagogical perspective, this 72% instructor-dependency rate signals a systemic failure to transition from transmission-based to constructivist learning models in the culinary laboratory context. The significant gap between instructor reliance (72%) and online resource use (18%) suggests that existing digital resources lack sufficient scaffolding or accessibility to serve as viable alternatives to direct instruction. *Merdeka Belajar–Kampus Merdeka (MBKM)* curriculum, which emphasizes student autonomy, self-directed learning, and independent skill development (Education, 2024; Hollmann, 2020).

When asked about preferred learning media, an overwhelming 83% of respondents selected video tutorials as their first choice, followed by interactive flipbooks (10%), e-books or PDFs (4%), and printed books (3%). This strong preference for multimedia-based instruction underscores the importance of adopting dynamic, visually supported learning resources in laboratory education. Mayer's (2009) Cognitive Theory of Multimedia Learning emphasizes that combining narration, visuals, and interactivity reduces cognitive load and enhances knowledge retention, particularly when students are learning complex procedures (Mayer, 2009; Sun & Nembhard, 2025). Such findings further reinforce the pedagogical value of developing video-based SOPs and integrating them with mobile-friendly platforms to facilitate "just-in-time" learning directly at laboratory workstations (Robertson & Kobylianskii, 2025; Thompson et al., 2024).

Beyond the quantitative data, qualitative responses provided deeper insights into students' expectations regarding the use of laboratory equipment and comprehension of SOPs. Many students expressed a desire for greater integration of laboratory devices particularly the Texture Profile Analyzer (TPA) with digital tools such as computers or laptops to ensure more precise and reliable results, as well as automated data storage. They also highlighted the need for clear, easily accessible usage guides, preferably attached to or placed near the equipment, with digital access available via QR codes. Such resources are essential for promoting independent operation and reducing reliance on instructor support (Thompson et al., 2024). In addition, respondents emphasized the importance of having laboratory assistants or lecturers present for troubleshooting, particularly when using complex or unfamiliar instruments, and called for improved equipment maintenance policies to prevent disruptions caused by damaged or outdated tools.

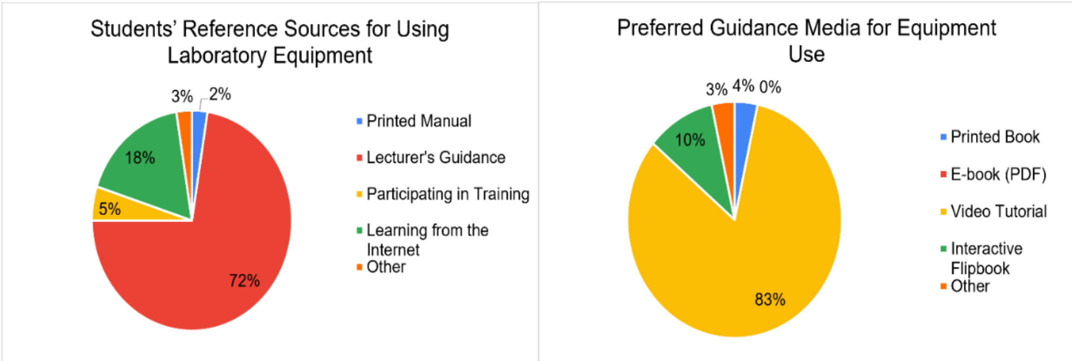


Figure 5. Students' Reference Sources and Preferred Guidance Media for Laboratory Equipment Use

Students also emphasized the importance of pre-use training and tutorial videos to prepare them for independent operation, which aligns with previous findings that video-based instruction is the most preferred format among digital-native learners (Alhashem & Alfailakawi, 2023; Robertson & Kobylianskii, 2025). They highlighted that traditional SOP documents are often difficult to interpret and recommended more intuitive visual formats, such as flow diagrams, color-coded steps, and interactive flipbooks. Respondents also stressed the need for SOPs written in clear, non-technical language to enhance comprehension, particularly for those new to laboratory instrumentation. Moreover, they advocated for video-enhanced SOPs that demonstrate step-by-step procedures with narration or captions derived from written materials, an approach that has been shown to significantly improve learning outcomes in technical training contexts (Mayer, 2009; Sun & Nembhard, 2025; Thompson et al., 2024). Finally, many suggested that SOPs should be readily accessible on-site, either in printed form or via QR codes, and organized according to specific testing contexts detailing which instruments are required and how to use them thereby enabling more efficient task execution and deeper conceptual understanding.

Taken together, these findings reveal a strong student preference for visually rich, easily accessible, and context-driven instructional materials. They further underscore the need for SOP design to evolve beyond static text documents toward integrated digital ecosystems that combine video tutorials, QR-based manuals, and interactive visual guides. Such approaches would not only align with the cognitive and behavioral characteristics of contemporary learners but also directly support the MBKM framework's emphasis on autonomy, innovation, and practical competency development in vocational education (Education, 2024).

SOP Feature Expectations

The final part of the survey focused on identifying students' expectations regarding the design, format, and functionality of future Standard Operating Procedures (SOPs). These expectations are critical for informing the development of a student-centered, digital SOP platform that not only enhances procedural understanding but also fosters independent learning a central objective of vocational education frameworks such as *Merdeka Belajar–Kampus Merdeka (MBKM)*. The analysis of open-ended responses, conducted following Braun and Clarke's six-phase thematic analysis approach (Braun & Clarke, 2006; Jungert et al., 2026), revealed several recurring themes that collectively define what students perceive as essential features of an effective SOP system.

A major expectation identified was the integration of digital technologies into laboratory operations. Students expressed a strong preference for laboratory instruments particularly devices such as the Texture Profile Analyzer (TPA) and VolScan Profiler to be compatible with computers or other digital interfaces, allowing for more precise measurements, automatic data logging, and seamless result storage. This reflects a broader trend in laboratory education where digital instrumentation and connectivity are considered integral to modern procedural workflows (Hollmann, 2020; Thompson et al., 2024). Additionally, respondents emphasized the need for clear, concise, and easily accessible procedural guidance. Many students reported difficulties understanding current SOP documents and advocated for the inclusion of simplified instructions written in plain language, accompanied by visual elements such as flow diagrams, labeled images, and step-by-step illustrations. The importance of accessible instructional design has been well established in educational literature, which demonstrates that clarity and visual support significantly improve comprehension, particularly for novice learners (Mayer, 2009; Sun & Nembhard, 2025).

Another recurring theme was the demand for multimedia-based learning resources. Students overwhelmingly supported the development of video-enhanced SOPs that demonstrate the step-by-step use of equipment, combined with narration or captions derived from written instructions. Such multimedia approaches are known to reduce cognitive load, improve procedural memory, and enhance skill acquisition in technical learning environments (Alhashem & Alfailakawi, 2023; Mayer, 2009). Furthermore, respondents highlighted the importance of embedding these resources into the laboratory environment itself for example, by linking SOP videos or digital manuals to QR codes placed directly on or near the equipment. This "just-in-time" learning strategy allows students to access procedural guidance in real time without disrupting their workflow, a technique that has been shown to enhance engagement and operational efficiency (Robertson & Kobylianskii, 2025; Thompson et al., 2024).

Thematic analysis also revealed students' desire for context-based SOP organization. Rather than generic instruction manuals, respondents preferred SOPs structured according to specific testing procedures or experimental goals, detailing which instruments are required and how each should be operated in that context. This approach aligns with best practices in instructional design, which emphasize task-based structuring as a means to improve procedural relevance and applicability (Alhashem & Alfailakawi, 2023). Additionally, several students highlighted the importance of having SOPs readily available at the point of use whether as printed guides attached to equipment or as digital manuals accessible via mobile devices to support on-demand reference during laboratory sessions.

Overall, these findings emphasize that students expect future SOP systems to go beyond traditional text-based documentation. They envision SOPs as comprehensive, interactive, and context-aware digital tools that integrate multimedia resources, simplified instructions, real-time accessibility, and procedural relevance. Such expectations reflect broader pedagogical shifts toward student-centered, technology-enhanced learning environments in vocational education (Education, 2024; Hollmann, 2020). Incorporating these features will not only improve students' procedural competence and confidence but also align SOP development with the principles of MBKM, Outcome-Based Education (OBE), and the 21st-century skills framework, thereby supporting deeper learning and more effective laboratory engagement.

Taken together, these findings present a compelling case for reimagining SOPs as integral components of vocational laboratory pedagogy. Rather than functioning solely as static instructional documents, SOPs should be reconceptualized as interactive, multimedia-enhanced learning systems embedded within the broader digital learning ecosystem. Such tools have the potential to address multiple pedagogical objectives simultaneously: improving procedural competence, fostering independent learning, reducing operational errors, and enhancing overall learning satisfaction. Importantly, they align with the goals of MBKM and Outcome-Based Education (OBE), which prioritize learner autonomy, digital literacy, and the development of 21st-century skills.

Finally, the results of this needs-assessment phase serve as a critical foundation for the next stage of research and development. The identified gaps, challenges, and user expectations will directly inform the design of a prototype interactive digital SOP system. This system will aim to integrate multimedia learning principles, QR-code-enabled access, and context-specific procedural content, thereby transforming the laboratory learning experience into one that is more engaging, efficient, and aligned with industry standards. Future studies should evaluate the effectiveness of such a system on student learning outcomes, procedural accuracy, and long-term skill retention, thereby contributing to the broader discourse on digital transformation in vocational education.

Discussion

Low Operational Independence of Students

The study results indicate that students' exposure to laboratory activities has not yet been sufficient to develop independent operational competencies. Although most students are familiar with laboratory instruments, the low frequency of practice has prevented procedural skills from developing optimally.

Students' reliance on lecturers and lab assistants indicates a teacher-centered approach, theoretically explained through Vygotsky's Zone of Proximal Development (ZPD) framework. The current instructional model positions students permanently within the ZPD without adequate scaffolding tools to enable progression toward independent mastery (Richardson et al., 2022). This dependency contradicts the MBKM concept emphasizing independent learning and practical competencies. From Self-Determination Theory (Deci & Ryan, 2000; Shen et al., 2026), the observed low operational independence reflects unfulfilled needs for autonomy and competence fundamental psychological needs for intrinsic motivation. When students lack structured procedural resources for autonomous practice, their perceived competence diminishes, leading to avoidance behaviors toward laboratory instruments. May et al. (2023) confirmed that in engineering laboratories, similar instructor dependency correlated with reduced self-efficacy and lower procedural retention, a challenge exacerbated in culinary education by the gap between students' artistic orientation and analytical instrument demands.

Limitations of SOPs and Their Impact on Instrument Use

The findings show that the availability of Standard Operating Procedures (SOPs) in the laboratory remains uneven. The absence of clear SOPs causes difficulties for students in understanding proper instrument usage, especially for less commonly used equipment such as the VolScan Profiler.

This situation limits students' exploration of laboratory capabilities. The disparity between TPA usage (45%) and VolScan Profiler usage (5%) reflects not merely paper SOP availability but a deeper conceptual gap. The TPA measures mechanical food properties such as hardness, springiness, and cohesiveness parameters with intuitive connections to culinary students' sensory experience. In contrast, the VolScan Profiler employs laser displacement technology to capture three-dimensional volumetric data, a measurement principle conceptually abstract to students without physics or engineering background (Selga et al., 2024). This unfamiliarity creates a knowledge barrier that static SOPs cannot overcome. Interactive digital SOPs can demystify the laser-based measurement process through animated visualizations, video demonstrations of how the laser scans food surfaces, and real-time feedback connecting abstract measurement concepts to tangible culinary outcomes (Hollmann, 2020; Mayer, 2009; Sun & Nembhard, 2025).

Operational Challenges in Laboratory Learning

Technical issues with laboratory instruments remain a major obstacle in practical learning. Equipment malfunctions, unclear instructions, and limited technical assistance create challenges for students performing independent testing.

The high dependence on lecturers or lab assistants indicates that the procedural support system is not yet fully functional. From the perspective of the Unified Theory of Acceptance and Use of Technology (UTAUT), this relates to low facilitating conditions, which affect students' intention and ability to use laboratory technology independently.

Moreover, limited technical understanding and insufficient software support indicate that laboratory learning has not fully facilitated experiential learning or enhanced students' self-efficacy.

Students' Preferences for Interactive Digital SOPs

Students show a strong preference for video tutorials and interactive visual media. This reflects a shift in digital-generation learning characteristics, which favor audiovisual media over conventional text-based documents.

These findings are directly explained by Mayer's (2009) Cognitive Theory of Multimedia Learning. Within a culinary laboratory (where students simultaneously manage food preparation, equipment operation, timing constraints, and hygiene protocols) cognitive load from reading text-based SOPs is substantially amplified (Sun & Nembhard, 2025). Mayer's multimedia principle is particularly critical here because students must process procedural information while their hands are occupied and attention divided across concurrent tasks. Video-based SOPs accessible via QR codes on equipment enable just-in-time learning aligned with the spatial and temporal constraints of the culinary workspace, allowing procedural guidance without disengaging from practical workflow (Robertson & Kobylianskii, 2025; Thompson et al., 2024). The multimedia redundancy principle further suggests that visual demonstrations with narration provide dual-channel processing that significantly enhances comprehension for students lacking technical vocabulary to interpret written analytical procedures (Mayer, 2009; Sun & Nembhard, 2025).

In addition to enhancing comprehension, using interactive digital SOPs can accelerate information access, support independent learning, and improve the efficiency of laboratory instrument usage.

Implications of SOP Development for Vocational Education

The study emphasizes that SOPs should no longer be presented solely as static documents; they need to be developed as interactive and contextual digital learning systems. Integrating multimedia, QR code access, and video-based guidance can enhance students' procedural competencies while supporting the digital transformation of vocational education.

Digital SOP development also aligns with Outcome-Based Education (OBE) principles and the MBKM framework, which emphasize 21st-century skills, digital literacy, and self-directed learning. Consequently, interactive SOPs function not only as procedural documents but also as effective learning media that can improve the overall effectiveness of laboratory practicals. This study contributes to the vocational education literature in three specific ways. First, it provides the first empirical evidence regarding the needs and challenges of culinary students in using analytical laboratory instruments, an area previously unaddressed. Second, it demonstrates that the gap between culinary students' practical orientation and the analytical demands of instruments like TPA and VolScan Profiler creates unique pedagogical challenges requiring discipline-specific solutions. Third, the integration of multimedia learning theory with the UTAUT framework within a culinary laboratory context extends both frameworks' theoretical applicability to a novel educational setting.

CONCLUSION

This study conducted a comprehensive needs assessment to evaluate current practices, challenges, and learning preferences related to the use of laboratory equipment and Standard Operating Procedures (SOPs) in vocational culinary education. The findings revealed that students demonstrated low procedural autonomy, frequently encountered operational difficulties, and remained highly dependent on instructor guidance, conditions that are not fully aligned with the principles of Merdeka Belajar–Kampus Merdeka (MBKM) and Outcome-Based Education (OBE). The limited availability and accessibility of SOPs, particularly for advanced instruments such as the Texture Profile Analyzer (TPA) and VolScan Profiler, also hindered students' ability to conduct laboratory work independently and accurately.

Students expressed a strong preference for multimedia-based instructional materials, including video tutorials and QR-linked digital manuals, which were perceived as more practical, engaging, and easier to understand than static text-based documents. The expected SOP features include visual clarity, interactivity, contextual relevance, mobile accessibility, and real-time guidance, which align with Mayer's Cognitive Theory of Multimedia Learning and the Unified Theory of Acceptance and Use of Technology (UTAUT). Theoretically, this study extends these frameworks to the underexplored context of vocational culinary laboratories, while practically, it provides recommendations for developing interactive digital SOPs that support learner autonomy, procedural competence, and digital skills. Future research should focus on designing, prototyping, and validating the digital SOP platform to measure its impact on student performance, procedural accuracy, and independent learning behavior.

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AUTHOR CONTRIBUTION STATEMENT

Efrina conceptualized the study, designed the research framework, coordinated data collection, and prepared the initial manuscript. Mahdiyah contributed to methodological development, instrument validation, data analysis, and theoretical refinement. Alvina Fadila Maulida assisted in data processing, literature review, interpretation of findings, and manuscript editing. All authors reviewed, revised, and approved the final version of the manuscript for publication.

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