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Digitally Enhanced Chunk & Check Learning: An Innovative, Instructor-Friendly Approach Powered by an Open-Source Tool for Effective Laboratory Instruction and Formative Assessment

Kanong Ruttanakorn and **Theerasak Rojanarata***
Silpakorn University
Nakhon Pathom, Thailand

Abstract. This study introduces digitally enhanced chunk & check learning, an innovative, user-friendly framework for active learning and formative assessment in laboratory instruction. Chunk & check learning uses familiar Google Workspace applications—Google Slides, Google Forms, and Google Sheets—for easy adoption. Central to this approach is the custom-built "Chunk & Check Creator", which automatically segments instructional content into discrete learning chunks on Google Slides, each paired with formative assessment quizzes delivered through Google Forms. Students unlock subsequent chunks only after completing preceding quizzes and receiving instructor approval, ensuring mastery before progression. Instructors can monitor student learning progress in real-time through dynamic dashboards in Google Sheets, facilitating timely and targeted feedback. Implemented in a pharmaceutical science laboratory with 158 students and 13 instructors, the approach received high satisfaction ratings (students: 4.70/5 for approach, 4.56/5 for tools; instructors: 4.91/5). Students reported increased engagement, improved interaction with peers and instructors, and deeper understanding. Instructors valued real-time tracking and automation. Academic outcomes were strong, with formative quiz scores averaging over 90% and a final exam average of 72.40%. The open-source Chunk & Check Creator is freely available at https://tinyurl.com/Chunkcheckcreator, offering an effective, scalable, low-overhead solution for digital pedagogy.

Keywords: chunk & check learning; laboratory; collaborative learning; formative assessment; Google Workspace

*Corresponding author: Theerasak Rojanarata; *Rojanarata_t@silpakorn.edu*

1. Introduction

As modern education becomes increasingly complex and content expands, educators face the challenge of designing strategies that enable learners to master material effectively. Among various approaches, chunked learning—organizing extensive content into logically ordered, manageable segments or chunks—has gained prominence for supporting student learning. Grounded in cognitive science, this method recognizes that learners process and retain segmented information more efficiently than content presented all at once (Ngandoh et al., 2025; Sharkey, 2025; Shibli & West, 2018). Each chunk addresses a distinct concept or procedural step, fostering deeper concentration before moving forward.

Effective chunked learning design involves organizing instruction into meaningful, coherent segments that align with the natural structure of the content. Chunk size should reflect cognitive load, with smaller chunks suited for complex or unfamiliar material and larger chunks appropriate for experienced learners (Ingram Nissen et al., 2024; Jones, 2012; Main, 2022; Tan et al., 2025). Sequencing chunks from foundational to advanced concepts enhances learning by building systematically on prior knowledge (Chen et al., 2015).

Allowing learners to control the pacing of chunks often leads to better outcomes, as it accommodates individual processing needs (Rey et al., 2019; Tullis & Benjamin, 2011). Incorporating active learning activities—such as questions or reflection prompts—within or after chunks further strengthens understanding and long-term retention (Prabawa et al., 2024; Zhang et al., 2023). Furthermore, contemporary educational technology provides unprecedented capabilities for implementing and optimizing chunked learning approaches. Learning management systems increasingly incorporate features specifically designed to support content segmentation, including modular course structures, sequential release mechanisms, and built-in assessment tools that provide feedback after each chunk (Learning Corner, 2024).

The principles of chunked learning have been successfully applied across remarkably diverse educational domains, from elementary science to professional medical training, demonstrating the broad applicability of segmentation strategies (Ingram Nissen et al., 2024; Tan et al., 2025). In hands-on or laboratory environments, chunked learning is especially effective—reducing cognitive overload, minimizing confusion, and ensuring each step is clearly understood before proceeding (Shibli & West, 2018).

The impact of chunked learning increases when formative checkpoints are integrated between segments. These checkpoints—such as brief quizzes, discussions with instructors, reflective exercises, and feedback opportunities—confirm understanding, enable timely correction of misconceptions, and reinforce knowledge retention (Ketonen et al., 2023). Integrating formative assessment into instruction not only facilitates real-time enhancement of student learning but also promotes sustained improvement over time (Carney et al., 2022). This process forms the basis of the "chunk & check" model, shown to enhance engagement, motivation, and skills development (Al Hadi & Zhang, 2025; Ngandoh et al., 2025). Structured, sequential learning environments that incorporate formative assessment ensure that misunderstandings do not accumulate and that all students progress with a solid foundation.

Simultaneously, digital transformation is reshaping educational methodology. Digital tools offer interactive, student-centred experiences both inside and outside the classroom, with resources such as online platforms and cloud-based collaboration tools allowing flexible access to materials, real-time communication, and efficient management of learning activities (Kayanja et al., 2025; Mukul & Büyüközkan, 2023). This shift enables educators to respond to diverse learner needs and drives innovative instructional models.

One key element of this transformation is the use of collaborative online platforms, such as Google Workspace and Microsoft Office 365, which support students working together synchronously or asynchronously (Parra et al., 2021; Robinson, 2022; Rojanarata, 2020). Such environments encourage group coordination and knowledge-sharing and strengthen communication and problem-solving skills—abilities vital in the modern world. In laboratory instruction, these tools provide new ways to structure group tasks, record observations, and facilitate communication among both students and instructors (Dao et al., 2025; Indumathi et al., 2024).

Google Slides is particularly popular for delivering interactive activities and digital worksheets, as it is a familiar tool that allows users to incorporate various types of content, such as text, images, video clips, audio, and links, along with the benefit of real-time editing (Rojanarata et al., 2021). However, delivering a single worksheet containing all learning content or assigning all lab activities at once can undermine chunked learning, particularly in group settings. In these situations, students might split the assignment so that each individual works on only one section before simply "stapling" their contributions together into a group paper.

This approach reduces overall engagement—especially when group discussions are absent—and may lead to gaps in understanding while limiting opportunities for collaborative learning (Frazee, 2021; Heflin & Meganck, 2017; Scager et al., 2016). Additionally, from a technical standpoint, Google Slides does not currently support revealing divided content section by section in response to student progress. It also lacks built-in formative checkpoints, making it difficult to identify and address student misunderstandings.

The study wanted to address the challenges of delivering learning content in a way that supports chunked learning and formative assessment within a new platform utilizing digital tools familiar to both teachers and students. To do so, the study was guided by research questions examining 1) how a digital chunk & check model impacts active learning in laboratory settings, 2) the extent to which this approach enhances content comprehension during hands-on instruction, 3) the effectiveness of integrating formative assessment into laboratory learning through digital checkpoints, and 4) student satisfaction levels with this digital learning approach. Based on these questions, the study aimed to develop and evaluate a digital chunk & check model designed specifically for hands-on laboratory instruction. In this approach, Google Slides files, serving as worksheets, are enhanced to allow content to be gradually revealed section by section, while the checkpoints for formative assessment—also functioning as mechanisms to unlock each subsequent section, such as short quizzes or student self-evaluations—are embedded within the platform by linking these worksheets with Google Forms. By integrating these components, the model seeks to enhance both the process and outcomes of group-based laboratory learning, offering valuable insights for best practices as education advances in the digital age.

2. Methods

2.1 Structure and Workflow of Digitally Enhanced Chunk & Check Learning

The digital chunk & check learning model is designed to foster progressive mastery of content while supporting continuous assessment through the integration of three core Google Workspace applications: Google Slides, Google Forms, and Google Sheets. Each application fulfills a distinct yet complementary role in the learning process. Figure 1 schematically presents the workflow between Google Slides and Google Forms, the two primary student interfaces that are employed to deliver sectioned instructional content and activities and to evaluate comprehension in structured, sequential segments.

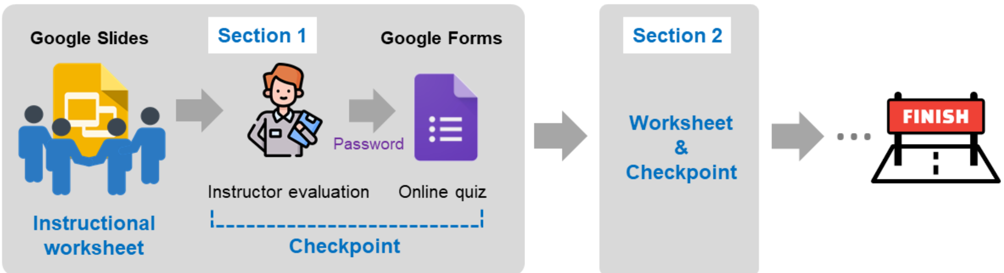

Figure 1: Concept of digital chunk & check learning

2.1.1 Google Slides as the worksheet for learning activities

Students receive their learning task and activity assignments through Google Slides, which functions as the digital worksheet. Instructional content is divided into small sections, each containing assignments such as problem-solving questions or experimental tasks. For example, Section 1 may span Slides 1–3, Section 2 covers Slides 4–6, and so forth. In these online slides, students working in groups can engage in real-time collaboration, using them as a digital laboratory notebook or report to record experimental results, upload images, and provide written responses (Figure 2).

Initially, students are granted access only to the first section of content—the initial set of slides—to ensure focused engagement with the current assignment before progressing further. Subsequent sections are released incrementally, becoming accessible only after students complete and pass instructor evaluations and online quizzes for the preceding sections. This controlled release mechanism ensures mastery before progression and mitigates the common issue of divide-and-conquer groupwork that often occurs when large assignments are given in their entirety.

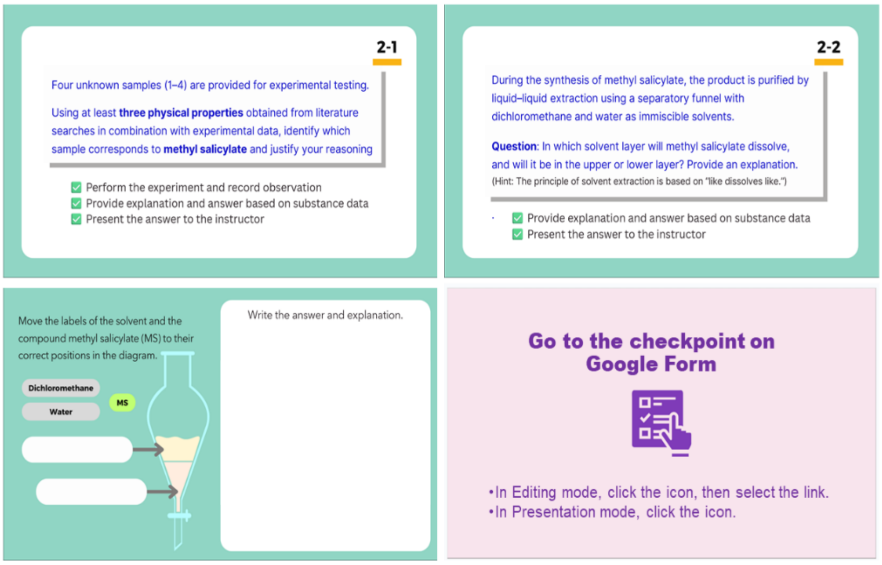

Figure 2: Example of Google Slides worksheets and report for learning Section 2, with the last slide embedding a link to the checkpoint quiz on Google Forms

2.1.2 Google Forms as formative checkpoints

After completing each section in Google Slides, students are directed via a link on the last slide of the current section to a corresponding Google Forms file. This form acts as a checkpoint, featuring a quiz and a self-assessment form to confirm their understanding of the material just learned. Prior to accessing the form, students are required to present and discuss their work with the instructor, serving as an in-person checkpoint to ensure understanding before progression. After reviewing the students' work, the instructor provides them with the access code or password used to unlock the form.

Once students complete the quiz and self-assessment form and submit them, the system automatically adds the next set of slides (i.e., the next section of content) to the same Google Slides file, allowing them to continue with the next assignment. In this way, student progress is assessed through blended in-person and online methods, ensuring rigor and interactivity in the learning experience. Technically, submitting the Google Forms file acts as the trigger mechanism that automatically appends the next section to the end of the Google Slides file the students are actively working on.

This process continues incrementally, with each task followed by a checkpoint, until all sections are completed. By organizing the workflow this way, all learning content is consolidated in one Google Slides file—making it easy for students to manage and export as a PDF file for reviews, such as exam preparation. Not only does this method ensure that students build their knowledge step by step, but it also supports immediate feedback and ongoing self-assessment throughout the learning journey.

2.1.3 Google Sheets as a centralized data platform and progress tracker

Exclusively for instructors, Google Sheets functions as an interface for inputting data—enabling the creation, management, and distribution of chunk & check document files. Additionally, it serves as a centralized hub to collect and monitor student progress and responses from multiple groups in real-time. This section is inaccessible to students, and data from completed Google Forms files are automatically aggregated into dashboards, providing instructors with a comprehensive overview to efficiently track performance, assess class progression, and identify areas that require extra support or instructional adjustments.

2.2 Development of the "Chunk & Check Creator"

To assist instructors in efficiently managing and executing the various steps involved in digital chunked learning activities—such as constructing sectioned worksheets, assigning tasks, linking Google Slides to corresponding Google Forms, and generating access codes—a new automated tool, the Chunk & Check Creator, was developed in this work. Operating as an add-on within Google Sheets, this tool streamlines the preparation and administration of digital chunked assignments and provides the following core functionalities.

2.2.1 Automated template generation

The instructor begins the assignment setup by specifying the number of content sections. The tool then automatically generates individual Google Slides files for each section (e.g., Section 1, Section 2), with the final slide of each file linking to a pre-made Google Forms file for quizzes and self-assessment. Since access to the Google Forms file is intentionally secured with access codes or passwords, the Chunk & Check Creator automatically generates these codes alongside the form. Depending on the instructor's preference, it can either create a single code for all sections or generate unique random codes for each section. All essential details, including file links and access codes, are compiled into a summary sheet within Google Sheets, while a dedicated Google Drive folder stores all the generated files for streamlined management.

2.2.2 Flexible section sequencing

The tool offers multiple options for sequencing content delivery. Instructors can choose sequential, random, or custom section orders for each group. These configurations are tracked in automatically generated summary sheets within Google Sheets, displaying each group's assigned sequence and storing participant details (names, emails, groups, instructors) in a participant list for easy reference and automation in subsequent assignment creation.

2.2.3 Automated assignment distribution

Using the predefined group structures and section orders, the tool automatically creates and shares Google Slides files with the students and instructors via email. File permissions are set to ensure that students only access their own group's assignments. All assignment files are organized into group-specific folders inside a "Student Files" directory in the instructor's Google Drive, making both distribution and management efficient.

2.2.4 *Real-time progress monitoring*

An activity tracking sheet on Google Sheets allows instructors to view each group's progress on every section, categorized as "Not started", "In progress", or "Completed" (Figure 3). This real-time tracking helps instructors spot where groups may be struggling and intervene promptly.

Group	Step 1	Step 1-Status	Step 2	Step 2-Status	Step 3	Step 3-Status	Step 4	Step 4-Status	Step 5	Step 5-Status	Step 6	Step 6-Status
1	Section-1	Completed (13:00:42)	Section-3	Completed (13:10:23)	Section-5	Completed (13:45:55)	Section-4	Completed (14:00:42)	Section-2	In progress	Section-6	Not started
2	Section-1	Completed (13:05:35)	Section-3	Completed (13:18:42)	Section-5	Completed (13:55:42)	Section-4	In progress	Section-2	Not started	Section-6	Not started
3	Section-1	Completed (13:03:40)	Section-3	In progress	Section-4	Not started	Section-2	Not started	Section-5	Not started	Section-6	Not started
4	Section-1	Completed (13:10:22)	Section-4	Completed (13:30:42)	Section-5	In progress	Section-2	Not started	Section-3	Not started	Section-6	Not started
5	Section-1	Completed (13:07:32)	Section-3	Completed (13:25:42)	Section-2	Completed (13:50:42)	Section-4	In progress	Section-5	Not started	Section-6	Not started
6	Section-1	Completed (13:08:56)	Section-3	Completed (13:20:42)	Section-5	Completed (13:53:42)	Section-2	Completed (14:10:42)	Section-4	Not started	Section-6	Not started

Introduction · Sections · Pattern Summary · Participant List · Activity Section tracking · Activity Summary

Figure 3: Google Sheets-based dashboard (Activity Section Tracking tab) for real-time monitoring of student group progress across learning sections, indicating status as "Not started", "In progress", or "Completed"

2.2.5 *Integrated score and student feedback reporting*

Quiz results from each Google Forms file are automatically compiled into user-friendly reports that display both average group scores and detailed breakdowns for individual students. All score summaries are dynamically linked to the participant list for comprehensive performance tracking. Additionally, student comments and feedback submitted via Google Forms are incorporated into the reports, enabling instructors to quickly address any issues and continually support the learning process.

In summary, the Chunk & Check Creator provides instructors with a comprehensive and automated solution for structuring, delivering, and managing chunked learning activities. By streamlining the preparation and administration process, this tool greatly reduces manual workload while enhancing instructional efficiency. The Chunk & Check Creator is now available as a free open-source tool and can be downloaded at https://tinyurl.com/Chunkcheckcreator.

2.3 Design and Implementation of the Lesson

The study was conducted within the laboratory topic "Physical and chemical properties of substances and their applications for industrial pharmacy", as part of the laboratory course at Silpakorn University, Thailand. All 158 second-year undergraduate pharmacy students enrolled in the course participated as part of their regular curriculum. The students were divided into two sections, each consisting of 10 collaborative groups of 7 to 8 students, for a total of 20 groups. The teaching team comprised 13 instructors, who served as supervisors and in-person checkpoints throughout the sessions.

Based on the learning outcomes of this lesson, students were required to demonstrate the ability to search for relevant information regarding the properties of pharmaceutical substances, conduct experiments to investigate certain properties, and apply their understanding to explain or solve problems encountered in industrial pharmacy contexts. To facilitate the development of these competencies, the instructional design incorporated multiple learning approaches, including literature and information searching, hands-on experimental work, problem-solving, brainstorming, and group discussion. In accordance with the chunked learning approach, the content was divided into five distinct sections, each focusing on different sub-topics and targeted assignments. Details of these sections and the learning activities are provided in Table 1.

Table 1: Learning sections and activities conducted in this study

Section	Topic	Learning activities
1	Exploring the properties of pharmaceutical substances	• Search the literature for the properties of five substances (salicylic acid, methyl salicylate, bismuth subsalicylate, sodium salicylate, acetylsalicylic acid). • Learn the basic operation of a melting point apparatus by watching the assigned YouTube video provided via the link.
2	Basic physical properties of substances (state of matter, water solubility, density)	• Four unknown samples (A1–A4) are provided for experimental testing. Using at least three physical properties obtained from literature searches in combination with experimental data, identify which sample corresponds to methyl salicylate and justify your reasoning. • During the synthesis of methyl salicylate, the product is purified by liquid–liquid extraction using a separatory funnel with dichloromethane and water as immiscible solvents. Question: In which solvent layer will methyl salicylate dissolve, and will it be in the upper or lower layer? Provide an explanation.
3	Properties of salts (solubility, pH, salting-out effect)	• Two samples (B1 and B2) are provided. Perform experiments and use solubility data from references to identify which sample is salicylic acid and which is sodium salicylate, with justification. • Conduct experiments to evaluate the acid–base properties of the samples in order to support the identification in the previous task. • Addition of citric acid to a sodium salicylate solution may cause precipitation. Explain the underlying reason for this phenomenon.
4	Melting point	• Two samples (C1 and C2) are provided, where one is pure acetylsalicylic acid and the other is acetylsalicylic acid containing salicylic acid as an impurity. Determine their melting points experimentally and identify the pure compound, providing justification based on the results.
5	Chemical properties	• Two samples (D1 and D2) are provided, where one is pure acetylsalicylic acid and the other is partially decomposed acetylsalicylic acid. Without relying on

		odor or physical property tests, perform a preliminary chemical test using ferric chloride to distinguish between the two samples, and explain the reasoning behind your conclusion.
End	Completion notification	Notification to students that all sections have been completed and the learning session is finished.

To enable collaborative, chunked learning, this lesson employed a digital learning framework integrating Google Slides and Google Forms. Each student group was assigned a shared Google Slides workspace for recording data, discussing results, and answering questions, while short quizzes hosted on Google Forms were used to verify understanding after each section. This setup allowed real-time collaboration, progress tracking, and immediate instructor feedback, both before and during the laboratory sessions.

One week before the on-site class, students received access to Section 1 of the Google Slides file to prepare by searching for information on the properties of the assigned pharmaceutical substances and watching demonstration videos on relevant laboratory instruments. During the on-site laboratory session, other sections were gradually unlocked. Students worked collaboratively in groups to perform experiments, summarize findings, and present their results to supervising instructors, who evaluated their work, facilitated discussions, and provided immediate feedback. Upon successful completion of each section, students received a password granting access to the corresponding Google Forms quiz, ensuring comprehension before proceeding to the next section.

To optimize laboratory resource utilization and maintain academic integrity, each group was assigned the lesson sections in a different randomized order, except that all groups began with Section 1 (pre-lab preparation) and concluded with the End section. This strategy minimized the risk of answer-sharing among neighbouring groups and staggered the use of limited laboratory equipment—such as the melting point apparatus—ensuring all groups could access the necessary tools efficiently. In terms of learning assessment, students were evaluated through a combination of pre-lab quizzes, laboratory techniques (assessed by the instructor), participation in lab activities, including discussions with peers and the instructor (assessed by the instructor), the quality of laboratory reports submitted via Google Slides (assessed by the instructor), and a paper-based midterm examination.

2.4 Data Collection, Evaluation, and Analysis Methods

A triangulated strategy was employed to evaluate the impact of the chunk & check learning system, combining both subjective and objective measures of educational effectiveness. Subjective data were collected via parallel online questionnaires completed by students and instructors upon conclusion of the class. The student survey utilized a five-point Likert scale to assess perceptions of learning facilitation, formative self-assessment, ease of use, collaborative engagement, and overall satisfaction. Open-ended questions allowed for qualitative feedback regarding the learning experience, group process, and suggestions for further improvement. Instructors provided corresponding feedback through a similar survey, which included items on teaching utility, efficiency of formative assessment, ease of monitoring group progress, and overall usability, as well as prompts for narrative elaboration.

Objective academic performance was measured through checkpoint quizzes embedded within each section, gauging immediate mastery of relevant content, alongside a midterm paper-based examination that assessed knowledge retention and transfer. All survey responses were anonymized, with voluntary participation and adherence to institutional ethics guidelines governing research with human participants. In addition, both students and instructors provided consent for the sharing of questionnaire data and the use of photographs in this article.

Descriptive statistics summarized Likert-scale responses, and percentages of "agree" or "strongly agree" reflected group consensus. Quiz and exam scores were aggregated to assess academic performance. Thematic analysis of open-ended responses identified key themes from student and instructor feedback.

3. Results and Discussion

3.1 Improved Course Delivery and Monitoring with Chunk & Check Creator

The introduction of the Chunk & Check Creator resulted in notable improvements in the management and delivery of laboratory coursework for the large class of 158 students. Automated generation of individualized, sectioned worksheets with embedded checkpoints substantially reduced administrative workload and enhanced the scalability of implementation. Each student group received a complete worksheet, with sections presented one at a time in the correct order. This allowed them to progress through content at their own pace while maintaining the overall structure and learning objectives of the course.

Real-time dashboards from student progress data gave instructors immediate insight into each group's status. Instructors could quickly see which checkpoints were completed or pending and identify groups that needed help, enabling timely feedback and early intervention. This helped address learning issues as they arose and reduced the risk of groups falling behind. These findings support the benefits of digital workflow automation and real-time analytics in collaborative education, showing clear improvements in instructional efficiency and classroom management (Lee, 2025; Timotheou et al., 2023).

3.2 Effects on Learning Environment and Stakeholder Perspectives

The implementation of the chunk & check learning approach in the laboratory promoted active student participation and fostered collaborative learning. Students engaged in experimental tasks to address questions, synthesized and discussed their findings, documented results on Google Slides, and presented outcomes to the instructor. These results show that dividing learning activities into smaller, sequential units promotes more active and equitable student participation. It also provides pedagogical advantages over traditional single worksheets that contain extensive content and activities. Importantly, the incorporation of checkpoints—consisting of direct presentation of experimental results or answers to the instructor, together with short quizzes or self-evaluation on Google Forms administered after each learning section—proved beneficial for formative assessment. This approach enabled instructors to monitor students' progress and understanding on a topic-by-topic basis, while also providing timely, targeted feedback to support learning before students advanced to subsequent content.

Building on the positive effects on the learning environment, the chunk & check model notably supports self-paced learning. It avoids imposing strict time limits for each section, giving each group the flexibility to progress at a pace that fits their needs. Students can take extra time on challenging material or quickly move through familiar content, unlike some traditional classroom settings where progress is uniform. This adaptability ensures that each student advances according to their own learning rate (Gera et al., 2022; Millet, 2023).

The student survey data are presented in Table 2, revealing a robustly positive response from students regarding the chunk & check learning. Students widely reported that progressing through laboratory activities in segmented sections contributed to deeper understanding and sustained engagement. The structure, which ensured that no key concepts were skipped and helped maintain focused attention, was credited with improving students' understanding and motivation. The built-in formative checkpoints—conducted through in-person supervisor evaluations and via Google Forms—were particularly valued. Students mentioned that these opportunities for immediate self-assessment and feedback were essential for clearing up misunderstandings and reinforcing correct knowledge before moving on to the next topic.

Table 2: Student evaluation results (n = 140 of 158; 88.61%)

Evaluation item	Mean score (out of 5)
The learning approach and activities facilitate comprehensive understanding of the content	4.71
The approach enables effective self-assessment throughout the learning process	4.70
Worksheets and checkpoints on Google Workspace enhance learning	4.59
Worksheets and checkpoints are convenient to use	4.56
The approach, together with digital worksheets and checkpoints, increases engagement in laboratory activities	4.70
Overall satisfaction with the learning approach	4.70
Overall satisfaction with digital worksheets and checkpoints	4.56

Note: The scores are based on a 5-point Likert scale, where 1 indicates "strongly disagree" and 5 indicates "strongly agree"

The following excerpts are open-ended feedback from the students on the chunk & check model:

> *"By fully completing every laboratory task, without skipping or leaving out any topics, I deepen my understanding."*

> *"I like both this way of learning and its tools. It is exciting because I have never experienced this before, and I feel that it truly allows me to learn together with my peers."*

> *"I much prefer this style of learning. In group work, sometimes tasks are divided, and I do not understand some topics, but with this method, I learn everything and improve my comprehension. Using Google Slides is also very convenient."*

> *"This learning method is excellent. I want it to be adopted as the main learning approach for laboratory."*

> *"I see the instructors' dedication. All of them explain and summarize the content very clearly, which enhances my understanding. I enjoy it very much and strongly support continuing this teaching method."*

> *"I really like this teaching approach. It gives me a clearer overall picture of the contents and allows me to re-check my own understanding."*

> *"It is very enjoyable. I appreciate the instructors' attentiveness in answering questions. I also like learning step by step, and Google Slides is easy to use."*

Regarding collaboration, students found that these tools encouraged genuine teamwork (not a divide-and-conquer approach), along with fostering individual responsibility and ensuring active participation from all group members. The integration of Google Workspace also enabled smooth real-time collaboration with minimal technical issues. Open-ended responses indicated a strong preference for this modern digital environment over traditional formats, highlighting the important roles of accessible and reliable technology in today's education.

Nevertheless, many students also expressed appreciation for the opportunity to discuss with supervisors—an integral part of the checkpoint process—as these interactions helped clarify concepts efficiently and deepen understanding through valuable explanations and feedback. This suggests that in-person interactions between instructors and students remain equally important compared to digital-based engagement, highlighting the need for a balanced approach that integrates both technology and direct human connection to optimize educational effectiveness (Asghar et al., 2022; Photopoulos et al., 2023).

The instructor survey data are presented in Table 3. The instructor perceptions closely mirrored those of the students, with instructors highlighting the efficacy of sequential, formative learning and the value of real-time progress tracking. The use of live dashboards enabled timely interventions and differentiated support, thus creating a more responsive and supportive classroom environment. Instructors also noted that the automation provided by the Chunk & Check Creator led to significant time savings and improved management of the laboratory workflow.

Table 3: Instructor evaluation results (n = 11 of 13; 84.62%)

Evaluation item	Mean score (out of 5)
The learning approach promotes comprehensive student learning and understanding	5.00
The approach enables effective formative assessment during the learning process	4.91
The digital worksheets and checkpoints enhance student learning	4.91
This instructional design increases engagement in laboratory activities	5.00
Overall satisfaction with the teaching approach and Google tools used in the laboratory	4.91

Note: The scores are based on a 5-point Likert scale, where 1 indicates "strongly disagree" and 5 indicates "strongly agree"

The following excerpts are open-ended feedback from the instructors on the chunk & check model:

> *"An innovative and engaging approach to learning and teaching! It not only enhances collaborative group work through hands-on activities but also fosters meaningful discussions between peers and instructor."*
>
> *"Brilliant idea for my next teaching topic! The automation features will make it easier for me to prepare and share instructional worksheets while reducing workload, hassle, and errors."*
>
> *"I've been using Google tools regularly but never thought to 'integrate' them strategically. This approach could really elevate both learning effectiveness and formative assessment."*
>
> *"I've noticed that students learn so much together with their peers, achieving a deeper understanding of the content within a truly enjoyable learning atmosphere."*

3.3 Academic Performance and Learning Outcomes

Analysis of performance on formative checkpoint quizzes indicated strong content mastery for the majority of laboratory sections, with mean scores for Sections 1, 3, 4, and 5 exceeding 90%. These outcomes suggest that the segmentation of learning and continual formative assessment was highly effective in facilitating students' immediate understanding and application of key concepts.

However, a notable exception was found in Section 2, where the average score dropped to 49%. This section—which featured quiz items that examined the subtle differences between "solubility" and "miscibility"—proved particularly challenging for many students. The live dashboard enabled instructors to quickly identify this issue and intervene with clarifications and extra resources, highlighting the advantage of real-time monitoring and adaptive instruction in overcoming conceptual difficulties.

Results from the paper-based midterm examination, administered two months after the instructional period, further underscored the model's effectiveness. The mean score of 72.40% (SD = 7.5%) not only shows that students exceeded the passing criteria (score of 70%) but also suggests that the knowledge acquired through this structured, formative approach showed evidence of retention and some degree of transferability.

While these results are promising, several areas warrant further investigation to build more comprehensive evidence of the model's effectiveness. This initial study focused on evaluating academic performance against a predefined criterion—rather than employing pre-intervention baselines and control groups, which naturally shapes the scope of causal inferences that can be drawn about the specific contributions of the digital tool. Our observations regarding knowledge retention, supported by the delayed midterm examination, while encouraging, would benefit from extended longitudinal validation to strengthen these preliminary findings.

Additionally, this study was conducted in a single laboratory course at one institution, and it would be valuable to explore how variations in digital infrastructure or educational culture might influence the effectiveness of the approach elsewhere. The model works optimally when all students have stable Internet access and are comfortable with digital tools, conditions that may vary across different contexts (Ampo et al., 2025). While clear benefits were observed for group-based laboratory learning, there remains considerable potential to explore the applicability of the approach for lecture-based or fully asynchronous courses.

Future research opportunities may incorporate pre- and post-test designs with control groups, extended follow-up periods, and multi-institutional studies across various educational contexts. Continued refinement and testing in various contexts will help determine the broader applicability of the approach.

4. Conclusions

The integration of chunk & check learning—combining sequenced online worksheets with brief formative checkpoints delivered both digitally and face-to-face—offers a clear, practical innovation for laboratory-based education. By breaking complex experiments and large volumes of material into smaller, manageable "chunks", students focus on mastering one task at a time without feeling overwhelmed. After each chunk, students complete a short checkpoint activity that delivers immediate feedback, highlights misconceptions, and reinforces correct reasoning. Instructors gain real-time insights through digital dashboards and in-person observations, allowing them to provide targeted guidance exactly when and where it is needed.

In our study, both students and instructors reported overwhelmingly positive experiences, noting increased confidence, deeper engagement, and stronger collaboration during group discussions around each checkpoint. Measurable gains in both formative quizzes and final assessments further confirmed the model's effectiveness in improving learning outcomes. The freely available Chunk & Check Creator tools integrate seamlessly with Google Workspace, streamlining the design, delivery, and management of worksheets and checkpoints for educators. Given its accessibility, flexibility, and potential for scaling, we recommend wider adoption and continuous refinement of chunk-and-check learning—not only in laboratory courses but in any educational context where structured, interactive, and feedback-driven instruction can enhance student success.

5. Acknowledgments

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6. Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to improve language and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

7. References

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