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Development of a Microsoft Excel-Based Management System for Secondary School Chemistry Laboratories

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ABSTRACT

Inefficient digital systems for managing chemistry laboratories in secondary schools often impede effective record-keeping, inventory management, and practicum reporting. This study developed Chemlab Excel, a practical and accessible offline Microsoft Excel-based laboratory management system, eliminating the need for an internet connection or additional software. Employing a Research and Development (R&D) approach with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), and involved nine purposively selected respondents, including chemistry teachers, laboratory heads, and lab assistants from SMA Negeri 1 Bireuen and SMA Negeri 1 Samalanga. The study utilized expert validation sheets, teacher response questionnaires, and the System Usability Scale (SUS) for data collection. Validity was assessed using Aiken's V, and inter-rater reliability was measured via the Intraclass Correlation Coefficient (ICC). Three experts validated the system, with trials conducted in two secondary schools in Bireuen Regency. Results showed high feasibility, with Aiken's V coefficients of 0.852 (media) and 0.869 (material), and ICC values of 0.768 (media) and 0.761 (material), indicating good reliability. The SUS score averaged 72.22%, and teacher responses reached 94.64%, reflecting user-friendliness and enhanced efficiency. Chemlab Excel proves to be a feasible, contextually relevant solution for laboratory management, contributing to streamlined administrative processes in science education and offering a scalable, accessible tool for secondary schools.

ARTICLE INFORMATION

Keywords:
addie model; laboratory management system; microsoft excel; science education; system usability scale (sus)

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INTRODUCTION

Education serves as a human-designed process to shape values, foster intellectual growth, and prepare individuals to be competent and competitive in an evolving world (Saputra et al., 2023; Kumari et al., 2024). In science education, chemistry laboratories at the secondary school level play a vital role by enabling students to apply theoretical knowledge through direct experimentation. These experiences reinforce conceptual understanding and foster attitudes of scientific reasoning, critical thinking, and inquiry-based learning (Yuliastrin et al., 2023). Laboratory-based learning deepens students' grasp of scientific principles by bridging theory and practice, making learning more meaningful (Accettone, 2023; Javaid & Javaid, 2024). Students involved in structured laboratory activities consistently show greater mastery of both qualitative and quantitative science skills compared to lecture-only environments (Efe & Abamba, 2023). Integrating scientific reasoning into laboratory procedures can help shift students' understanding from a superficial to an analytical level (Eymur, 2019). Together, these findings highlight that laboratory learning is not only a complementary practice but also a central pillar for achieving scientific literacy.

However, significant challenges persist in managing chemistry laboratories at the secondary school level, particularly in developing countries. In the Indonesian context, media pembelajaran has been developed to enable interpersonal interaction between teachers and students, providing significant learning situations (Pursitasari et al., 2024). According to the UNESCO Institute for Statistics (2023), while global science curricula widely incorporate laboratory practicals to foster scientific skills, only a minority of schools in developing countries are equipped with adequate laboratory facilities, thereby limiting student access to achieving Sustainable Development Goal 4 (Quality Education) by 2025. Furthermore, the WHO (2024) reports that laboratory accidents in schools are frequently attributed to poor inventory management, including the use of expired materials and errors in manual record-keeping, contributing to substantial annual economic losses in OECD countries. In Southeast Asia, including Indonesia, the OECD-PISA 2022 survey highlights that a considerable number of schools experience chemical wastage due to the lack of digital tracking systems (Organisation for Economic Co-operation and Development, 2023). These issues are exacerbated by a reliance on error-prone manual methods and an insufficient technological infrastructure, which undermines operational efficiency and laboratory safety. This situation reflects the urgent need for innovative yet accessible solutions.

The efficacy of laboratory learning hinges critically on robust laboratory management, encompassing inventory control, safe chemical storage, scheduling, and adherence to safety protocols (Mohzana et al., 2023). In many Indonesian secondary schools, however, management practices remain heavily reliant on manual systems, such as logbooks and handwritten records (Ahnaf & Puspitasari, 2023; Rasagama et al., 2023). These methods are susceptible to inefficiencies, data loss, and human errors, which can jeopardize safety standards and diminish the quality of science education. Such challenges are compounded by a shortage of trained personnel and inadequate digital infrastructure, particularly in rural and semi-urban regions (Jofrishal & Munandar, 2021; Nurhafidhah et al., 2021). This situation aligns with global trends, as highlighted by UNESCO (2023), which notes that only a minority of schools in developing countries possess adequate laboratory facilities. Similarly, WHO (2024) reports that poor inventory management contributes to a significant proportion of laboratory accidents. These overlapping issues create barriers that directly affect students' opportunities for meaningful learning.

Findings from a preliminary study conducted at SMA Negeri 1 Samalanga and SMA Negeri 1 Bireuen illustrate how these global and national challenges manifest at the school level. Observations revealed that approximately 70% of laboratory inventory data were not updated regularly, hazard labels on chemicals were frequently missing, and equipment monitoring relied heavily on handwritten logbooks. Interviews with teachers and laboratory staff further revealed that manual documentation frequently resulted in scheduling conflicts, inefficient material utilization, and an increased risk of accidents. Moreover, the absence of systematic digital recording resulted in difficulties in tracking material usage and preparing audit reports, thereby reducing administrative accountability. These conditions are exacerbated by the fact that the overall availability of laboratory equipment in Indonesian schools remains below standard, with readiness levels ranging from 65.67% to 87.27% (Nabila et al., 2024; Fitri, 2024), highlighting inequities in access to proper facilities. Together, these findings confirm that local schools face persistent systemic barriers in laboratory management, reinforcing the need for contextually relevant solutions that are both accessible and feasible within the resource constraints of Indonesian schools (Hanifah & Irwansyah, 2021; Duke et al., 2022; Adekunle et al., 2024).

In this context, Microsoft Excel presents a promising, low-cost, and widely available alternative. It supports data entry, logical operations, visualization, and custom programming through macros. Excel works offline and is compatible with most school environments, making it an appropriate

solution for resource-limited settings. Studies have shown that Excel-based systems can enhance inventory accuracy, minimize errors, and improve safety documentation (Moser et al., 2021; Mamajonov & Zhaparov, 2025). While Excel has been used in various school administrative tasks, its use as an integrated chemistry lab management tool remains underexplored. Prior studies have primarily examined complex systems that require digital literacy and infrastructure, which are not universally available (Riza, 2024). Excel, in contrast, offers ease of use, adaptability, and aligns well with the digital competencies of most teachers in low-resource environments (Moser et al., 2021). Its ability to support contextual and project-based learning further strengthens its potential alignment with the Merdeka Curriculum.

The development of an Excel-based system represents a timely and practical initiative. This system aligns with educators' digital readiness, operates offline, and supports project-based learning, one of the key strategies of the Merdeka Curriculum. Additionally, it promotes awareness of laboratory safety, streamlines practicum preparation, and improves documentation practices, thereby contributing to the overall enhancement of laboratory education quality. This research offers a distinctive advantage through the development of Chemlab Excel. This Microsoft Excel-based laboratory management system is not only modular and contextual, but also visually appealing, intuitive to navigate, and tailored to the conditions of secondary schools with limited or no internet connectivity. The system includes a dashboard interface, uniform navigation buttons, automated search functions, real-time practicum logging, automatic reporting, and features for data security and laboratory SOPs. Other strengths of this system include its user-friendly design, cost efficiency, and independent usability by teachers and laboratory technicians, eliminating the need for additional technical training.

Nevertheless, most prior studies have focused on developing laboratory management systems based on Microsoft Access or web-based applications (Riza, 2024). These systems are often complex and incompatible with the infrastructural and human resource limitations of secondary schools, especially in areas such as Bireuen Regency. For instance, a case study at SMK Negeri 1 Sigli developed an Access-based system to replace Excel, yet failed to thoroughly evaluate the optimization potential of Excel as a laboratory management platform (Riza, 2024). In contrast, Excel has proven capable of supporting automated recording, inventory tracking, and efficient data visualization for laboratory activities, all of which are accessible and practical for teachers and school staff. Hence, a significant research gap exists in the development of functional, spreadsheet-based laboratory management systems tailored to schools with limited infrastructure. Chemlab Excel emerges as a solution to this need by emphasizing a contextual approach rooted in school realities. This research aims to develop an efficient, practical, and user-friendly laboratory management system based on Microsoft Excel, validate its quality from the perspectives of media, content, and user response through expert and practitioner evaluations, and assess the system's practicality and acceptance through limited implementation in two secondary schools in Bireuen Regency. This system is expected to serve as a systemic and sustainable solution for science laboratory governance in resource-constrained schools, while also making a theoretical contribution to the literature on Excel-based system development in the context of digital science education.

METHOD

This study adopts a Research and Development (R&D) approach, employing the ADDIE model, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Sugiyono, 2022). The procedure of the ADDIE model was adapted from Cahyadi (2019) because it provides a clear, structured, and systematic representation of the educational technology development process. The primary objective of this research is to design and evaluate a Microsoft

Excel-based chemical laboratory management system, Chemlab Excel, specifically designed for chemistry teachers and laboratory personnel in secondary schools. The developed system is designed to function as an inventory tracker, a stock monitoring platform, and an automated reporting tool that can be operated offline. The instruments used in this study included media feasibility assessment sheets, teacher response questionnaires, and the System Usability Scale (SUS) questionnaire, which were used to evaluate usability dimensions such as effectiveness, efficiency, and user satisfaction. The development process relied on Microsoft Excel 2021 as the primary platform, with optimization through features such as data validation, conditional formatting, pivot tables, worksheet protection, and basic macros to enhance functionality and maintain system reliability in school environments.

System implementation required a minimum setup of an Intel Core i3 laptop with 4 GB RAM and Windows 10, along with basic peripherals (LCD projector, printer, USB drives, and optional cloud backup). The population for this study consisted of 38 senior high school chemistry teachers in Bireuen Regency. A purposive sample of nine participants was selected, including two laboratory heads, two lab assistants, and five chemistry teachers. The purposive sampling technique was chosen since only those directly involved in laboratory management were considered relevant to achieve the research objectives. The research was conducted at SMA Negeri 1 Bireuen and SMA Negeri 1 Samalanga during the even semester of the 2024/2025 academic year. Participants were purposively selected, comprising two heads of chemistry laboratories, two laboratory technicians, and five chemistry teachers (N = 9). Selection criteria included active involvement in laboratory operations. Data collection took place between March and May 2025, involving observations, semi-structured interviews (lasting 15–20 minutes), and field testing. All participants were anonymized using pseudonyms. Ethical clearance was obtained from the relevant ethics committee, and informed consent was secured from all participants prior to data collection. The field-testing stage included teacher response questionnaires and the SUS scale as instruments for measuring user perception of the system's practicality and efficiency.

The development of the Microsoft Excel-based chemical laboratory management system followed the five main phases of the ADDIE model, beginning with the analysis phase. At this stage, a needs analysis was conducted to identify the essential components required for developing a laboratory management system specifically designed to support the implementation of chemistry practicum at the secondary school level. The process began by reviewing practical guidelines and the national chemistry curriculum to determine the key documentation and laboratory management requirements (Ministry of Education and Culture, 2017). In addition, secondary data were obtained from reputable scientific sources and peer-reviewed journals to enrich the analysis, including information on hazardous chemical inventories and laboratory safety protocols as outlined in the Laboratory Safety Guidelines (Ménard & Trant, 2019; Zhao et al., 2024; Wang et al., 2025). International references such as the Globally Harmonized System (GHS) and Safety Data Sheets (SDS) (United Nations, 2021) were also considered. Furthermore, insights were drawn from previous studies that emphasized the importance of safety awareness and documentation in school laboratories (Ayi & Honje, 2020; Fagbohun et al., 2021), as well as from examples of digital inventory systems, such as LabArchives (LabArchives, 2023). Based on this analysis, the Chemlab Excel system was conceptualized to integrate inventory recording, automatic reporting, and practicum monitoring features into a Microsoft Excel-based platform that operates offline and remains user-friendly for educators in technology-limited environments.

The design phase focused on developing the initial layout of the Excel-based laboratory management template, which included essential features such as drop-down menus for data entry, an expiry warning system for chemicals, protected worksheets to maintain data integrity, and auto-generated summary reports for equipment and material usage. This was followed by the development

phase, in which the system was enhanced through the application of logical and statistical formulas such as COUNTIF and SUMIF, supported by conditional formatting to improve both visual clarity and analytical functionality. Validation of the system involved three expert validators specializing in content, media, and technology who used Likert scale-based instruments to assess the product. Feedback obtained from these experts was utilized to refine the system until it met feasibility standards. The implementation phase was carried out through workshops at each partner school, consisting of two sessions per day, which involved chemistry teachers, laboratory heads, and laboratory staff. In these workshops, participants were trained to perform real-time inventory data entry, chemical usage logging, and printing of inventory and practicum logbook reports, ensuring that the developed system could be applied directly in the school laboratory setting.

The evaluation phase was conducted through in-depth interviews, analysis of user feedback, and examination of the documents generated by users. This allowed for both qualitative and quantitative assessment of the system's usability, practicality, and effectiveness in actual laboratory management. The evaluation process provided comprehensive insights into the extent to which the system improved the efficiency and accuracy of laboratory management practices in secondary schools. Furthermore, feasibility data were collected through validation instruments administered to three expert validators who assessed the content, media, and technology aspects of the developed system. The assessments used a five-point Likert scale, which was later converted into percentage-based feasibility scores to ensure standardization of the results. The classifications of system feasibility were categorized into five levels as presented in Table 1.

Table 1. Media Feasibility Interpretation Criteria

Media Feasibility Assessment (%)	Interpretation Criteria
$x > 81$	Highly Feasible
$61 < x \leq 80$	Feasible
$41 < x \leq 60$	Moderately Feasible
$21 < x \leq 40$	Less Feasible
$x \leq 20$	Not Feasible

(Source: Rustandi, 2021)

The practicality aspect of the system was obtained from the responses of primary users: teachers, laboratory assistants, and laboratory heads. It was through a structured questionnaire that contained indicators related to ease of use, efficiency, and relevance to the actual needs of school laboratory management. Data reflecting teacher and user responses toward the Chemlab Excel media were collected during the field trial process through questionnaires distributed to all participants involved in laboratory operations. The assessment employed a five-point Likert scale with scoring criteria of 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, and 1 = Strongly Disagree, allowing participants' perceptions to be quantified and subsequently analyzed. The use of this measurement tool ensured that the practicality of the system was evaluated not only from a descriptive perspective but also through systematic and empirical analysis.

Furthermore, the interpretation of the practicality results was carried out by referring to classification categories of response quality, ranging from "very impractical" to "very practical," thereby enabling the identification of the system's level of usability in school contexts. This categorization was essential in determining whether the Chemlab Excel system could be implemented independently by users without requiring additional technical training, thus ensuring its alignment with the practical conditions and resource limitations of schools. As a reference for the interpretation process, the benchmark for classifying the percentage of teacher responses is summarized in Table 2.

Table 2. Practicality Interpretation Criteria

Score Range (%)	Qualitative Criteria
81 – 100	Very Practical
61 – 80	Practical
41 – 60	Moderately Practical
21 – 40	Impractical
0 – 20	Very Impractical

(Source: Sugiyono, 2019)

The System Usability Scale (SUS) is a widely adopted instrument for evaluating the usability of digital systems, applications, and platforms. The SUS questionnaire consists of ten statements, alternating between positively and negatively worded items, which are rated using a 5-point Likert scale (1 = *Strongly Disagree* to 5 = *Strongly Agree*) (Welda et al., 2020). Scoring follows a standardized process in which the responses to positively worded items (odd-numbered) are adjusted by subtracting one point from the user's score (i.e., *score = x – 1*), while responses to negatively worded items (even-numbered) are adjusted by subtracting the user's score from 5 (i.e., *score = 5 – x*) (Khaldun et al., 2022). The adjusted values for all ten items are then summed and multiplied by 2.5, resulting in a final SUS score that ranges from 0 to 100, as described by standard methodology (Souza et al., 2024; Putra et al., 2024). This score provides a quantitative measure of system usability from the user's perspective and has been proven to be both valid and reliable across various contexts, including educational platforms, mobile applications, and website usability studies (Vlachogianni et al., 2021; Hyzy et al., 2022). The interpretation of SUS scores generally follows the Acceptability Range, Grade Scale, and Adjective Rating systems. According to established guidelines (Ardhana, 2022), the scores are categorized as in Table 3.

Table 3. Interpretation of SUS Scores

Score Range (%)	Qualitative Criteria
71-100	Acceptable
51-70,9	Marginal
0-50,9	Not Acceptable

(Source: Ardhana, 2022)

Furthermore, a SUS score above 68 is generally interpreted as an indicator of good usability, whereas scores below this threshold suggest that certain aspects of the system require further improvement to enhance effectiveness and user satisfaction (Vlachogianni et al., 2021). These interpretations are consistent with prior usability studies and serve as an important benchmark for determining the practicality, efficiency, and user-friendliness of digital systems across various contexts. To ensure the robustness of the findings, the instruments employed for data collection, including observation sheets and questionnaires, underwent a rigorous process of validation and reliability testing to guarantee that they accurately measured the intended constructs and consistently produced dependable results. Content validity was evaluated through expert judgment and quantified using Aiken's V coefficient, which statistically examines the extent to which each instrument item adequately represents the targeted concept (Maulana, 2022; Subarkah et al., 2022). In parallel, the reliability of the instruments, which comprised both the teacher response questionnaire and the SUS questionnaire, was tested using the Intraclass Correlation Coefficient (ICC), a statistical approach widely applied to measure internal consistency and inter-rater reliability in educational and usability research. An instrument was deemed reliable when it achieved both an ICC and an Aiken's V value of at least 0.70, thereby reflecting a strong level of agreement among expert raters as well as a high

degree of internal consistency across the items (Tong et al., 2020). Establishing both validity and reliability is therefore essential, as it strengthens the credibility of the data collection instruments and ensures that the results obtained from this research can be considered trustworthy, accurate, and generalizable.

RESULTS AND DISCUSSION

The ADDIE development model comprises five primary stages: analysis, design, development, implementation, and evaluation. A literature review revealed that many senior high school chemistry laboratories in Indonesia still rely heavily on manual inventory methods, such as logbooks or paper documentation, which are prone to data loss, slow tracking, and poor integration between equipment, chemical records, and practicum activities (Ahnaf & Puspitasari, 2023; Rasagama et al., 2023). Additional barriers include the lack of trained laboratory staff and limited access to digital infrastructure, particularly in non-urban areas where schools face significant challenges in adopting modern systems (Jofrishal & Munandar, 2021; Nurhafidhah et al., 2021). Field observations in SMA Negeri 1 Samalanga and SMA Negeri 1 Bireuen confirmed these issues, revealing that handwritten inventory systems, the absence of labeling for hazardous chemicals, unmonitored equipment conditions, and uncoordinated practicum scheduling remain prevalent. These constraints collectively contribute to inefficiencies in laboratory preparation, accumulation of chemical waste, and heightened safety risks. Moreover, current management systems are unable to support the pedagogical demands of the Merdeka Curriculum and 21st-century learning, both of which emphasize digital integration, collaboration, and safety as essential components of effective science education. Curriculum analysis further confirmed that practicum-based learning is strongly encouraged, especially for core topics such as atomic structure, chemical bonding, colligative properties, and redox reactions. However, the absence of a structured and practical laboratory management system continues to hinder its optimal implementation.

Observation and interview data indicated that both teachers and laboratory staff prefer using familiar and straightforward digital tools such as Microsoft Excel, as this platform requires neither internet connectivity nor additional software installation, making it more practical for schools in areas with limited infrastructure. Desired features for such a system include automatic inventory tracking, practical scheduling, data search functions, and a user-friendly interface that can be operated without technical training. Based on these needs, the Chemlab Excel system was conceptualized as an offline, spreadsheet-based platform that integrates automatic inventory, practicum monitoring, and reporting functions. The design of this system is aimed at enhancing administrative efficiency while maintaining accessibility and contextual appropriateness for school environments, particularly those constrained by inadequate resources, thereby offering a feasible and sustainable solution for laboratory management in Indonesian senior high schools.

The initial system design was developed by considering the key components identified during the needs analysis, namely: 1) an inventory of laboratory tools and materials that can be updated in real time; 2) a practicum logbook that records schedules, implementation, and student practicum evaluation notes; 3) automatic search and reporting features using Excel formulas such as COUNTIF, SUMIF, and VLOOKUP to facilitate data tracking and report generation; 4) chemical expiration alerts through conditional formatting; 5) protected sheets to maintain data integrity; and 6) inter-sheet navigation using hyperlink buttons to assist non-technical users such as teachers and laboratory staff. The system's structure and interface were designed with a user-friendly layout to ensure ease of operation, eliminating the need for intensive training. At this stage, validation and feasibility test forms were also prepared to collect feedback from expert validators covering aspects of content, media, and technology, thereby ensuring the accuracy and practicality of the system. Once the

requirements were identified, the Chemlab Excel system was constructed as a set of interlinked Microsoft Excel worksheets supporting comprehensive laboratory management tailored to the context of secondary school settings. The system integrates essential functions, including inventory tracking, practicum documentation, automated reporting, safety monitoring, and navigation features, within an offline, user-friendly interface. Similar approaches using spreadsheet-based platforms have been reported to be effective in managing chemical inventories in educational laboratories with limited infrastructure (Ismail & Prihatini, 2023; Ng, 2018). Core sheets, such as "Chemical Materials" and "Standard Tools," serve as primary databases to record item names, quantities, storage locations, and conditions, equipped with data validation functions to minimize input errors (Kim et al., 2015). While spreadsheets remain widely adopted due to their accessibility, transitioning to a more advanced database management system (DBMS) has been suggested to improve scalability, search efficiency, and compliance with FAIR data principles (Findable, Accessible, Interoperable, and Reusable) (Duke et al., 2022).

Furthermore, the system features transaction capabilities that track both incoming and outgoing materials, enabling semi-digital monitoring of circulation processes in accordance with recommended best practices for laboratory inventory management (Lab Manager Editorial Team, 2025). The design also incorporates summary sheets that automatically generate monthly and activity-based reports, facilitating administrative oversight and supporting internal audits in schools. In addition, the "PRACTICUM" sheet serves to align planned activities with the actual utilization of laboratory tools and materials, while the "SAFETY" and "ORGANIZATION" sheets ensure compliance with standard operating procedures (SOPs) and clarify task distribution among laboratory staff. To strengthen data protection, password locks and worksheet protection are applied to critical data tables, thereby preventing unintentional modifications to sensitive data. Overall, Chemlab Excel offers a cost-effective and practical solution that strikes a balance between efficiency, data security, and accountability, making it particularly suitable for school environments with limited internet access or insufficient specialized software support. By combining familiar spreadsheet features with automation and protection mechanisms, the system not only addresses the current challenges of manual documentation but also lays the groundwork for sustainable and safer laboratory management practices in Indonesian senior high schools. As outlined in Table 4 regarding the user workflow steps, Figure 2 provides a visual representation of the system's logic and the sequential flow of operations within the Chemlab Excel system.

This flowchart illustrates the logic of using the Chemlab Excel system systematically, starting from the input of tools and material data, followed by quick search and navigation processes, practicum recording, and automatic report generation, which are integrated with laboratory safety monitoring to ensure efficiency and accountability in school laboratory management. These interconnected pipelines are designed with enclosed and protected structures to minimize errors and safeguard data integrity, while ensuring that all activities are well-documented. The initial interface of the Chemlab Excel system was developed in the form of a dashboard equipped with navigation buttons that provide direct access to essential functions such as inventory management, practicum activity logging, automated reporting, and laboratory safety features, making it intuitive for teachers and laboratory staff. Furthermore, based on feedback from expert validators, the interface was refined with more colorful visual elements and representative icons to improve readability, usability, and the overall aesthetic appeal of the system. Such improvements in user interface design, guided by expert input and visual affordances, have been shown to enhance user engagement and system usability, particularly in educational tools designed for non-technical users (Papavlasopoulou et al., 2019).

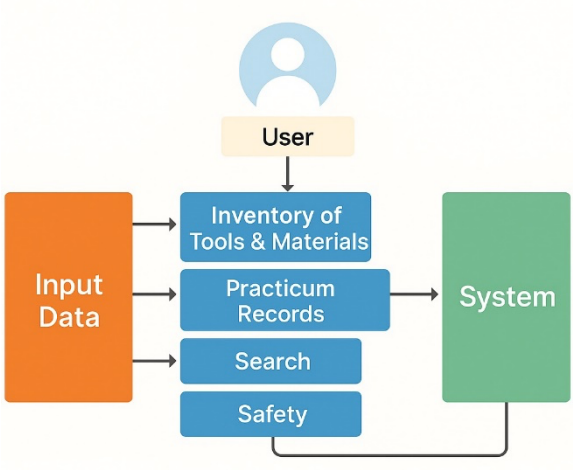

Figure 1. System logic flow diagram and user workflow

Table 4. User Workflow in Chemlab Excel

Usage Levels	Activity Description
Log in to the Initial Dashboard	The user opens the "HOME" sheet as a navigation center to access all the main features (inventory, practicum, reports). It features an intuitive view with visual icons.
Tool and Material Data Input	The user selects the "TOOLS" and "MATERIAL" sheets to record the name, quantity, condition, storage location, and status of the materials (active/expired).
Quick Search and Navigation	Through the "SEARCH" and "Search Materials" sheets, users can instantly search for items based on keywords, thereby accelerating data access and practical efficiency.
Practicum Recording	In the "PRACTICUM" sheet, the user documents the date, class, topic, tools/materials used, number of uses, and damage records.
Automated reports	The system automatically compiles reports in "notes" sheets and series sheets (1.1, 2.1, etc.) for teacher documentation and reporting purposes.
Data Security System	Important worksheets, such as material inventory and practicum notes, can be locked or restricted in access using the worksheet protection feature in Excel.
Laboratory Safety System & SOP	The "SAFETY" sheet provides information on safety procedures, handling of hazardous materials, and laboratory work learning to support safe work practices.
Lab Monitoring & Organization	The "ORGANIZATION" sheet records the organizational structure of the laboratory, including the duties of the teachers, students, and heads of the laboratories involved.

The development stage involves completing the whole design of the Chemlab Excel system, which includes the interface layout, content structure, and functional integration across worksheets to ensure that all components are operational and ready for expert validation. At this stage, the implementation process translates the initial design into an interactive Excel-based application in which each feature is systematically organized and interconnected to meet the practical needs of high school laboratory users. Design iteration based on expert judgment is crucial to produce a product that is not only academically valid but also practical in field implementation (Papavlasopoulou et al.,

2019). The validation and revision process supports the strengthening of system effectiveness prior to widespread implementation, with input from media experts contributing to the refinement of visual aspects and subject matter experts ensuring chemical accuracy and pedagogical appropriateness. Learning media validated by experts from both content and technology domains are more prepared to be applied in real classroom settings, as they have undergone both functional and aesthetic trials (Zydney et al., 2020). The results of the validation cycle in the Chemlab Excel development not only produced a feasible medium but also strengthened user trust in the system by reflecting a user-centered and iterative design approach (van den Berg & Bozalek, 2024).

Table 5. Excel-based Chemlab Eligibility Validity

Category	*Aiken Index*	Standard Validity	*Intraclass Correlation Coefficient (ICC)*	Standard Reliability
Media	0,852	Valid	0,768	Good Reliability
Material	0,869	Valid	0,761	Good Reliability
User response	0,963	Valid	0,778	Good Reliability

The validation of the Microsoft Excel-based laboratory management system (Chemlab Excel) demonstrates that the developed media, content materials, and user response instruments meet established standards of validity and reliability through the application of Aiken's V and the Intraclass Correlation Coefficient (ICC). The Aiken's V indices obtained for media (0.852), content (0.869), and user responses (0.963) all surpassed the commonly accepted threshold of 0.80, which classifies them as "very valid" according to established criteria (Arum & Khumaedi, 2022), while particularly high values in the user response domain indicate that the instruments effectively capture user perceptions with clarity, relevance, and ease of understanding (Hanum et al., 2023; Aisyah et al., 2023). A value approaching one further reflects strong agreement among validators regarding the appropriateness and relevance of each item (Yadiannur & Rahmah, 2025). In terms of reliability, the ICC values for media (0.768), content/material (0.761), and user responses (0.778) fall within the "good reliability" category, as coefficients above 0.75 demonstrate high levels of agreement among raters and confirm the consistency of the validation process (Kotake et al., 2020; Ginsburg et al., 2023), a conclusion that aligns with findings across various fields where an ICC value above 0.75 is consistently regarded as indicative of good to excellent reliability for instruments, questionnaires, and assessment systems (Praveen et al., 2024).

The results confirm that the validation process conducted by three independent expert validators yielded credible and consistent assessments, thereby enhancing the legitimacy of the instrument's use in research and practical applications. Notably, the highest ratings were obtained from the user response instruments, indicating that the Chemlab Excel system is perceived as practical, easy to use, and responsive to actual field needs. These findings align with Hügel (2019), who emphasized that familiar interfaces, such as those based on Excel, enhance the acceptability and usability of digital tools, particularly among educators and laboratory staff with varying degrees of digital literacy. Additionally, the system's offline capability and customizability make it particularly suitable for schools with limited technological infrastructure, a common issue in many educational settings. The high Aiken's V values in this context reflect not only technical accuracy but also the instrument's capacity to capture the practical reality of users. From a broader perspective, Aiken's V-based validation plays a crucial role in the framework of Education 5.0, particularly in identifying conceptual gaps and promoting continuous improvement in technology-integrated curriculum design (Ramírez, 2024).

These results underscore the importance of striking a balance between material complexity and user comprehensibility in the development of science learning media, ensuring that innovations remain efficient, pedagogically sound, and widely adoptable (Maghfirah et al., 2023; Nabila et al., 2024; Al-Sultan et al., 2021). Based on validator feedback, several revisions were made to improve the Chemlab Excel system, particularly in terms of interface design and navigation. The homepage was enhanced with more representative visual icons, brighter color gradients, and proportionally placed system titles to create a more user-friendly and recognizable display, especially for teachers and students using the system for the first time. This design approach aligns with established principles in educational media design, where the application of visual hierarchies and affordances enhances cognitive accessibility and engagement (Clark & Mayer, 2023). To address criticisms regarding limited navigation, "Back" and "Main Menu" buttons were added in each section and arranged uniformly, supported by built-in pop-ups and hyperlinks that facilitated more straightforward navigation without manual scrolling. Validators also emphasized the need for more precise categorization of information, which was addressed by adding color to data tables, rearranging margins and text blocks, and inserting borders between important sections. These revisions not only improved aesthetics but also enhanced functional clarity, enabling users to identify the function of each element quickly. According to multimedia learning theory, visual grouping and color-coding can significantly improve the efficiency of information processing, particularly for novice users with limited digital literacy (Clark & Mayer, 2023). Three expert validators validated the management system of the chemistry laboratory using Microsoft Excel. The results are presented in Figure 2.

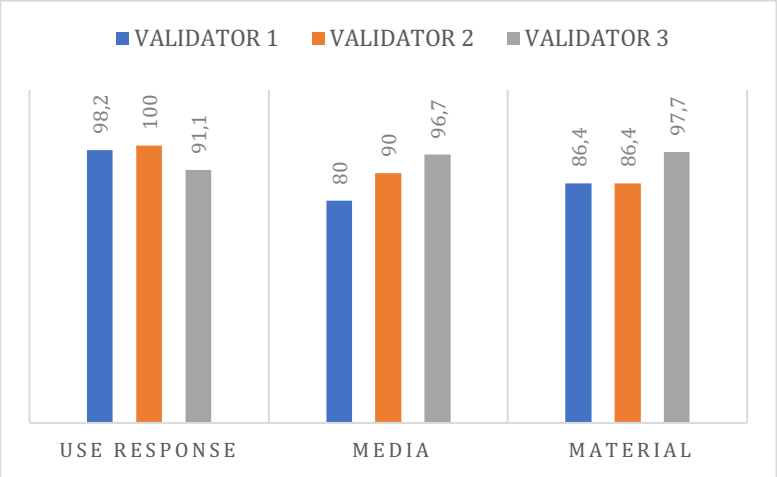

Figure 2. Instruments Validity

The validation results of the ChemLab Excel system, assessed by three expert validators, demonstrate consistently high feasibility scores across all measured aspects, with the teacher response questionnaire obtaining average scores of 98.2%, 100%, and 91.1% from Validator 1, Validator 2, and Validator 3, respectively, placing it within the "very feasible" category. The media feasibility aspect recorded average scores of 80%, 90%, and 96.7%, reflecting strong agreement among validators on the adequacy of the system's interface, auxiliary information, navigation, and robustness features. In comparison, the material feasibility aspect achieved average scores of 86.4%, 86.4%, and 97.7%, indicating high content relevance, accuracy, and appropriateness for the intended educational context. These results confirm that the ChemLab Excel system meets both content and media feasibility standards for educational technology products, with consistently high percentages, particularly in the teacher response and media feasibility components, suggesting strong alignment

between the system's design features and user expectations, as supported by previous findings on usability and acceptability in digital laboratory management tools.

The implementation stage involves the direct application of a Microsoft Excel-based chemical laboratory management system in two schools: SMA Negeri 1 Samalanga and SMA Negeri 1 Bireuen. The objective is to evaluate the system's functionality, ease of use, and effectiveness in the actual working context of the school laboratory. The primary target users included chemistry teachers, laboratory staff, and the head of the laboratory, who are responsible for managing equipment, materials, and practical activity documentation, and the implementation was carried out through hands-on training sessions where users tested features such as inventory logging, practicum reporting, data search for materials/equipment, and automatic recap functions. Observations conducted in a participatory manner assessed users' understanding of workflows, data entry accuracy, and navigation efficiency. The results showed that most users were able to operate the system independently after a brief orientation, demonstrating that the system is user-friendly and suitable for schools with limited technological resources.

Chemistry teachers expressed positive responses to the practicum search feature based on teaching topics, while laboratory staff appreciated the efficiency of recording and monitoring the stock of tools and materials. The head of the laboratory focused on the validity and integration of data for internal reporting. All users stated that the system helped simplify laboratory workflows that were previously managed manually. To complement the evaluation, users completed a practical usability questionnaire that covered aspects of user-friendliness, system usefulness, and work efficiency. Both quantitative and qualitative feedback indicated that the ChemLab Excel system is not only feasible to use but also has the potential for broader adoption as a practical digital-based laboratory management solution in secondary schools. In the implementation of Chemlab Excel, teachers reported that tasks such as inventory management, practicum reporting, and tracking laboratory equipment became significantly more efficient compared to previous manual methods. These findings confirm that the Chemlab Excel system meets practical usability standards and is well-suited for integration into laboratory-based learning environments.

In the ADDIE-based research and development (R&D) model, the evaluation stage focuses not only on technical aspects such as usage time or input error rates, but also on users' perceptions of ease of use, interface consistency, and interaction efficiency. In this context, the System Usability Scale (SUS) serves as a highly relevant instrument for evaluating the efficiency of the Chemlab Excel system. SUS provides standardized quantitative data that reflects the overall quality of a system, particularly across four main dimensions: 1) Ease of use; 2) Consistency and comfort of interaction; 3) Usability and effectiveness of features and navigation; and 4) Time required to understand and adapt to the system. Its simplicity, quick analysis process, and psychometric validity make the SUS a widely used instrument in the evaluation of digital educational tools (Sauro & Lewis, 2016; Albert & Tullis, 2022). By employing SUS in this study, the evaluation process remains aligned with the goals of assessing system efficiency and effectiveness from the user's perspective. The resulting quantitative usability score enables academic comparison with other systems, supporting the principle of practicality validation emphasized in modern R&D evaluation models (Zydney et al., 2020). This approach ensures that the Chemlab Excel system is not only functional but also user-centered, measurable, and applicable in real-world educational contexts.

Table 6. Results of Teachers' Responses to the SUS Questionnaire against Microsoft-based *Chemlab*

RESPONDENT	1	2	3	4	5	6	7	8	9	10	SUM	SCORE (Total*2.5)
R1	3	1	4	3	4	0	3	3	3	2	26	65
R2	3	1	3	2	3	1	3	1	2	1	20	50
R3	4	1	4	4	3	4	2	1	4	1	28	70
R4	3	1	4	4	4	4	4	4	4	2	34	85
R5	4	2	3	4	3	4	3	4	4	4	35	87,5
R6	4	1	4	4	4	3	3	3	3	3	32	80
R7	4	3	4	3	2	2	4	1	1	3	27	67,5
R8	3	3	4	4	3	2	3	2	2	3	29	72,5
R9	3	3	4	4	2	2	3	2	2	4	29	72,5
											Total	650
											Average SUS Score	72,22
											Category	Acceptable

The practicality of the Chemlab Excel system was further evaluated using the System Usability Scale (SUS), which is a standardized and widely recognized instrument designed to assess usability from the user's perspective in digital systems. The system achieved a SUS score of 72.22%, placing it in the "Usable/Acceptable" category and surpassing the minimum threshold that indicates ease of operation without requiring intensive training or advanced digital literacy (Ardhana, 2022). This finding demonstrates that the system can be effectively operated by teachers and laboratory staff with only minimal guidance, reflecting its practicality in real educational contexts where time and resources are often limited. The use of SUS as an evaluation tool in this study also strengthens the validity of the results, as its psychometric properties have been confirmed in numerous previous applications. For instance, SUS-based evaluation of Excel-based learning media for spectrophotometry obtained a comparable score of 72.5%, leading to recommendations for its integration into school laboratory practices (Khaldun et al., 2022). Likewise, interactive laboratory learning media developed by Nazar et al. (2020) achieved a SUS score of 71%, confirming the broader applicability of SUS for determining the acceptability of educational innovations. These comparative findings highlight that the Chemlab Excel system is not only feasible and reliable but also practical for classroom and laboratory implementation, supporting its potential as a scalable solution for school-based laboratory management.

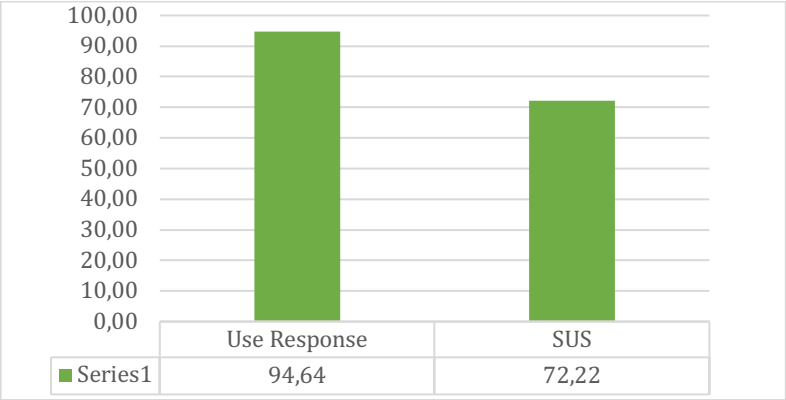

Figure 3. Average Results

User responses were obtained through two main instruments: a Likert scale-based practicality questionnaire and the System Usability Scale (SUS). The ChemLab Excel system has demonstrated

significant potential as an educational tool, as evidenced by the validation results presented in Figure 4. The average score percentages for usage and response, as well as the System Usability Scale (SUS), indicate a high level of acceptance among users, with scores of 94.64% and 72.22%, respectively. These figures reflect the system's effectiveness in supporting laboratory activities with minimal guidance, aligning with prior studies that emphasize the importance of intuitive design in educational technologies. Laboratory inventory best practices, such as those involving technology-based tools to enhance engagement and outcomes, are crucial for mitigating inefficiencies and risks in school laboratories (Ryanto et al., 2025). This approach aligns with the need for critical cognitive skills in addressing educational challenges (Ramadani et al., 2025), as evidenced by the system's ability to support teachers in analyzing inventory data and ensuring safety during trials at SMA Negeri 1 Bireuen and SMA Negeri 1 Samalanga. Moreover, digital-based student worksheets are an innovative alternative to learning because they can increase students' interaction, understanding of concepts, and critical thinking skills (Nilawati et al., 2025), a principle that Chemlab Excel exemplifies through its core sheets for managing chemical materials and tools. Teacher acceptance is a critical factor in the successful adoption of educational technology. In this case, the high practicality score highlights the system's user-friendliness, relevance to daily tasks, and its offline accessibility features, which are particularly beneficial for schools with limited internet connectivity or infrastructure.

CONCLUSION

The development of the Microsoft Excel-based laboratory management system, Chemlab Excel, has been demonstrated to be valid, practical, and effective in enhancing the management of secondary school chemistry laboratories. Validation results confirmed high feasibility, with Aiken's V scores of 0.869 for content and 0.852 for media, alongside inter-rater reliability (ICC) values ranging from 0.761 to 0.778, reflecting good consistency among expert assessments. A limited implementation trial with teachers yielded an average practicality score of 94.64%, covering essential aspects such as media usability, content accuracy, and administrative efficiency. Furthermore, usability testing using the System Usability Scale (SUS) produced a score of 72.22%, which falls within the "Usable/Acceptable" category, affirming that the system is user-friendly and requires minimal training to operate effectively. Chemlab Excel was also found to support efficient laboratory administration, minimize chemical waste, and reinforce compliance with laboratory safety protocols, while simultaneously facilitating practice-oriented learning aligned with the Merdeka Curriculum. Taken together, these findings indicate that Chemlab Excel is not only scalable and sustainable but also provides a practical and user-centered digital solution to modernize school laboratory management. Therefore, it is strongly recommended as a reliable tool to improve safety compliance, optimize administrative processes, and enhance the overall quality of science education in secondary schools.

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