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PRINTED HYPERMEDIA-BASED PBL INSTRUCTIONAL MATERIALS FOR THE MOTORCYCLE IGNITION SYSTEM: A SYSTEMATIC REVIEW

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ABSTRACT

Learning the motorcycle ignition system in Vocational High Schools requires instructional materials that can visualize electrical processes, intercomponent relationships, and contextual fault-diagnosis procedures. This study formulates a conceptual framework for developing printed hypermedia-based Problem-Based Learning (PBL) instructional materials for the motorcycle ignition system, guided by three research questions: the characteristics of relevant hypermedia materials (RQ1), the contribution of PBL to problem solving and critical thinking (RQ2), and the conceptual basis for integrating printed materials, QR-code-based hypermedia, and PBL (RQ3). A Systematic Literature Review was conducted following the PRISMA flow; literature was retrieved from the Sinta and Scopus databases for 2021–2025. Of 487 records identified, 30 met the inclusion criteria and were analyzed through thematic synthesis. The findings show that hypermedia, multimedia, augmented reality, and virtual laboratories support the visualization of abstract electrical processes (RQ1); PBL builds diagnostic reasoning and problem solving, raising competency mastery in automotive contexts (RQ2); and the print–hypermedia–PBL integration is conceptually feasible but not yet tested, as only two studies address the ignition system and only four support printed hypermedia materials (RQ3). The synthesis is formulated into a conceptual framework as a basis for further development research through expert validation, practicality testing, and effectiveness testing.

Keywords: printed instructional materials, hypermedia, Problem-Based Learning, motorcycle ignition system, systematic literature review

INTRODUCTION

Vocational education plays a strategic role in preparing graduates with technical skills, work readiness, and the ability to adapt to industrial needs (Nurjanah et al., 2022; Astuti & Setyonaluri, 2022; Mahanani et al., 2024). In the Motorcycle Engineering and Business program of Indonesian Vocational High Schools (SMK), one essential competency is the motorcycle ignition system, because it is directly related to understanding electrical systems, component operation, and diagnosing vehicle malfunctions (Rassyi et al., 2025). Mastering this topic requires not only naming component functions but also explaining the working sequence, interpreting fault symptoms, determining possible causes, and selecting appropriate inspection procedures (Husein et al., 2023).

The ignition system is highly abstract because its processes involve electric current flow, electromagnetic induction, electrical discharge, and the conversion of electrical energy into a spark, which students cannot observe directly. Visual and multimedia representations are therefore needed to help students connect concepts, components, and technical symptoms (Muskhir et al., 2024). From the perspective of the Cognitive Theory of Multimedia Learning,

learning is more effective when verbal and visual information is integrated, designed to fit working memory, and structured to reduce irrelevant cognitive load (Mayer, 2024; AlShaikh et al., 2024). Problem-Based Learning (PBL) is also relevant, as it can confront students with authentic scenarios (such as a motorcycle that is hard to start, a weak spark, or a malfunctioning CDI) and develop the diagnostic reasoning that lies at the core of technical work (Abele, 2018).

However, vocational learning is not always supported by adequate media and digital infrastructure. Limitations in devices, digital skills, and internet connectivity remain barriers to equitable digital learning in Indonesia (UNICEF Indonesia, 2021; Aisiah et al., 2025). One adaptive alternative is the printed hypermedia-based instructional material, in which QR codes embedded in a printed book link the text to supporting videos, animations, and simulations (Abeywardena, 2017; Sağıt et al., 2024). Such materials retain the accessibility of print while providing multimedia support and become more meaningful when integrated with PBL, guiding students through the stages of problem solving.

Previous studies have examined multimedia, hypermedia, QR codes, PBL, and automotive media separately, and several products have demonstrated good validity and effectiveness in their respective contexts. However, studies that specifically integrate printed materials, QR-code-based hypermedia, and PBL syntax for the motorcycle ignition system remain limited. This gap calls for a systematic review to develop a transparent and accountable conceptual basis, rather than relying solely on practical assumptions.

Accordingly, this study formulates a conceptual framework for developing printed hypermedia-based PBL instructional materials for the motorcycle ignition system, guided by three research questions:

RQ1. What characteristics of hypermedia instructional materials are relevant to motorcycle ignition system learning?
RQ2. How does PBL contribute to developing problem-solving and critical-thinking skills in automotive learning?
RQ3. What conceptual basis for integrating printed materials, QR-code-based hypermedia, and PBL can be formulated for the motorcycle ignition system?

LITERATURE REVIEW

Multimedia learning and cognitive load. The Cognitive Theory of Multimedia Learning holds that learning improves when verbal and visual channels are presented together and when extraneous load is minimized (Mayer, 2024). Recent applications confirm that well-designed multimedia and video assistants support understanding of complex material (AlShaikh et al., 2024), while the order and relevance of worked examples affect cognitive load

(Wesenberg et al., 2022). For abstract electrical content, this implies that visual elements must be selective and aligned with learning objectives rather than merely numerous.

Hypermedia and QR-code-enriched print. Hypermedia integrates text, images, audio, video, animation, simulation, and digital links within a flexible, non-linear structure, and adaptive hypermedia systems can improve engineering learning outcomes (Sumarlin et al., 2024). In printed form, QR codes connect the page to multimedia resources (Abeywardena, 2017), and a systematic review shows that QR codes are widely used pedagogically to link learners with supporting videos (Sağıt et al., 2024). This positions printed hypermedia as a transitional medium between traditional and digital learning.

Problem-Based Learning and diagnostic reasoning. PBL encourages students to understand problems, gather information, analyze alternatives, and evaluate solutions, and meta-analytic evidence links problem-driven learning to motivation and critical thinking (Lu et al., 2025; Wijnia et al., 2024). In technical work, the cycle of identifying symptoms, hypothesizing causes, and selecting procedures is essentially diagnostic reasoning, a core professional competence (Abele, 2018; Meier et al., 2023). Specifically for the ignition system, PBL with a multi-CDI ignition medium has been associated with improved critical thinking among vocational students (Rassyi et al., 2025).

METHODOLOGY

This study used a Systematic Literature Review (SLR) following the PRISMA 2020 flow to ensure transparency and traceability of the selection process (Page et al., 2021). The search combined the keywords "hypermedia instructional materials", "problem based learning", "motorcycle ignition system", and "vocational education" with Boolean operators (AND/OR) across the Sinta and Scopus databases, limited to 2021–2025 and to articles in Indonesian or English.

The selection followed the four PRISMA stages: identification, screening, eligibility, and inclusion (Figure 1). Of 487 records identified, 113 duplicates were removed, leaving 374 for title-and-abstract screening; 248 were excluded, and 126 reports were sought, of which 39 could not be retrieved in full text. Of the 87 reports assessed for eligibility, 57 were excluded for three reasons: off-topic focus (26), inadequate methodological design (19), and findings that could not be extracted (12), yielding 30 included studies (coded A1–A30). Inclusion and exclusion criteria are summarized in Table 1.

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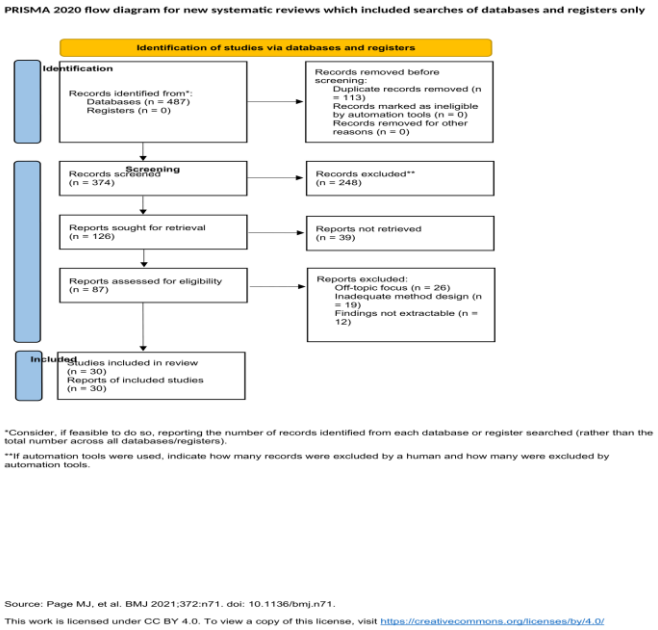

Figure 1. PRISMA 2020 flow diagram of the article selection process

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Scientific journal articles published between 2021 and 2025.	Articles outside the 2021–2025 period.
Articles in Indonesian or English.	Articles in languages other than Indonesian or English.
The article is available in full text.	The article is not available in full text, or only the abstract is available.
The article discusses teaching materials, learning resources, hypermedia, hypercontent, interactive multimedia, and QR codes in education.	The article does not discuss teaching materials, learning resources, or learning technologies.
The article discusses Problem-Based Learning, problem-solving learning, or the problem-based learning model.	The article has no connection with PBL or problem-solving.
Articles relevant to vocational education, vocational secondary schools (SMK), TVET, the automotive sector, engineering, or abstract topics requiring visualization.	The article is not relevant to education, learning, vocational training, engineering, or visualization-based material.
The article employs a clear research method, such as R&D, experiments, quasi-experiments, classroom action research, qualitative descriptive research, or structured conceptual studies.	The article does not adequately describe the research methods.
The article contains findings that can be drawn upon to support a synthesis regarding the design, validity, practicality, effectiveness, or framework of teaching materials.	The article presents no findings relevant to the synthesis process.

The article is directly or indirectly relevant to the development of PBL-based hypermedia teaching materials on motorcycle ignition systems.	The article strays too far from the study's focus and cannot be used to construct a conceptual framework.

Screening and extraction were conducted independently by two reviewers, and any disagreement was resolved through discussion until consensus was reached. Each retained article was appraised for methodological quality using an adapted critical-appraisal checklist covering clarity of design, fit between method and objective, adequacy of the sample, and reporting of validity, practicality, or effectiveness; studies with unclear designs or findings that could not be extracted were excluded. The 30 studies were analyzed using thematic synthesis (Thomas & Harden, 2008); the extracted data for each study (authors, year, objective, method, sample, and main findings) are provided as supplementary material.

RESULT AND DISCUSSION

The 30 included studies were published between 2021 and 2025 and span diverse contexts, from elementary, science, and language education to higher and automotive vocational education. As shown in Figures 2–5, the studies peaked in 2023 (Figure 2: 2 in 2021, 3 in 2022, 10 in 2023, 7 in 2024, 8 in 2025), were dominated by Research and Development designs (Figure 3: 20 studies, mainly ADDIE, Borg & Gall, and 4-D, with 4 classroom action research, 2 quasi-experiments, 3 descriptive/qualitative, and 1 conceptual study), and were largely situated in vocational education (Figure 4: 14 of 30). Crucially, Figure 5 shows that only two studies directly target the ignition system, while most remain in adjacent or general contexts.

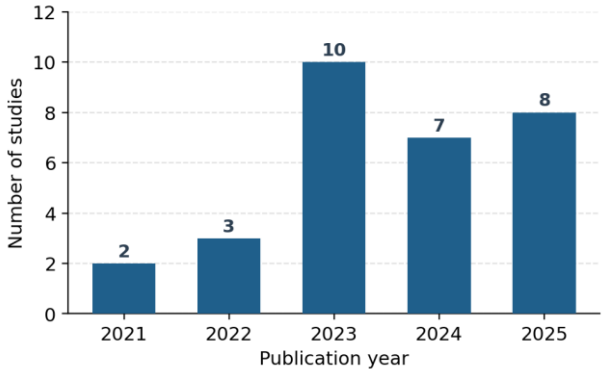

Figure 2. Distribution of the 30 included studies by publication year

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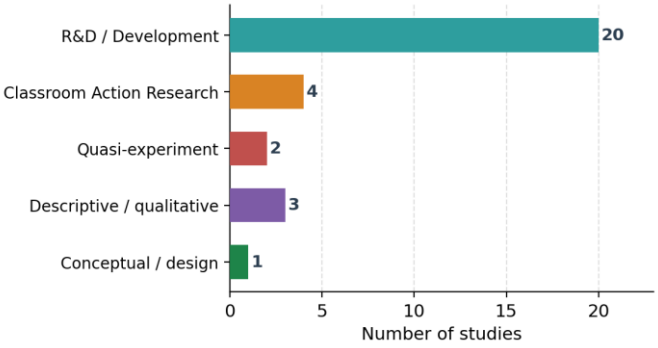

Figure 3. Distribution of the 30 included studies by research method

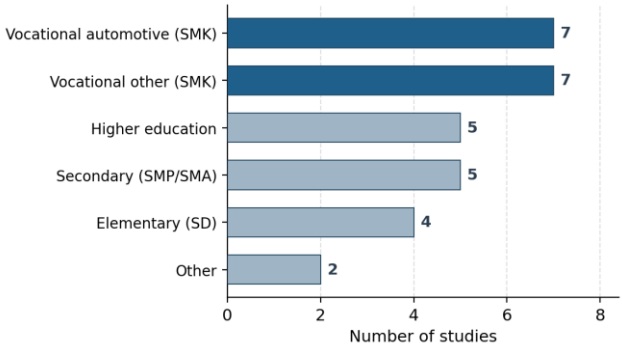

Figure 4. Distribution of the 30 included studies by educational context

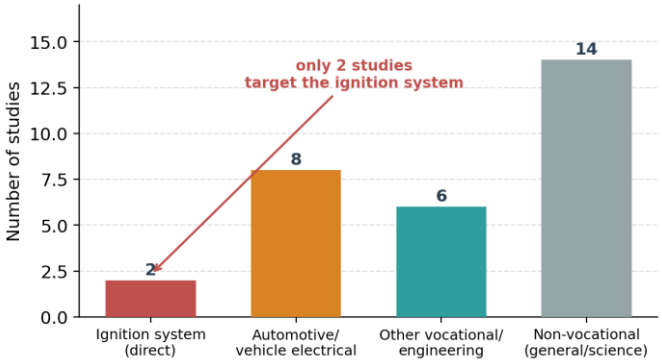

Figure 5. Proximity of the 30 included studies to the ignition-system topic

Thematic synthesis produced five themes mapped to the three research questions: Theme 1 (hypermedia/multimedia for visualization) answers RQ1; Theme 2 (PBL/problem solving) answers RQ2; and Themes 3 (printed hypermedia), 4 (validity, practicality, effectiveness), and 5 (vocational/automotive education) jointly answer RQ3. Table 2 summarizes the synthesized answer to each question; Table 3 details the themes and their supporting studies; and Figure 6 maps each study to the themes, showing that printed hypermedia (Theme 3) remains the least-supported theme.

Table 2. Synthesis Matrix by Research Question

Research Question	Supporting Studies (Theme; n)	Synthesised Answer	Main Gap
RQ1. Characteristics of hypermedia materials	Theme 1; A1, A2, A4, A5, A9, A10, A12, A16–A18, A24–A30 (n=17)	Relevant hypermedia materials contain text, video, animation, simulation, hyperlinks, QR codes, AR, and non-linear navigation to visualize abstract electrical processes.	Conceptually strong, but most studies lie outside the ignition-system topic.
RQ2. Contribution of PBL	Theme 2; A3, A6, A7, A8, A10, A11, A13, A15, A22–A25 (n=12)	PBL and problem solving improve problem-solving, critical thinking/HOTS, and diagnostic reasoning; in automotive contexts, they raise competency mastery (e.g., 39.39%→93.93%).	Strong evidence across contexts; PBL syntax must be translated to the ignition topic.
RQ3. Conceptual basis for integration	Themes 3–5; print-QR A5, A19–A21 (n=4); validity A2–A4, A9, A14–A20, A25–A27 (n=16); vocational/automotive A5–A8, A11–A17, A28–A30 (n=13)	Integrating printed materials + QR hypermedia + PBL is conceptually feasible and supported by evidence of validity and effectiveness in related contexts; formulated as a conceptual framework (Figure 7).	Only 2 studies address the ignition system (A6, A11), and only 4 support printed hypermedia materials; none combine all three.

Table 3. Thematic Synthesis of the 30 Included Studies

Theme	Supporting Studies	Key Finding
Hypermedia/multimedia for visualizing abstract concepts	A1, A2, A4, A5, A9, A10, A12, A16, A17, A18, A24, A25, A26, A27, A28, A29, A30	Hypermedia, hypercontent, interactive multimedia, augmented reality, and simulation/virtual labs help visualize abstract concepts that are hard to grasp through static text.
PBL/problem solving for problem-solving skills	A3, A6, A7, A8, A10, A11, A13, A15, A22, A23, A24, A25	PBL and problem solving drive problem identification, cause analysis, diagnostic reasoning, and improved learning outcomes, including in automotive contexts.
Printed hypermedia-based instructional materials (QR code)	A5, A19, A20, A21	Printed materials enriched with QR codes (pop-up books, modules, textbooks) to access video, simulation, and digital exercises; the least-supported theme and not yet addressing the ignition system.

Validity, practicality, and effectiveness	A2, A3, A4, A7, A9, A10, A12, A14, A15, A17, A18, A19, A20, A25, A26, A27	Most developed products are reported valid, practical, and/or effective (high validity, high N-Gain, good user response) in their respective contexts.
Vocational/automotive education	A5, A6, A7, A8, A11, A12, A13, A14, A16, A17, A28, A29, A30	Automotive/vocational studies address vehicle electrical systems, starter, fuel, lighting, and engine maintenance, but only two studies touch the motorcycle ignition system (A6, A11).

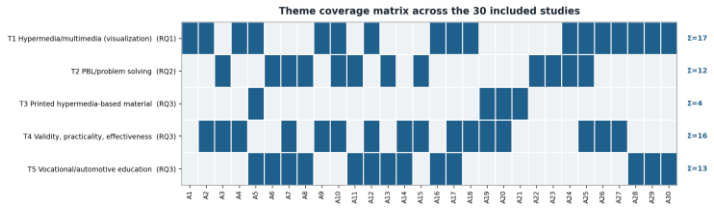

Figure 6. Theme-coverage matrix of the 30 included studies and their mapping to the research questions

Findings for RQ1: Characteristics of Hypermedia/Multimedia Instructional Materials

Characteristics of relevant hypermedia materials. The corpus indicates that hypermedia suited to ignition learning integrates text, video, animation, simulation, hyperlinks, QR codes, augmented reality, and non-linear navigation to visualize abstract electrical concepts (Table 3; Figure 6). Hypercontent modules combine video, audio, hyperlinks, and interactive content in a non-linear structure [A1], a pattern reinforced by an AI-based hypercontent worksheet supporting learner independence [A26]. Guided-inquiry hypermedia affected higher-order thinking in thermodynamics [A4]; mobile interactive multimedia and augmented reality made abstract electrical phenomena concrete [A27; A28]; and PhET-based worksheets and virtual laboratories supported visualization when physical laboratories were unavailable [A9; A29; A30], consistent with broader evidence that PhET-based virtual laboratories raise students' learning activity (Simbolon & Silalahi, 2023). Daeli et al. argued that printed books, limited to text and static images, need enrichment through QR-linked video and simulation [A5].

These findings are consistent with the Cognitive Theory of Multimedia Learning and cognitive load theory: visual elements help most when they are relevant to the objective rather than merely abundant (Mayer, 2024; Wesenberg et al., 2022). For the ignition system, this implies placing digital elements only where visualization is genuinely needed (current flow, CDI operation, coil inspection, and the link between symptoms and causes), so that the printed hypermedia design remains selective and functional [A5; A16].

Findings for RQ2: Contribution of PBL to Problem-Solving and Critical Thinking

Contribution of PBL. PBL and problem solving consistently strengthened problem solving, critical thinking, and diagnostic reasoning (Table 2). PBL-based flipbooks, interactive digital materials, and e-modules demonstrated high validity and N-Gain in understanding and creative thinking [A3; A10; A25], and classroom and quasi-experimental studies confirmed significant gains in critical and higher-order thinking among vocational students [A22; A23; A24]. In automotive contexts, PBL increased learning mastery from 17.4% to 82.6% [A8] and fuel-system repair mastery to 100% [A13], while trainer-assisted PBL for the electronic ignition system increased competency mastery from 39.39% to 93.93% [A11]. Rassyi et al. placed PBL within a multi-CDI ignition system, directing students to identify faults, analyze causes, apply repair procedures, and evaluate outcomes [A6].

This sequence is, in essence, the diagnostic-reasoning process central to technical work (Abele, 2018; Meier et al., 2023). PBL in ignition materials should therefore be translated into a concrete activity structure: each unit can begin with an authentic workshop case, followed by symptom identification, cause hypothesizing, concept exploration through hypermedia, inspection-procedure selection, solution design, and reflection [A6; A11]. Such a structure aligns with evidence that multimodal PBL strengthens vocational learning outcomes (Al Husaeni et al., 2025).

Findings for RQ3: Conceptual Basis and Evidence on the Ignition System

Conceptual basis and evidence on the ignition system. On the quality dimension, most developed products were reported valid, practical, and/or effective (Table 3): an adaptive hypermedia system reached a gain score of 0.735 [A2], a PBL flipbook reached N-Gain 0.8106 [A3], and a PBL e-module for lathe machining reached N-Gain 0.71 [A15], while automotive Android media for gasoline-engine and network material reported high validity and effectiveness [A12; A14; A18]. Printed hypermedia is supported by only four studies: a QR-assisted pop-up book (validity 4.85) [A19], a QR-based biodiversity module (validity 88.60) [A20], and a QR-based Arabic textbook that motivated speaking skills [A21], alongside Daeli et al. [A5].

However, the evidence is bounded by two gaps. First, direct evidence on the ignition system is scarce: only Rassyi et al. and Husein et al. address it [A6; A11], while related automotive studies cover the starter system, fuel system, light-vehicle electricity, and lighting rather than the ignition system [A7; A8; A16; A17], with recent module development also targeting automotive air-conditioning maintenance (Azzaky et al., 2025). Second, printed

hypermedia remains the least-supported theme, and no study combines printed materials, QR-code hypermedia, and PBL on the ignition topic. The positive validity results therefore support the feasibility of the constituent elements but cannot be generalized to prove that an integrated ignition product is effective.

Synthesizing the three questions, this review develops a conceptual framework for printed hypermedia-based PBL instructional materials on the motorcycle ignition system (Figure 7). The framework integrates three pillars, namely the accessibility of printed materials [A5], the visualization of electrical processes through QR-code-based hypermedia [A1; A19–A21; A27; A28], and diagnostic reasoning through PBL syntax [A6; A11; A22; A23], grounded in the Cognitive Theory of Multimedia Learning, cognitive load theory, and diagnostic-reasoning theory. The PBL syntax is aligned with ignition-diagnosis procedures, from problem orientation through concept exploration via QR codes to evaluation and reflection, targeting conceptual understanding, process visualization, diagnostic reasoning, and technical problem solving. These outcomes still require validation through Research and Development.

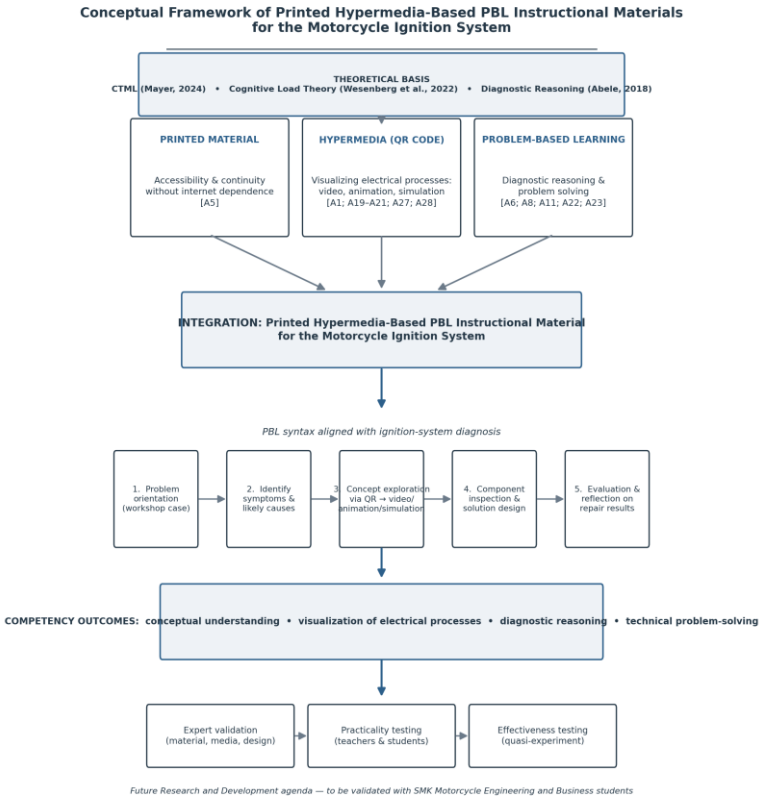

Figure 7. Conceptual framework of printed hypermedia-based PBL instructional materials for the motorcycle ignition system

Limitations of the Review

This review has several limitations that should temper its conclusions. First, the search was restricted to two sources (Sinta and Scopus) and to articles in Indonesian or English published between 2021 and 2025, so relevant work in other databases, languages, or periods may not have been captured, and some risk of selection and publication bias remains. Second, because the included studies were heterogeneous in design and outcome measures, the synthesis was qualitative (thematic) rather than statistical, so no pooled effect size was estimated. Third, most included products were evaluated in single-context developmental studies with limited experimental control, which means the reported validity, practicality, and effectiveness are context-bound rather than generalizable. Finally, the proposed conceptual framework is an analytical construction derived from the literature and has not yet been empirically tested; its validity, practicality, and effectiveness must be established through subsequent development research.

CONCLUSION

This systematic review of 30 studies shows that hypermedia, interactive multimedia, augmented reality, and digital simulation can strengthen the presentation of abstract material through text, video, animation, hyperlinks, and QR codes (RQ1), while PBL and problem solving guide students to identify problems, analyze causes, and evaluate solutions, raising competency mastery in automotive contexts (RQ2). For the ignition system, these potentials matter because the material involves electrical processes, CDI operation, and intercomponent relationships that demand dynamic visualization.

The central finding is that no study has directly integrated printed materials, QR-code-based hypermedia, and PBL for the motorcycle ignition system (RQ3). Only two studies address the ignition topic, and only four support printed hypermedia. The main contribution of this review is therefore the thematic mapping and the conceptual framework (Figure 7), which position printed hypermedia as a transitional, accessible solution for schools with limited digital infrastructure. Because the framework has not been empirically tested, future research should develop the product through Research and Development with a suitable model (ADDIE, Borg & Gall, or ASSURE), conduct expert validation and practicality testing with SMK Motorcycle Engineering and Business teachers and students, and measure effectiveness using stronger designs such as quasi-experiments on conceptual understanding, diagnostic skill, and cognitive load.

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