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Instructional Design for Computer Assembly Using Mobile Learning-Supported Flipped Classroom in Vocational High Schools

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ABSTRACT

This study aimed to develop and design computer assembly instruction using a mobile learning-supported flipped classroom approach and to evaluate its feasibility for Grade X students at SMK Tahta Syajar, Bekasi City. The study employed Research and Development (R&D) using Atwi Suparman's Instructional Development Model (MPI), with formative evaluation limited to expert review. The development produced a 12-session instructional design package integrating pre-class mobile learning, in-class hands-on practice, and after-class consolidation. The package included text and video materials, preliminary questions, student worksheets, readiness and connector checklists, formative assessments, reflections, and performance rubrics. Feasibility was evaluated by one subject-matter expert, one instructional-design expert, and one learning-media expert using five-point Likert questionnaires and descriptive percentage analysis. The overall expert-assessed feasibility score was 82.38%, categorized as highly feasible. The product's novelty lies in integrating instructional design, mobile learning, flipped classroom sequencing, physical computer assembly practice, occupational safety, and performance assessment within a single 12-session learning system. However, the study was limited to expert validation. No individual, small-group, or field student trials were conducted, and no practicality, usability, learning-outcome, or effectiveness data were collected. Therefore, the 82.38% result should be interpreted only as evidence of expert-assessed feasibility after revision, not as evidence of effectiveness. Further research is required to test the practicality and effectiveness with students.

Keywords: computer assembly, flipped classroom, mobile learning, instructional design, feasibility, vocational high school

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INTRODUCTION

Vocational high schools are expected to develop graduates who can integrate knowledge, practical skills, and work attitudes within authentic occupational tasks. Computer assembly is a procedural competency because students must identify components, interpret specifications, select tools, apply occupational safety and health (K3), install components in the correct sequence, test the system, and troubleshoot faults. These competencies require repeated observation, guided practice, immediate feedback, and opportunities to connect conceptual explanations with physical actions. An instructional design for computer assembly, therefore, needs to allocate classroom time to activities that cannot be replaced by digital materials, while moving suitable conceptual preparation to activities that students can complete independently.

The learning context at SMK Tahta Syajar, Bekasi City, includes a broad sequence of computer assembly topics, from computer development and input-output devices to motherboards, processors, RAM, storage, cases, tools, K3, component installation, testing, and troubleshooting. When introductory explanations consume substantial face-to-face time, laboratory sessions have less time for demonstration, practice, corrective feedback, and repeated performance. This problem requires a coherent instructional design rather than a simple addition of digital media. The design must specify what students learn before class, what they practice during class, what they consolidate after class, and how assessment and feedback connect the three phases.

The flipped classroom provides a suitable structure for this allocation of learning time because it places initial exposure to instructional content before class and uses classroom time for active application. Research reviews and meta-analyses report generally positive learning effects, but they also show that outcomes depend

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on how pre-class and in-class activities are designed and connected. Akçayır and Akçayır (2018) identified inadequate preparation outside of class as a recurring implementation challenge. Van Alten et al. (2019) found that learning outcomes were more favorable when face-to-face time was maintained, and quizzes were integrated into the design. Strelan et al. (2020) reported a moderate overall effect and identified structured active learning and problem solving as important contributors. Cheng et al. (2019) similarly showed that the effects of flipped instruction vary across educational levels, subjects, and implementation characteristics. These findings indicate that the flipped classroom should be treated as an instructional design problem, not merely as a method of distributing videos.

This consideration is especially relevant to vocational learning. Karabulut-Ilgu et al. (2018) found that research in engineering education has increasingly focused on the design and development of flipped learning, while also calling for stronger theoretical and evaluation frameworks. In vocational settings, the flipped approach can create more time for practice, but students still need clear guidance about what to study before class and how the preparation will be used during practical work. Wagner and Urhahne (2021) also showed that student characteristics influence the benefits obtained from flipped instruction in secondary education. Thus, an instructional design for computer assembly should include readiness checks, guided pre-class tasks, supervised hands-on activities, and feedback rather than assuming that students will independently prepare in the same way.

The importance of structured classroom activities is particularly evident in computer assembly instruction. Procedural knowledge cannot be adequately developed by simply memorizing sequences of steps because students need to understand the rationale behind each step, the consequences of installation errors, and the methods used to inspect their work. Herlambang, Fransisca, and Afirianto (2023) demonstrated that flipped classroom procedures designed for teaching procedural knowledge in vocational high schools can help address limited face-to-face instructional time and increase opportunities for practice. Accordingly, the implementation of the flipped classroom in computer assembly instruction should not merely involve "studying at home and completing assignments at school." Instead, it should constitute an interconnected sequence of learning experiences encompassing pre-class, in-class, and after-class activities.

To enable flexible participation in pre-class activities, the flipped classroom requires learning media that are readily accessible to students. Mobile learning is particularly relevant because smartphones can provide flexible access to texts, images, videos, quizzes, and self-directed worksheets. Systematic reviews show that mobile learning can extend learning beyond the classroom and support different forms of student activity when the technology is aligned with pedagogical purposes (Crompton et al., 2017; Crompton & Burke, 2018). Sung et al. (2016), based on 110 experimental and quasi-experimental journal studies, reported a moderate overall effect of mobile-device integration, although the effect varied according to pedagogical and contextual factors. Crompton and Burke (2020) further showed that mobile devices can support more transformative learning activities when instructional design uses their affordances rather than simply reproducing conventional materials. These findings support the use of mobile learning as a connector between pre-class preparation and laboratory practice.

Mobile learning should therefore be designed as an instructional environment rather than as a digital container for printed materials. The product should use concise content units, clear navigation, visual explanations, procedural videos, preliminary questions, and learning tasks that prepare students for the next face-to-face activity. Kukulska-Hulme and Viberg (2018) highlight flexibility, continuity, feedback, personalization, and self-evaluation as important affordances of mobile learning. Lo (2018) likewise argues that the flipped classroom requires an educational-technology foundation that aligns technology with pedagogical activity. In this study, mobile learning is consequently positioned as a component of the instructional design, not as the sole innovation.

Although research on the flipped classroom and mobile learning is substantial, a specific development gap remains in computer assembly instruction at the vocational high-school level. Existing studies have examined flipped classroom implementation, Android-based mobile learning media, or the effectiveness of individual digital resources. However, fewer studies have developed a complete instructional design that integrates objectives, competency sequencing, mobile pre-class materials, supervised assembly practice, after-class consolidation, K3, checklists, formative assessment, and performance rubrics across a series of vocational learning sessions. The present study addresses this gap by developing a 12-session instructional design package for computer assembly. The novelty is therefore located in the integration and instructional alignment of the components, not in the use of mobile learning or the flipped classroom as isolated technologies.

Conceptually, the development is based on three principles. First, informational materials and initial concept introductions are studied through mobile learning before classroom sessions. Second, classroom time is used for activities that require interaction, physical equipment, supervision, and teacher feedback. Third, after-class activities consolidate students' understanding through formative tests, reports, summaries, infographics, and reflections. This sequencing is consistent with evidence that flipped learning depends on explicit connections among pre-class preparation, active classroom work, and assessment (DeLozier & Rhodes, 2017; van Alten et al., 2019; Hew et al., 2021).

The study was designed as a development study and did not seek to establish the effectiveness of the product at this stage. The specific objectives were: (1) to develop and design a 12-session computer assembly instructional system using a mobile learning-supported flipped classroom approach; and (2) to evaluate the feasibility of the developed instructional design through expert validation. The feasibility claim is limited to expert assessment of content, instructional design, and learning media. Student practicality and effectiveness are outside the scope of the present study and are reserved for subsequent trials.

METHODS

This study employed a Research and Development (R&D) approach using the Instructional Development Model (Model Pengembangan Instruksional, MPI) proposed by Suparman (2014). The MPI was selected because it provides a systematic instructional-design framework for identifying needs, developing instructional components, and conducting formative evaluation and revision. The procedure comprised eight steps: (1) identifying instructional needs and formulating general instructional objectives; (2) conducting instructional analysis; (3) identifying learners' entry behaviors and characteristics; (4) formulating specific instructional objectives; (5) developing learning-outcome assessment instruments; (6) developing instructional strategies; (7) developing instructional materials; and (8) conducting formative evaluation. In the present study, formative evaluation was deliberately limited to expert review by one subject-matter expert, one instructional-design expert, and one learning-media expert. Individual, small-group, and field trials were not conducted and are planned as subsequent development stages. This boundary is important because the study evaluates product feasibility at the expert-review stage rather than product practicality or effectiveness.

The study was conducted at SMK Tahta Syajar, Bekasi City, during the second semester of the 2024/2025 academic year. Data sources during the identification stage included curriculum documents, existing instructional materials and tools, the characteristics of computer assembly content, laboratory facilities, and the needs of teachers and students. The needs analysis was conducted through observations of instructional activities and laboratory facilities, interviews with the subject teacher and students, and a review of curriculum documents and existing instructional materials. The formative evaluation involved one subject-matter expert, one instructional design expert, and one learning media expert. The validators were selected based on their relevant educational backgrounds, experience in teaching or instructional development, and understanding of technology-enhanced learning.

The identification stage comprised three steps. First, instructional needs were identified to determine the gap between the expected computer assembly competencies and the existing instructional conditions, after which the general instructional objectives were formulated. Second, instructional analysis was conducted by mapping the sequence of competencies, beginning with hardware identification, component functions and locations, tool utilization, and the application of occupational safety and health (K3) principles, followed by component installation, testing, and troubleshooting. Third, students' entry behaviors and characteristics were

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identified based on their prior knowledge, learning habits, smartphone availability, ability to access digital materials, and experience using laboratory equipment. The results of this stage served as the basis for organizing the instructional content into twelve sessions.

The development stage included formulating specific instructional objectives, developing learning outcome assessment instruments, designing instructional strategies, and developing instructional materials. The objectives for each session were derived from the competency map and subsequently aligned with preliminary exercises, formative assessments, student worksheets (LKPD), checklists, and performance assessment rubrics. The instructional strategy comprised three interconnected phases: pre-class activities for learning concepts through *mobile learning*; in-class activities for demonstrations and guided practice under teacher supervision; and after-class activities involving tests, reports, summaries, or reflections. The instructional materials developed included texts, images of computer components, videos or video links, self-directed learning worksheets, presentation slides, practical student worksheets, preparation and connector checklists, digital formative assessments, and assessment rubrics.

The equipment and materials used in the development process and practical activities included computer units and their components, computer cases, motherboards, processors, RAM, storage devices, power supply units, internal cables, screwdrivers, thermal paste, occupational safety equipment, and computer laboratory facilities. The instructional media included smartphones, *mobile learning* content, digital texts, images, demonstration videos, presentation slides, quizzes, and reflection forms. The research instruments consisted of validation questionnaires using a five-point Likert scale, comprising 20 items for the subject-matter expert, 20 items for the instructional design expert, and 14 items for the learning media expert. The subject-matter validation framework covered the alignment of objectives, conceptual accuracy, breadth and depth of content, content sequencing, readability, and relevance to practical activities. The instructional design validation framework covered the integration of instructional phases, objectives, methods, activities, time allocation, assessment, and feedback. Meanwhile, the learning media validation framework covered visual appearance, navigation, text and visual elements, mobile-device accessibility, consistency, and support for independent learning. Each questionnaire also provided space for comments and recommendations for improvement.

The formative evaluation procedure was conducted by providing each validator with the developed product, validation framework, and questionnaire. Validators scored each item, provided written comments, and submitted recommendations for revision. Quantitative data were analyzed descriptively using feasibility percentages. The interpretation criteria were 81–100% = highly feasible, 61–80% = feasible, 41–60% = moderately feasible, 21–40% = less feasible, and 0–20% = not feasible. Qualitative comments were grouped into content, instructional design, media, language, and technical-use issues and were used to revise the product. The product was considered to have met the expert-feasibility criterion when the validation result reached at least the feasible category and substantive recommendations had been addressed. This criterion does not represent evidence of student usability or effectiveness.

RESULTS AND DISCUSSION

The identification stage of the MPI revealed three primary instructional needs. First, computer assembly content needed to be organized progressively, moving from declarative knowledge to procedural skills. Second, face-to-face instructional time needed to be prioritized for identifying physical devices, conducting demonstrations, practicing component installation, performing testing, and troubleshooting. Third, students required learning resources that could be accessed before and after classroom sessions to review component functions and working procedures. Based on these needs, a mobile learning-assisted flipped classroom instructional design was developed by providing texts, videos, interactive images, and preliminary questions during the pre-class phase.

The primary product was a twelve-session instructional design package. Each session specified instructional objectives, pre-class activities, in-class activities, after-class activities, instructional media, time allocation, and assessment methods. The package was supplemented with teacher and student instructions. Pre-class activities used mobile learning materials to establish conceptual readiness. In-class activities used physical computer components, demonstrations, guided practice, feedback, testing, and troubleshooting. After-class activities consolidated learning through formative tests, reports, summaries, infographics, and reflection. This structure follows evidence that flipped learning is stronger when pre-class preparation is explicitly connected to active classroom tasks rather than treated as an independent video assignment (DeLozier & Rhodes, 2017; Awidi & Paynter, 2019; Baig & Yadegaridehkordi, 2023).

Table 1. Twelve-Session Computer Assembly Instructional Design

No.	Main topic	Pre-class activities	In-class activities	Time allocation
1	Development of computer technology	Texts on computer history and generations, videos, notes, and preliminary exercises	Trigger questions, discussion of computer generations, presentations, and concept reinforcement	1–3–1 LP
2	Input devices	Texts and videos on input-device functions, notes, and preliminary exercises	Direct identification, classification based on functions, and discussion	1–3–1 LP
3	Output devices	Texts and videos on output-device functions, notes, and preliminary exercises	Classification of output devices, identification practice, and evaluation	1–3–1 LP
4	Motherboards and processors	Texts about components, installation videos, and notes on component functions	Identification and installation practice involving motherboards and processors	1–4–1 LP
5	RAM and storage devices	Texts about RAM and storage devices, installation videos, and notes	Identification and installation practice involving RAM, HDDs, and SSDs	1–4–1 LP
6	Component layout	Texts, videos on installation inside a computer case, and interactive images	Demonstrations, discussions of component positions, and component-placement exercises	1–5–1 LP
7	Types of computer cases	Texts, images of computer cases, and comparison tables	Case classification, laboratory identification, and installation practice	1–6–1 LP
8	Computer assembly tools and materials	Texts, videos explaining tool functions, and notes	Classification of tools and materials, presentations, and correction of misconceptions	1–3–1 LP
9	Occupational safety and health	Materials on personal protective equipment and K3, videos, and procedural notes	Risk analysis, personal protective equipment practice, and observation of K3 implementation	1–5–1 LP
10	Assembly preparation	Preparation texts and videos on tools and occupational safety	Workspace organization, identification of tools and components, and readiness checklist completion	1–4–1 LP
11	Installation of major components	Texts and videos on processors, RAM, heat sinks, and motherboards	Demonstrations and practice in installing major components	1–4–1 LP
12	Testing and troubleshooting	Texts about connectors, testing videos, and notes on common problems	Connector checklist completion, POST testing, symptom identification, and troubleshooting	1–4–1 LP

Note: LP = lesson period. The time allocation indicates the sequence of pre-class, in-class, and after-class activities.

Table 1 demonstrates that the proportion of classroom activities increased as the instructional content progressed toward practical skills. Sessions 1–3 allocated three lesson periods to in-class activities because

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they focused on device introduction and classification. Sessions 4–9 required four to six lesson periods for component identification, preliminary installation practice, component layout, computer cases, assembly tools, and occupational safety and health. Sessions 10–12 allocated four lesson periods to assembly preparation, installation of major components, and testing. This distribution reflects the principle that activities suitable for independent learning are assigned to the pre-class phase, whereas activities involving potential risks and requiring physical equipment are conducted under teacher supervision.

The *mobile learning* product was designed with a main menu containing instructions, learning objectives, materials for each session, videos, preliminary exercises, formative assessments, and reflections. The textual materials were presented in concise paragraphs and supplemented with images of computer components. Videos were primarily used for procedures requiring demonstrations of physical movements, such as installing processors, RAM, storage devices, motherboards, and internal cables, as well as performing troubleshooting. To prevent the pre-class phase from becoming a passive activity, each learning unit concluded with preliminary questions and a note-taking worksheet that students were required to bring to class.

Figure 1. Halaman Pembuka

Figure 2. Halaman Menu Utama

Figure 3. Daftar Isi Materi

Figure 4. Petunjuk Penggunaan

Figure 6. TIK dan TIU

Figure 5. Latihan Soal

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Figure 1. Illustrative interface structure of the mobile learning product. The illustration reconstructs the product components described in the study and is not a screenshot of the original application.

Figure 1 makes the product structure more tangible by showing the main menu, procedural video, pre-class preparation, and formative assessment. The interface structure reflects the product description in the study: students access instructions, objectives, materials, videos, preliminary exercises, assessments, and reflections through a connected learning sequence. The visual clarifies the intended relationship between mobile preparation and practical laboratory activities.

The supporting products for classroom activities consisted of device-identification worksheets, a computer-case classification table, a tool-and-material classification worksheet, a K3 risk-analysis worksheet, a practical-readiness checklist, component-installation worksheets, an internal-connector checklist, and a troubleshooting worksheet. The assessment rubric was designed to evaluate procedural accuracy, tool utilization, K3 implementation, precision, work organization, collaboration, the ability to explain results, and problem-solving skills. Accordingly, the assessment was not based solely on whether the assembled computer successfully operated, but also on the students' work processes.

A formative evaluation involving expert reviews of the subject matter, instructional design, and learning media components was conducted by three validators, with one validator representing each area of expertise. The validation aspects and data sources are summarized in Table 2.

Table 2. Product Validation Aspects

Validator	Number	Assessed aspects	Instrument
Subject-matter expert	1	Conceptual accuracy, depth, sequencing, alignment with objectives, language, and relevance to practical activities	Questionnaire
Instructional design expert	1	Integration of pre-class, in-class, and after-class phases; methods; time allocation; activities; and assessment	Questionnaire
Learning media expert	1	Visual appearance, navigation, readability, visual and video quality, mobile accessibility, and interactivity	Questionnaire

The quantitative validation results are presented in Table 3. The overall average score was used to determine product feasibility, while the scores for individual aspects were used to establish priorities for product revision.

Table 3. Expert Validation Results

Validation aspect	Score obtained	Maximum score	Percentage	Category
Subject matter	90	100	90.00%	Highly feasible
Instructional design	80	100	80.00%	Feasible
Mobile learning media	54	70	77.14%	Feasible
Overall average	—	—	82.38%	Highly feasible

As shown in Table 3, the overall validation result was 82.38%, placing the product in the highly feasible category. The subject-matter aspect received a score of 90.00%, the instructional design aspect received 80.00%, and the media aspect received 77.14%. The subject-matter aspect obtained the highest score, whereas the media aspect required further improvement, particularly in terms of navigation, readability, and access efficiency. Following revision, the product was declared highly feasible for progression to practicality testing.

The experts' comments were analyzed to identify both substantive and technical improvements. The primary revisions included clarifying procedural sequences and occupational safety requirements, strengthening the integration of pre-class, in-class, and after-class activities, adjusting time allocation and assessment, and simplifying the navigation and visual presentation of the media. A summary of the experts' recommendations and the corresponding revisions is presented in Table 4.

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Table 4. Product Revisions Based on Expert Recommendations

Aspect	Expert recommendations	Revision measures	Status
Subject matter	Clarify the sequence of component installation, ensure consistency in technical terminology, add K3 indicators, and provide troubleshooting examples.	The content sequence and installation procedures were revised; technical terminology was standardized; and K3 indicators and a troubleshooting checklist were added.	Completed
Instructional design	Strengthen the alignment among objectives, pre-class activities, in-class practice, after-class reflection, time allocation, and assessment.	Objectives, activities, and assessments were aligned; preliminary questions and reflections were clarified; and practical time allocation and assessment rubrics were adjusted.	Completed
Learning media	Simplify navigation, improve the readability of texts and images, and optimize videos for easier access through mobile devices.	The menu structure and buttons were clarified; font size, contrast, and visual quality were improved; and videos were shortened and compressed.	Completed

The development results demonstrate that the product is not merely a collection of digital materials but an instructional system that connects independent preparation with practical activities. Evidence of this integration can be observed in the use of preliminary questions as the basis for classroom apperception, the direct practice activities following each instructional video, and the formative assessments and reflections conducted after each practical session. The design also accommodates progressively increasing levels of complexity, beginning with identifying devices, understanding their positions and functions, applying K3 principles, and installing components, and culminating in diagnosing computer problems.

Discussion

The developed product treats the flipped classroom as an instructional design for allocating learning time rather than as a strategy for simply moving lectures to students' homes. The pre-class phase provides concise conceptual preparation through mobile learning. The in-class phase uses that preparation for identification, demonstration, assembly, testing, troubleshooting, and teacher feedback. The after-class phase consolidates the experience through assessment and reflection. This design is consistent with systematic reviews showing that flipped learning outcomes depend on the quality of the relationship among pre-class materials, classroom activities, assessment, and learner support (Akçayır & Akçayır, 2018; van Alten et al., 2019; Hew et al., 2021). The product therefore, contributes primarily at the instructional-design level.

The twelve-session structure reflects the procedural nature of vocational learning. Computer assembly requires students to coordinate declarative knowledge with physical performance and workplace behavior. The product progressively moves from component identification to installation, testing, and troubleshooting. This progression is consistent with research in technical and engineering education that emphasizes structured active learning and the alignment of pre-class preparation with practice (Karabulut-Ilgu et al., 2018). The design also responds to evidence that flipped learning benefits can vary with student readiness and independence, particularly in secondary education (Wagner & Urhahne, 2021).

The increasing allocation of in-class time to practical topics is a deliberate design decision. Introductory sessions emphasize identification and classification, whereas later sessions allocate more time to component installation, K3, testing, and troubleshooting. This allocation is consistent with evidence that the value of flipped instruction is not created by reducing classroom contact but by using contact time for structured active learning (van Alten et al., 2019; Strelan et al., 2020). In computer assembly, teacher supervision remains essential because students handle physical components and must apply safe procedures.

Material feasibility depends mainly on conceptual accuracy and procedural safety. Computer assembly material includes steps that can damage components if explained ambiguously, such as processor orientation, standoff placement, CPU power connection, thermal paste application, RAM installation, and front panel connectors. Expert validation of material, therefore, goes beyond checking alignment with the curriculum. It must also check procedural accuracy. The 90.00% material validation result should be read together with expert comments to confirm that images, terminology, and action sequences do not lead to misinterpretation.

For the instructional-design aspect, alignment among objectives, activities, media, time allocation, and assessment is central. Pre-class questions function as readiness checks and prompts for classroom discussion. Procedural videos are linked to the same components that students handle during practice. After-class reflections direct students to identify errors and difficulties. This alignment is supported by research emphasizing that flipped learning requires explicit pedagogical connections across learning phases rather than technology alone (Lo, 2018; Cheng et al., 2019; Baig & Yadegaridehkordi, 2023).

Mobile learning functions as the connecting medium across these phases. Students can access material through smartphones, pause and replay procedural videos, review component images, and complete preliminary questions before entering the laboratory. Systematic reviews of mobile learning show that flexibility and continuity can expand learning opportunities when mobile affordances are deliberately connected to learning tasks (Crompton et al., 2017; Crompton & Burke, 2018). Sung et al. (2016) also found a moderate overall effect of mobile-device integration, while emphasizing variation across pedagogical and contextual conditions. In the present study, mobile learning is used to support preparation and repetition, while the laboratory remains the primary environment for physical skill development.

The design also recognizes constraints associated with mobile learning. Screen size, storage capacity, connectivity, and competing smartphone applications can affect access and attention. The product addresses these constraints through concise text, short procedural videos, enlarged component images, simple navigation, and lightweight learning materials. These decisions are consistent with research that emphasizes the need to align mobile technology affordances with learner activities and context rather than treating the device itself as the innovation (Crompton & Burke, 2020; Kukulska-Hulme & Viberg, 2018).

The product assessment design combines knowledge and performance measures. Formative tests check conceptual understanding, while checklists and rubrics assess practical execution. This dual approach matters because a computer that powers on successfully does not necessarily mean it was assembled through a safe and correct procedure. Students can reach the same end result through a risky process, such as messy cable management, improper tool use, or ignoring static electricity precautions. With a rubric, teachers can assess sequence accuracy, safety compliance, precision, teamwork, and troubleshooting ability.

The troubleshooting activity in the final meeting creates space for problem-solving development. Symptoms such as a computer that will not power on, no display, beep codes, a fan that does not spin, undetected storage, or system restarts require students to connect symptoms to possible causes. This activity shifts practice from simply following a tutorial to evidence-based diagnosis. Students check connectors, RAM seating, CPU power, monitor cables, fans, and storage media using a checklist. This process supports work competency, since technicians rarely encounter ideal conditions in the field.

The expert validation result of 82.38%, categorized as highly feasible, indicates that the product met the study's predefined expert-feasibility criterion after revision. The result should be interpreted narrowly. It demonstrates that the three validators judged the content, instructional design, and mobile learning media to be suitable for progression to the next development stage. It does not demonstrate that students can use the product easily, that teachers can implement it efficiently, or that the product improves learning outcomes. This distinction is essential because the present study stopped before individual trials, small-group trials, field trials, practicality assessment, and effectiveness testing.

The product differs from earlier mobile learning and flipped classroom studies in the scope of instructional integration. Imania et al. (2020) developed flipped classroom learning supported by mobile learning, while Irfan et al. (2024) integrated mobile learning with flipped direct instruction in computing education. Sukardi et al. (2020a, 2020b) focused on Android-based mobile learning for computer assembly and examined its validity and effectiveness. The present development extends this line of work by designing a 12-session instructional system that connects mobile learning with physical assembly practice, K3, checklists, formative assessment, and performance rubrics. The contribution, therefore, concerns instructional-system integration rather than the novelty of the mobile platform alone.

The practical novelty of the study lies in the integration of instructional design with a laboratory practice ecosystem. The product connects mobile preparation, real computer hardware, supervised practice, K3, checklists, formative assessment, and performance rubrics. This integration addresses a central instructional problem in computer assembly: digital preparation can reduce repetitive explanations, but it cannot replace physical manipulation of components. The product assigns each learning resource to the phase in which it has the greatest instructional function. This design principle is consistent with evidence that effective flipped learning depends on coherent pedagogical sequencing and active learning opportunities rather than on technology adoption by itself (Strelan et al., 2020; Hew et al., 2021).

The additional literature from Journal PAJAR (Pendidikan dan Pengajaran) provides a relevant Indonesian comparison for the present development. Studies in PAJAR have reported the feasibility or implementation of digital modules, Android-based learning media, flipped classroom models, and technology-supported learning. Fatmawati et al. (2021) examined an information-technology-based flipped classroom, while Suarlin et al. (2022), Hidayatullah et al. (2023), Mustika et al. (2024), Utami et al. (2023), and Jayanti et al. (2025) reported development or validation of digital learning resources. Studies by Astuti et al. (2020), Sumandiyah et al. (2023), Dewi et al. (2025), and Ritaningsih and Bramastia (2026) further show the relevance of digital modules and interactive learning media across applied and school contexts. These studies support the importance of feasibility and design quality in early-stage development research. At the same time, the present study differs because its product integrates mobile learning with a flipped classroom sequence and physical computer assembly practice, while its empirical claim remains deliberately limited to expert-assessed feasibility.

The broader international literature also supports the need to interpret the present findings within the limits of the development stage. O'Flaherty and Phillips (2015) emphasized that flipped classroom research in higher education varies substantially in design and implementation. DeLozier and Rhodes (2017) argued that the value of flipped activities depends on the cognitive processes elicited by those activities rather than on the label "flipped" itself. Thai et al. (2017) highlighted the importance of the balance between lectures and guided practice, while Gilboy et al. (2015) demonstrated the relevance of pre-class resources, quizzes, and active classroom activities. Wu et al. (2012) and Sung et al. (2016) showed that mobile learning research has expanded across different purposes and contexts, but effects depend on how mobile devices are integrated pedagogically. Xu et al. (2019) further illustrate that flipped learning can support procedural skill development in practice-oriented education, while also requiring careful evaluation of study quality. These findings reinforce the present study's decision to treat expert validation as a feasibility checkpoint rather than as evidence of effectiveness.

This development has four main limitations. First, the study stops at expert validation, so no evidence is available regarding student practicality, usability, learning gains, skill performance, or comparative effectiveness. Second, mobile learning access depends on students' devices and connectivity. Third, hardware generations and form factors may differ from the components represented in the learning materials, requiring periodic updates. Fourth, the flipped classroom requires students to complete pre-class preparation, and compliance may vary. These limitations define the next research stage and prevent the current findings from being interpreted as proof of effectiveness.

The implications for teachers point to a shift in role, from information deliverer to experience designer and practice mentor. Teachers need to monitor baseline data, identify misconceptions, manage tool rotation, maintain safety, and give specific feedback. For schools, implementing the product requires a material access policy, laboratory equipment maintenance, availability of practice components, and network support. For developers, mobile learning material needs regular maintenance, since hardware specifications and connector standards continue to evolve.

Based on the feasibility result and its limitations, the product is positioned as an expert-reviewed instructional design ready for user testing, not as a validated effective intervention. Subsequent research should conduct individual, small-group, and field trials; measure teacher and student practicality; document implementation fidelity across pre-class, in-class, and after-class phases; and test learning outcomes and procedural skills. A stronger evaluation can then determine whether the instructional design produces measurable advantages in computer assembly knowledge, assembly performance, K3 implementation, learning independence, and troubleshooting ability.

CONCLUSION AND RECOMMENDATIONS

This study developed a 12-session computer assembly instructional design using Atwi Suparman's Instructional Development Model (MPI) and a mobile learning-supported flipped classroom approach for Grade X students at SMK Tahta Syajar, Bekasi City. The product integrates pre-class mobile learning, in-class demonstrations and hands-on practice, after-class assessment and reflection, LKPD, checklists, and performance rubrics. Expert validation produced an average feasibility score of 82.38%, categorized as highly feasible after revision. This result demonstrates expert-assessed feasibility of the instructional design, content, and media. It does not demonstrate student practicality or learning effectiveness. Therefore, individual, small-group, and field trials, followed by practicality and effectiveness testing, are required before claims about implementation success or learning gains can be made.

The main conclusion is that the developed product is ready to proceed to student-based evaluation after expert revision. Future studies should test usability and practicality, implementation fidelity, and effects on computer assembly knowledge, procedural skills, K3 implementation, learning independence, and troubleshooting performance.

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