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Perceived effectiveness of component-linked QR code learning media for learning lathe machine components in vocational high schools

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Abstract: Vocational machining education requires learning resources that can connect theoretical explanations with direct interaction with industrial equipment. However, students in lathe-machining courses often struggle to identify machine components, understand their functions, and relate components to appropriate operating procedures and safety practices. This study aims to develop and evaluate a component-linked Quick Response (QR) Code learning media system that provides contextual digital information directly through physical lathe components. This study employed a Research and Development (R&D) approach based on the ADDIE framework. The study was conducted at SMK Negeri 5 Padang, Indonesia, involving 74 Grade XI Machining Engineering students. Data were collected through content and media-design expert appraisal, student-response questionnaires, and teacher interviews. The results showed that the developed QR Code learning media achieved very good feasibility ratings from experts, with mean scores of 3.57 for content quality and 3.67 for media-design quality. Student responses produced an overall mean score of 66.78, classified as good, with 89.18% of students providing positive evaluations. Teacher perspectives indicated that the media supported independent access to information, increased student engagement, and facilitated understanding of lathe-component functions and operations during practical activities. The study contributes a physical–digital learning model that integrates QR Code technology with authentic vocational equipment and provides preliminary evidence for further experimental investigations of learning effectiveness.

Keywords: QR code learning media; lathe machining; vocational education; physical–digital learning; multimedia learning; mechanical engineering education

1. Introduction

Vocational education requires instructional environments that connect conceptual knowledge with the equipment, procedures, and practices students encounter in occupational settings (Canut-Montalva et al., 2025; Zhang, 2025). This requirement is particularly important in mechanical-engineering education, where learners must understand not only what individual machine components are called but also how they function, interact, and are operated safely. Digital multimedia can support this process by combining verbal explanations with visual representations, demonstrations, and procedural information, thereby helping learners connect abstract explanations with observable mechanical processes (Abdulrahaman et al., 2020; Noetel et al., 2022; Staneviciene & Žekiene, 2025).

Quick Response (QR) codes provide a relatively simple way to connect physical learning environments with digital resources (Sondhi & Kumar, 2022). In educational settings, QR codes can provide immediate mobile access to videos, images, explanatory text, formative activities, and other online learning resources without requiring students to manually search for the relevant material (Rakha, 2025; Tukhtabayeva et al., 2024). Early work identified QR codes as a bridge between physical objects and mobile digital information, while more recent reviews indicate that video is among the most frequently incorporated resources in QR-supported learning and that such integration can support academic learning and self-directed access to instructional content (Law & So, 2010; Seta, 2023).

This affordance is particularly relevant to vocational workshops because learning frequently takes place in direct interaction with machines and equipment. QR-linked instructional resources can provide procedural information at the point of use rather than requiring students to alternate between a machine, a printed manual, and teacher explanation (Li et al., 2025; Rakha, 2025). Recent vocational applications have linked QR codes with SOP videos, occupational-safety information, and practical demonstrations, while QR-based equipment information systems have also been used to provide more efficient access to laboratory operating instructions. These developments suggest that QR codes can function as an instructional access layer between physical equipment and digital procedural support (Lestari et al., 2026; Marselino & Suhartadi, 2026; Saputra et al., 2026).

The potential is especially relevant to lathe-machine instruction. Before students perform machining operations, they need to recognize major lathe components, understand their functions, and relate each component to appropriate operating procedures and occupational safety. Previous research in an Indonesian vocational-school context has already demonstrated that QR Code-based media for introducing lathe-machine components can contribute to learning outcomes (Ariansyah et al., 2025; Prasetya et al., 2026; Pratiwi et al., 2020). A quasi-experimental study involving Grade XI machining students at SMK Negeri 1 Padang reported higher learning outcomes for students exposed to QR Code-based learning media than for the comparison group (Dioandanno & Prasetya, 2025).

Despite this progress, an important developmental gap remains. Existing research confirms the potential of QR-supported media in vocational and lathe-machine learning. However, comparatively little evidence exists on component-linked instructional design in which each QR Code is physically associated with a specific lathe component and provides immediate access to component-specific video information on its function and operation (Prasetya et al., 2026; Waskito et al., 2024). Moreover, QR-based vocational studies have used different evaluation approaches. In contrast, evidence combining expert appraisal, responses from an entire target student cohort, and teacher perspectives on classroom implementation remains useful for assessing whether such media are sufficiently relevant, accessible, and usable before stronger effectiveness testing is undertaken (Nisa, 2025).

This research gap is directly relevant to SMK Negeri 5 Padang. A preliminary needs assessment conducted through classroom observation and consultation with the lathe-machining teacher identified three recurring concerns: students experienced difficulty understanding lathe-machine content, some students showed limited awareness of safe machine operation, and many had difficulty identifying the function and operation of individual lathe components. These observations indicated a need for learning support that students could access directly while interacting with the machine.

Accordingly, this study's novelty lies not in introducing QR codes to vocational or lathe-machine education per se, but in developing a component-linked QR Code learning system in which codes placed at relevant lathe components provide immediate access to component-specific instructional videos. The design aims to reduce the gap between the physical object being observed and the digital explanation students need at that moment. The resulting media are evaluated through content and media-design expert appraisal, student responses, and teacher perspectives following classroom implementation. Figure 1 illustrates the conceptual relationship between the identified learning problem, component-linked access, and the evaluation of the developed media.

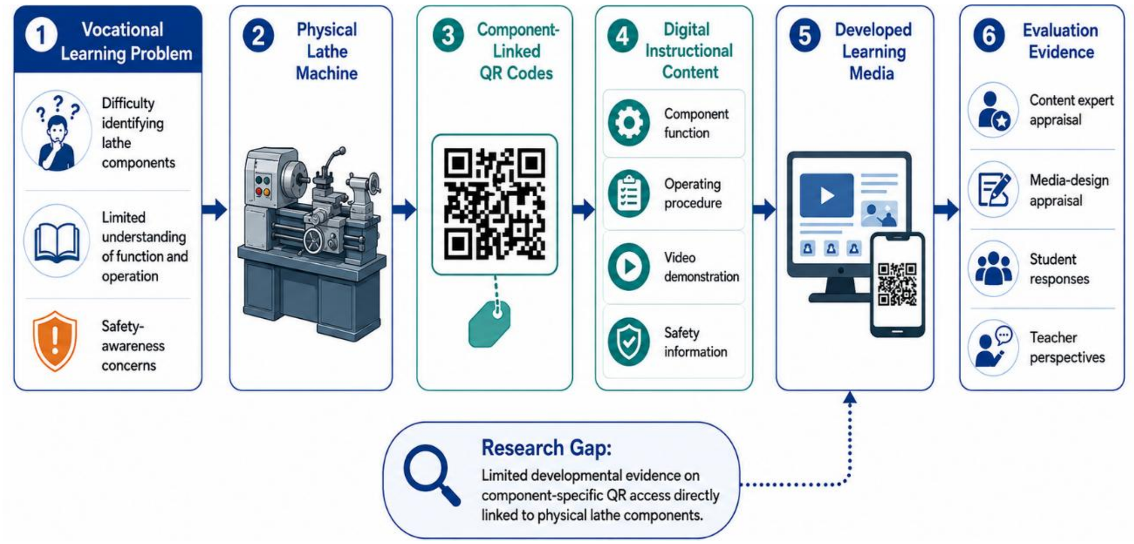

Figure 1. Conceptual framework and research gap

As illustrated in Figure 1, the QR Code is not treated merely as an additional digital feature. Instead, it acts as a contextual bridge between the physical lathe component and its corresponding instructional explanation. Based on this framework and the outcomes actually measured in the study, the following research questions were formulated:

RQ1. How can component-linked QR Code learning media be developed to provide students with contextual information about the functions and operation of lathe-machine components?
RQ2. How do content and media-design experts appraise the developed QR Code learning media?
RQ3. How do students evaluate the developed media after classroom implementation, and what do teachers report regarding students' understanding, learning interest, and classroom engagement?

The study makes three corresponding contributions. Developmentally, it translates QR-supported mobile learning into a component-specific physical–digital learning system for lathe-machine instruction. Empirically, it provides evidence from expert appraisal and responses from the full target cohort of Grade XI machining students. Practically, teacher perspectives provide complementary evidence concerning how the media functioned within an authentic vocational-learning environment.

2. Methods

2.1 Research design

This study employed a developmental Research and Development (R&D) design structured by the ADDIE framework: Analyze, Design, Develop, Implement, and Evaluate. ADDIE was selected because it provides a systematic sequence for identifying instructional needs, designing and producing learning resources, implementing the resulting product, and using evaluation evidence to guide revision (Branch, 2009).

The study combined developmental procedures with quantitative descriptive evaluation and supporting qualitative evidence. Quantitative data were obtained from expert-appraisal forms and student-response questionnaires, while teacher interviews provided contextual information about classroom implementation. The design is therefore not presented as a causal effectiveness experiment because it did not include a pre-intervention learning measure or comparison group. Figure 2 presents the overall research procedure.

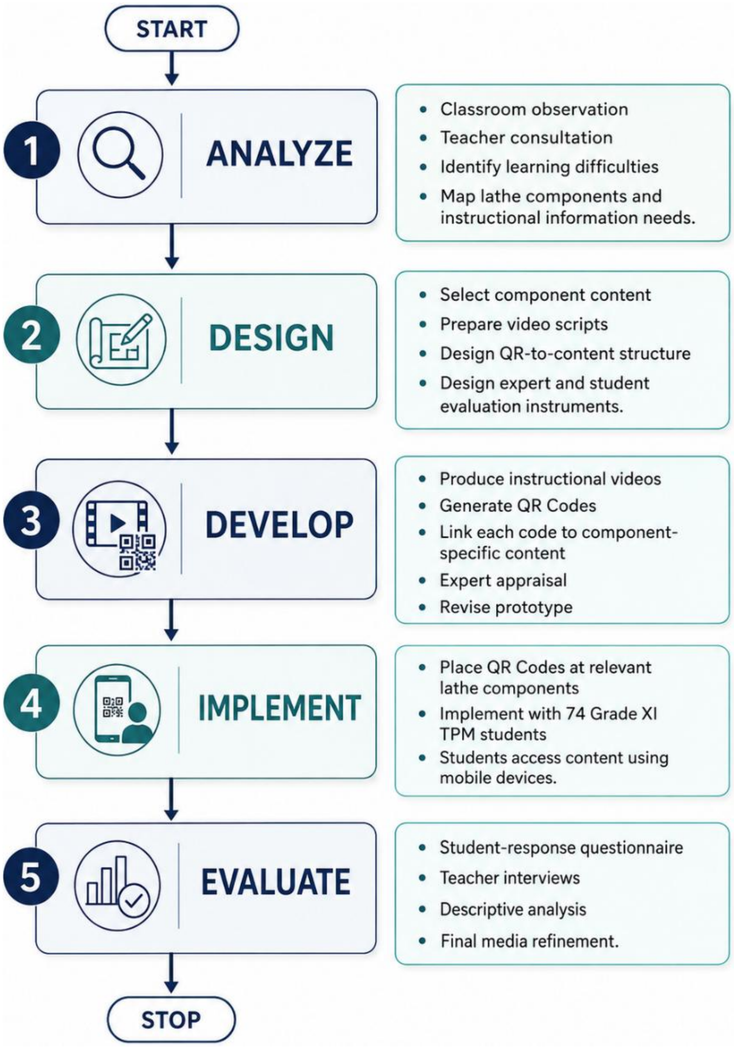

Figure 2. ADDIE-based development and evaluation procedure

As shown in Figure 2, expert appraisal occurred during the *Develop* stage before Implementation, whereas student responses and teacher perspectives were collected after classroom use during the *Evaluate* stage.

2.2 Setting and participants

The study was conducted at SMK Negeri 5 Padang, Padang, West Sumatra, Indonesia, from 11 May to 19 June 2026, during the 2025/2026 academic year. The target population comprised all Grade XI students enrolled in the Machining Engineering (*Teknik Pemesinan*) program and studying Lathe Machining.

All 74 students in the target population were included in the implementation and student-response evaluation. Accordingly, the study employed total population sampling (census sampling) rather than selecting a probabilistic subsample. The study setting and participants are summarised in Table 1.

Table 1. Study setting and participant profile

Aspect	Description
Research site	SMK Negeri 5 Padang, West Sumatra, Indonesia
Academic year	2025/2026
Implementation period	11 May–19 June 2026
Programme	Machining Engineering
Grade	XI
Subject	Lathe Machining
Student population	74 students
Student participants	74 students
Sampling approach	Total population/census sampling
Development framework	ADDIE
Evaluation evidence	Expert appraisal, student questionnaire, teacher interview

2.3 Development of the QR code learning media

The instructional media were developed through the five ADDIE stages. During *Analyze*, classroom observation and teacher consultation were used to identify learning difficulties and determine which lathe components required additional instructional support. Information concerning component function, operation, and relevant safety considerations was then organized as the content basis for the digital resources.

During *design*, each identified component was mapped to a dedicated QR Code and corresponding instructional content. Video scripts and visual explanations were prepared so that the information accessed through a code corresponded directly to the component being observed. This design reflects the educational function of QR codes as links between physical environments and mobile digital resources and draws on multimedia-learning principles in presenting verbal and visual explanations together (Law & So, 2010; Mayer & Fiorella, 2021).

During *Develop*, the instructional videos were produced, QR Codes were generated and linked to the appropriate content, and the prototype system was reviewed by content and media-design experts. Expert feedback was used to revise both instructional information and media presentation before classroom implementation.

During *Implementation*, the QR Codes were placed at the relevant lathe-machine components. Students could scan a code using a mobile device and access the corresponding video explanation while observing the physical component. This point-of-use architecture distinguishes the media from conventional QR-enhanced documents because access is organized around the physical machine component itself.

During *Evaluate*, students completed a response questionnaire after using the media, and teachers were interviewed regarding their observations of classroom implementation. Table 2 summarises the activities and evidence associated with each ADDIE stage.

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Table 2. ADDIE stages, development activities, and evidence

ADDIE stage	Main activity	Output/Evidence
Analyze	Classroom observation, teacher consultation, identification of learning difficulties and relevant learning components	Needs-assessment findings
Design	Content mapping, video scripting, QR–component architecture, instrument preparation	Media blueprint and prototype design
Develop	Video production, QR generation, expert appraisal, prototype revision	Revised QR Code learning media
Implement	QR Codes attached to relevant components and used by 74 students	Classroom implementation
Evaluate	Student questionnaire and teacher interviews	Student-response data and teacher perspectives

Table 2 shows that evaluation was incorporated across the development process rather than restricted to the final stage: expert appraisal informed prototype revision during development, while user evidence informed post-implementation evaluation.

2.4 Instruments and data collection

Three principal sources of evaluation evidence were used: expert appraisal, student responses, and teacher interviews. The expert-appraisal instruments assessed two major dimensions. The content appraisal addressed the relevance and clarity of information concerning component function and operation, whereas the media-design appraisal examined the presentation and usability of the QR-supported learning media. Expert ratings produced the mean scores subsequently reported for content (3.57) and media design (3.67).

The student-response questionnaire used a Likert-type format to evaluate students' experiences after using the media. The resulting scores were summarised quantitatively and interpreted according to the instrument's predefined response categories. The student data produced an overall mean score of 66.78, corresponding to the good category. Teacher interviews provided supporting qualitative evidence regarding Implementation. Interview responses focused on observable changes in students' understanding of lathe components, interest in the learning activities, and active engagement when accessing QR-linked instructional materials. Table 3 presents the alignment between the research questions and the evidence collected.

Table 3. Alignment of research questions, evidence, and analysis

Research question	Evidence	Main indicator	Analysis
RQ1: Development and operationalization	Needs assessment, media blueprint, final QR-linked media	Component–QR–video integration	Descriptive developmental analysis
RQ2: Expert appraisal	Content and media-design expert forms	Mean expert ratings	Descriptive statistics
RQ3: Student and teacher evaluation	Student questionnaire; teacher interviews	Student response score; perceived understanding, interest, and engagement	Descriptive statistics and qualitative summarisation

2.5 Data analysis

Quantitative data obtained from expert appraisal and student questionnaires were analyzed descriptively to summarize the overall evaluation of the developed media. Expert appraisal scores were calculated by determining the mean rating provided by all experts involved in the evaluation process. The mean score represented the overall assessment tendency across expert judgments. Equation (1) presents the calculation procedure for the mean expert-appraisal score.

$$\bar{X} = (\Sigma X_i) / n \tag{1}$$

where $\bar{X}$ represents the mean score, X_i represents each rating, and n represents the number of ratings included in the calculation.

Student questionnaire scores were likewise summarised using descriptive statistics and classified according to the questionnaire's predefined interpretive categories. Because the study did not include pretest–posttest learning measures or a comparison group, these data were interpreted as student-reported evaluations of the media rather than as causal estimates of learning effectiveness.

Teacher interview responses were reviewed and organized descriptively around the implementation outcomes reflected in the research questions, particularly students' understanding, learning interest, and active engagement. The interview evidence was used to contextualize the quantitative student-response results rather than to claim independently measured changes in achievement. Table 4 summarises the complete analytical structure, including the data source, data type, reported outcome, and analytical procedure.

Table 4. Data sources and analytical procedures

Data source	Data type	Reported outcome	Analytical procedure
Content-expert appraisal	Quantitative rating	Mean = 3.57	Descriptive mean
Media-design expert appraisal	Quantitative rating	Mean = 3.67	Descriptive mean
Student questionnaire	Quantitative Likert-type response	Mean = 66.78; good category	Descriptive score and categorical interpretation
Teacher interviews	Qualitative	Perceived understanding, interest, and engagement	Descriptive qualitative summarisation

This analytical strategy aligns with the study's developmental purpose: it establishes whether experts judged the QR Code learning media appropriate and whether users received them positively, while avoiding causal claims not supported by the study design.

3. Results

3.1. Development of component-linked QR code learning media

This section addresses RQ1, which examined how component-linked QR Code learning media could be developed to provide contextual information about the functions and operation of lathe-machine components. The development process followed the ADDIE framework and resulted in a physical–digital learning system that connected actual lathe components with corresponding digital instructional resources.

During the Analyze stage, classroom observations and teacher consultations identified several learning challenges in lathe-machining instruction at SMK Negeri 5 Padang. Students had difficulty identifying machine components, understanding their functions, and linking each component to appropriate operating procedures. In addition, teachers reported that students required further support in understanding safe machine-operation practices. The existing learning process mainly relied on teacher explanations and printed materials, which limited students' ability to access component-related information independently during workshop activities.

Based on these needs, the media was designed using a component-linked QR Code architecture. Each QR Code was assigned to a specific lathe component and linked to digital instructional resources that explained component functions, operating procedures, video demonstrations, and relevant safety information. This arrangement allowed students to access learning resources directly while observing the corresponding physical component.

The final instructional product consisted of three integrated elements: physical QR Code labels attached to selected lathe components, digital video-based instructional materials, and supporting explanatory content. These components were designed to function as a unified learning system rather than separate digital materials. Table 5 summarises the structure and instructional functions of the developed media.

Table 5. Structure and function of the developed QR code learning media

Component	Description	Instructional function
Physical QR Code labels	QR Codes attached directly to relevant lathe components	Provide immediate access to component-specific learning resources
Digital instructional videos	Videos explaining component function, operation procedure, and demonstrations	Support visualization of mechanical processes and operating steps
Supporting information content	Textual explanations and safety-related information	Reinforce conceptual understanding and safe operating practices

As presented in Table 5, the developed media integrated physical machine objects with digital instructional content. This design allowed students to obtain information related to a specific component without separating the observation process from the learning process.

3.2. Expert appraisal of the developed QR code learning media

This section addresses RQ2, which examined how content and media-design experts appraised the developed QR Code learning media. Following the development and revision stages, experts evaluated the prototype to determine its suitability before classroom implementation.

Two aspects were assessed: content quality and media-design quality. Content appraisal focused on the accuracy, relevance, and clarity of information related to lathe-component functions and operating procedures. Media-design appraisal examined the presentation quality, usability, and technical organization of the QR Code-supported learning resources. The results of expert appraisal are presented in Figure 3.

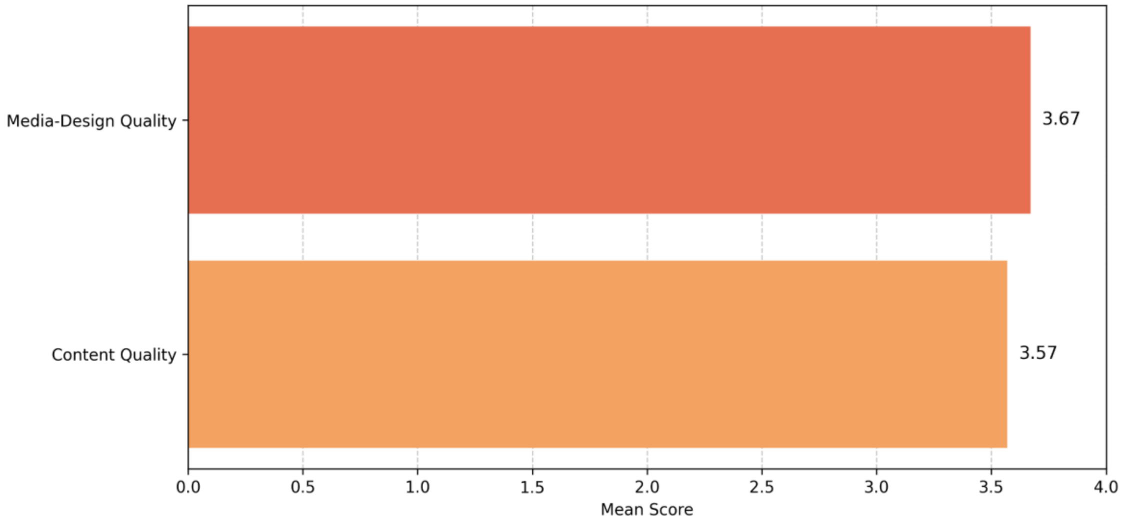

Figure 3. Expert appraisal results of QR code learning media

The expert evaluation showed that both assessed dimensions fell within the very good category. The content evaluation obtained a mean score of 3.57, indicating that the information provided through the QR-linked resources was considered appropriate for supporting lathe-machining learning. Meanwhile, the media-design evaluation obtained a mean score of 3.67, suggesting that the visual presentation and technical arrangement of the learning media were considered suitable for instructional use.

The distribution of expert ratings further confirmed the consistency of these results. The content evaluation indicators were concentrated within the good and very good categories, with no indicators receiving negative classifications. A similar pattern was found for media-design evaluation, where all indicators were classified within acceptable categories. These findings indicate that the developed media met the expected criteria for both instructional content and digital presentation before Implementation with students.

3.3. Student responses and teacher perspectives after Implementation

This section addresses RQ3, which investigated students' evaluations of the developed media and teachers' perspectives regarding students' understanding, learning interest, and classroom engagement after Implementation.

Following expert revision, the QR Code learning media were implemented with 74 Grade XI students of the Machining Engineering program at SMK Negeri 5 Padang. During learning activities, students accessed QR-linked instructional videos through mobile devices while interacting with lathe-machine components. Student responses were collected using a Likert-type questionnaire covering accessibility, usefulness, clarity of information, and perceived learning support. The distribution of student responses is presented in Figure 4.

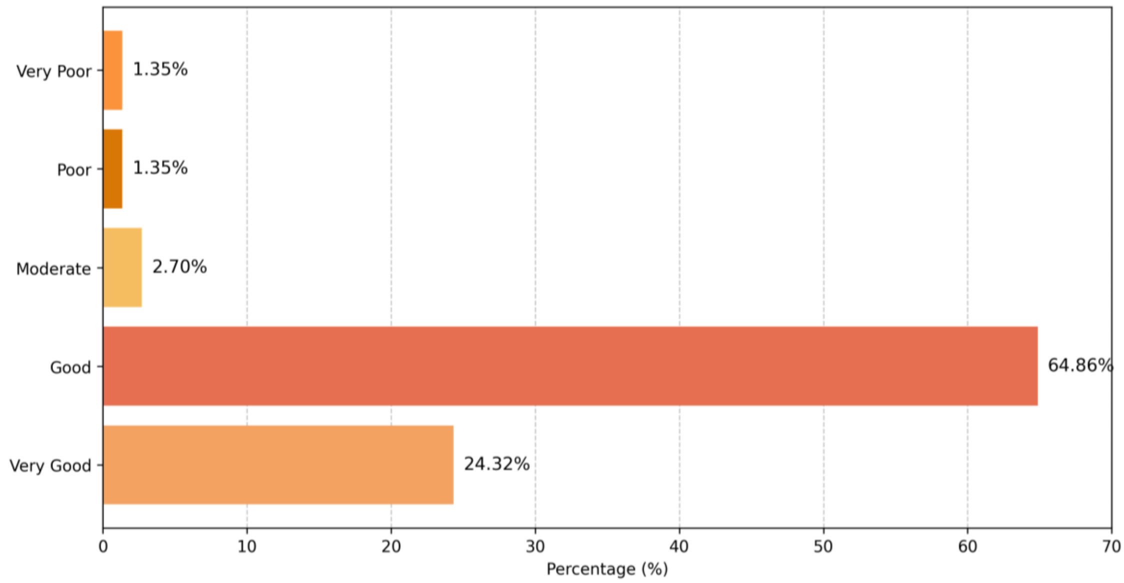

Figure 4. Student responses toward QR code learning media

The overall student-response score was 66.78, which was classified as good according to the predetermined interpretation criteria. The response distribution indicated that most students evaluated the media positively, with 89.18% of students responding in the good and very good categories. Teacher interviews provided additional qualitative evidence regarding classroom implementation. Before using QR Code learning media, teachers reported that students mainly depended on direct explanations and demonstrations during learning activities. Consequently, students had limited opportunities to independently review information about specific lathe components outside direct teacher guidance.

After Implementation, teachers observed that students could access explanations of component functions and operating procedures more independently. Teachers also reported increased student interest and participation because students could directly explore instructional videos while observing the corresponding machine components.

These findings indicate that users received the developed media positively and that it supported a more interactive learning environment. However, the teacher observations represent implementation perspectives rather than direct measurements of learning improvement. Therefore, the results can be interpreted as evidence of usability and classroom acceptance rather than causal evidence of increased learning achievement.

4. Discussion

4.1 Component-linked QR code as a physical–digital learning bridge

The primary contribution of this study lies in transforming QR Code technology from a general digital access tool into a component-linked instructional system for vocational machining education. Unlike conventional QR-based learning media that typically provide access to general learning materials, the developed media establishes a direct relationship between a physical lathe component and its corresponding digital explanation. This design addresses a key characteristic of vocational learning, where students must build understanding through interaction with real equipment, operational procedures, and workplace-related practices.

The findings demonstrate that the QR Code system was developed as an integrated physical–digital learning environment rather than merely as a supplementary online resource. Each QR Code was positioned on specific lathe components and connected to instructional videos explaining component functions, operating procedures, and safety-related information. This point-of-use access reduces the distance between the object being observed and the information required to understand it. This approach aligns with the broader principle of contextual learning, in which knowledge construction is stronger when learners interact directly with authentic objects and situations rather than receiving information only through abstract explanations (Abdulrahaman et al., 2020; Canut-Montalva et al., 2025).

This finding extends previous QR Code research in education. Earlier studies have shown that QR Codes can bridge physical environments and digital resources by enabling rapid access to multimedia content through mobile devices (Law & So, 2010; Sondhi & Kumar, 2022). However, many existing implementations position QR Codes as additional links to learning materials rather than as component-specific instructional interfaces. The present study advances this approach by embedding the QR Code within the vocational learning environment itself, allowing students to obtain information while directly observing and interacting with the machine component.

The instructional value of this design can also be interpreted through multimedia learning principles. By combining visual demonstrations, verbal explanations, and real machine objects, the developed media provides multiple representations that may help students form more complete mental models of mechanical systems. Multimedia learning research has shown that appropriately integrated visual and verbal information can improve learners' ability to understand complex processes by supporting meaningful cognitive processing (Mayer & Fiorella, 2021; Noetel et al., 2022). Therefore, this study's contribution is not simply the use of QR technology, but the instructional arrangement that connects digital explanations with authentic vocational objects.

4.2 Expert-appraised feasibility of QR code learning media for lathe instruction

The expert appraisal results indicate that the developed QR Code learning media demonstrated strong initial feasibility in terms of both instructional content and media presentation. The resources were considered appropriate in terms of the accuracy of lathe-component information, clarity of explanation, and suitability of the digital presentation prior to classroom implementation.

This favorable evaluation is consistent with previous research emphasizing that digital learning media in vocational education must satisfy both pedagogical and technical requirements. In practical subjects such as machining, instructional resources must convey technically accurate information while remaining usable in workshop environments. Inaccurate representations of procedures, equipment functions, or safety requirements may generate misconceptions rather than support competency development (Canut-Montalva et al., 2025; Zhang, 2025).

The present findings also extend previous research on QR Code-based vocational learning. Earlier studies have shown that QR-supported learning media can improve accessibility and provide efficient access to instructional resources in technical education contexts (Rakha, 2025; Tukhtabayeva et al., 2024). The current study adds to this evidence by examining not only QR-based access but also the suitability of a component-specific instructional design through expert appraisal of both content and media quality.

The slightly higher appraisal of media design than content quality indicates that the technical presentation of the QR-supported resources was a particular strength of the developed product.

This finding is relevant in vocational education because learners frequently depend on clear visual representations when studying mechanical systems. Poorly organized instructional interfaces may increase unnecessary cognitive demands and reduce the practical value of digital resources. Accordingly, accessibility, visual organization, and ease of use represent important design dimensions alongside information accuracy (Abdulrahaman et al., 2020; Staneviciene & Žekiene, 2025).

Expert appraisal, however, reflects product feasibility rather than evidence of instructional effectiveness. The findings indicate that the media were considered suitable for Implementation, but they do not independently demonstrate improvements in students' technical competence. In this study's developmental design, expert evaluation established the product's appropriateness before classroom-based assessment.

4.3 Student acceptance and classroom implementation perspectives

Positive student responses and teacher perspectives indicate that the developed QR Code learning media were well received in the vocational classroom context. Students evaluated the media positively, particularly because the QR Codes provided direct access to explanations and demonstrations through their mobile devices. This pattern suggests that the media supported a more flexible learning process by enabling students to revisit information according to their individual needs.

This accessibility aligns with the principles of mobile learning, in which instructional resources can be accessed beyond conventional classroom boundaries. Previous studies have reported that mobile-supported learning can enhance learner autonomy by allowing students to revisit learning materials independently and at appropriate learning moments (Amzalag et al., 2025; Pedraja-Rejas et al., 2024; Sophonhiranrak, 2021). In vocational workshop settings, this feature is particularly relevant because students may require immediate clarification while interacting with equipment.

Teacher interview findings provide further support for this interpretation. Teachers reported that students became more active in accessing information about lathe components and appeared better able to explain component functions and operations after using the QR Code media. These observations indicate that the media functioned as an additional instructional resource during practical activities and may have reduced students' reliance on repeated teacher explanations.

The findings are consistent with previous studies reporting that technology-supported learning environments are associated with greater student engagement through more interactive and learner-centered learning experiences (Noetel et al., 2022; Walela et al., 2025). However, the present evidence warrants cautious interpretation because the student questionnaires and teacher interviews capture perceptions and classroom observations rather than directly measured learning outcomes. The findings therefore support positive acceptance and implementation feasibility, but they do not establish a causal improvement in technical competence.

Technological accessibility also remains relevant to interpreting the findings. Although most students responded positively, QR-based learning depends on access to mobile devices and sufficient internet connectivity. Previous research has similarly identified technological infrastructure and digital readiness as important conditions influencing the Implementation of technology-enhanced learning (Sophonhiranrak, 2021; Walela et al., 2025).

4.4 Contributions, limitations, and future research directions

This study contributes to vocational education research in three ways. First, it contributes conceptually by showing how QR Code technology can be integrated into a physical–digital learning architecture in which digital information is directly connected to specific machine components. Second, it contributes methodologically by evaluating the developed media through multiple sources of evidence, including expert appraisal, student responses, and teacher perspectives. Third, it contributes practically by providing a feasible instructional model that can support machining education where students require immediate access to equipment-related explanations.

The findings also extend existing QR Code research by addressing a specific gap in vocational learning. Previous studies have demonstrated the usefulness of QR Codes for educational access and multimedia delivery, but fewer studies have examined component-specific QR integration in authentic workshop environments. The present study therefore provides preliminary evidence regarding the feasibility of linking physical vocational equipment with digital instructional resources.

Several limitations should nevertheless be acknowledged. First, the study was conducted in one vocational school involving Grade XI machining students; therefore, transferability to other vocational contexts requires further investigation. Second, the evaluation focused on feasibility, student responses, and teacher perspectives rather than measuring changes in technical knowledge or practical performance. Third, because the study did not employ an experimental or quasi-experimental design, it cannot establish conclusions about learning effectiveness.

Future research should therefore investigate the impact of component-linked QR Code learning media using stronger evaluation designs, such as quasi-experimental studies involving comparison groups. Further studies may also examine whether this approach improves specific vocational outcomes, including component identification ability, procedural understanding, machining performance, occupational safety awareness, and long-term learning retention. Expanding the approach to other vocational equipment, such as milling machines, CNC systems, and welding equipment, may also determine the broader applicability of physical–digital learning integration in technical education.

5. Conclusion

This study developed and evaluated a component-linked QR Code learning media system for lathe-machining instruction in vocational education. The findings demonstrate that the developed media successfully transformed QR Code technology from a general digital access tool into a physical–digital learning bridge that connects specific lathe components with corresponding instructional explanations. Through the ADDIE-based development process, the media integrated QR Code labels, video-based instructional content, and supporting information related to component functions, operating procedures, and safety practices. Expert evaluations confirmed that the developed media achieved very good feasibility in terms of content quality (mean = 3.57) and media-design quality (mean = 3.67). Furthermore, Implementation with 74 Grade XI machining students showed positive acceptance, reflected in the student-response score of 66.78 and supported by teacher perspectives on increased accessibility, student engagement, and support for independent learning.

This study contributes preliminary developmental evidence for integrating digital resources directly into authentic vocational learning environments. The findings indicate that component-linked QR

Code media are feasible and positively received as instructional support for lathe-machining education. However, because this study employed a descriptive developmental evaluation design without a control group or pretest–posttest measurement, the results should not be interpreted as direct evidence of improved learning achievement. Future studies should employ experimental designs to examine the effects of this approach on students' technical knowledge, machining performance, safety awareness, and long-term learning retention across broader vocational contexts.

Author's declaration

Author contribution

Ferdhio Surya Muzakki: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Visualization. **Eko Indrawan:** Supervision, Validation, Methodology, Writing – review & editing. **Budi Syahri:** Supervision, Validation, Resources, Writing – review & editing. All authors have read and approved the final version of the manuscript.

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Conflict of interest

The authors declare no known financial or non-financial competing interests related to this study.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical considerations

Ethical approval was not required because this study involved educational evaluation activities without clinical intervention or collection of sensitive personal data.

AI statement

During manuscript preparation, the authors used Gemini AI only to improve readability and language clarity. The authors remain fully responsible for the content, analysis, interpretation, and scientific integrity of the manuscript. AI was not used to generate data or replace the authors' academic contributions.

Publisher's and Journal's note

Universitas Negeri Padang, as the publisher, and the Editor of Jurnal Pendidikan Teknologi Kejuruan state that there is no conflict of interest towards this article publication.

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