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Project-based learning and critical thinking in car audio video installation: a quasi-experimental study

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ABSTRACT

This study examined changes in critical thinking assessment scores during Project-Based Learning (PjBL) activities involving car audio video installation in vocational education. A quasi-experimental design with a nonequivalent control group involved 30 Grade XI students, 15 in each instructional group, over two meetings within one month. The experimental group completed installation projects, while the control group received conventional instruction. Assessment comprised 15 multiple choice questions and 10 essay questions covering technical knowledge and reasoning. Across the combined sample, mean scores increased from 60.10 at pretest to 82.97 at posttest, and standard deviation decreased from 10.246 to 4.672. The mean normalized gain was 0.563, indicating moderate improvement. These descriptive findings show higher overall performance following instruction, but do not establish a difference in effectiveness between PjBL and conventional teaching because results were not reported separately for the two groups. The study illustrates how project activities can integrate technical decision making, analysis, and reflection, while highlighting the need for group comparisons and documented instrument quality.

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Introduction

Car audio video installation requires students to integrate electronic knowledge with decisions about component compatibility, electrical protection, signal routing, and system performance. When faults occur, students must examine possible causes, select appropriate tests, and justify corrective measures. Such activities offer opportunities to develop analytical reasoning alongside technical competence. Previous studies of automotive engineering projects and light vehicle maintenance have shown the relevance of authentic technical problems in vocational learning (Zhou, 2023; Muslim, Ambiyar, Setiawan, & Putra, 2020). Research on vocational competencies likewise identifies critical thinking, creativity, and problem solving as important educational outcomes (Samani, Sunwinarti, Putra, Rahmadian, & Rohman, 2019; López et al., 2023).

Project-Based Learning (PjBL) organizes instruction around sustained inquiry, collaborative work, the development of a concrete product, and reflection on the learning process. Its educational value depends not only on completing practical tasks but also on the guidance and intellectual engagement that accompany them (Blumenfeld et al., 1991; Bell, 2010). Reviews have emphasized the importance of instructional support and the alignment of learning activities with assessment (Kokotsaki, Menzies, & Wiggins, 2016; Guo, Saab, Post, & Admiraal, 2020). Chen and Yang (2019) found that achievement outcomes varied across PjBL settings,

suggesting that the learning context and outcome measures deserve careful consideration. Similar concerns arise in vocational education, where the effectiveness of project work may depend on task design, learning resources, and the competencies assessed (Ahmad, Watrianthos, Samala, Muskhir, & Dogara, 2023; Andriyanto & Rahdiyanta, 2025; Kristiana et al., 2026). The need for methodological care is also highlighted in a review of existing meta-analyses (Farshad & Fortin, 2026).

In technical education, critical thinking can be observed through the identification of problems, analysis of causes, evaluation of alternatives, and justification of decisions. For example, diagnosing an audio system requires students to interpret symptoms, test possible explanations, and select a technically appropriate solution. These skills are conceptually distinct from an individual's general disposition toward critical thinking (Loyens, van Meerten, Schaap, & Wijnia, 2023). Research in technical and vocational education further indicates the value of tasks that make students' reasoning explicit (López et al., 2023). Accordingly, this study examined performance on tasks involving technical understanding and reasoning in the context of car audio video installation.

Studies of project learning in vocational education have addressed entrepreneurship (Febrianti et al., 2023), mathematics modules (Baidowi, Arjudin, Novitasari, & Kertiyani, 2023), digital learning resources (Rizal, Ganefri, & Ambiyar, 2024), and practical competencies related to work readiness (Sudarsono et al., 2022). Related research has considered industry collaboration (Naseer, Tariq, Alshahrani, & Alruwais, 2025; Martini et al., 2024), critical thinking in electronics education (Djatmiko, Setyowati, & Wahyuni, 2026), and problem based learning in electrical technology (Orji, 2025). These investigations provide useful pedagogical evidence, but their instructional activities and assessment measures differ from those used in car audio video installation. Research focused on reasoning during the selection, installation, and diagnosis of automotive audio components can therefore extend the understanding of PjBL in this particular vocational setting.

This study examined changes in students' assessment performance before and after instruction and considered whether PjBL through car audio video installation could offer an advantage over conventional teaching. The research hypothesis anticipated greater improvement among students who received PjBL. The conceptual relationship between project activities and the reasoning tasks assessed is presented in Table 1. Assessment scores combined questions on technical knowledge with essay responses that required explanation, analysis, and evaluation. The analysis focuses on changes in assessment scores and their implications for vocational instruction.

Table 1. Conceptual relationship between installation activities and reasoning tasks

PjBL activity	Reasoning opportunity	Assessment evidence
Project planning and component selection	Identify constraints; compare technical options	Problem identification and evaluation
Assembly, signal routing, and safety checks	Explain system relationships and justify procedures	Analysis and reasoned decisions
System testing and troubleshooting	Diagnose faults; compare remedies	Problem analysis and proposed solutions
Evaluation and reflection	Defend or revise technical decisions	Evidence-based conclusions

Method

The research used a quasi-experimental design with pretest and posttest assessments and a nonequivalent control group. Participants comprised 30 Grade XI students enrolled in the Audio Video Engineering program at SMK Negeri 7 Surabaya during the even semester of 2026. Fifteen students participated in the PjBL condition and 15 received conventional instruction. Purposive sampling considered enrollment in the relevant course, prior exposure to introductory audio system content, and participation in instructional activities. As the groups were not assigned at random, differences in initial competence and learning experience could have influenced their subsequent performance.

Both groups attended two instructional meetings over one month. In the experimental group, students planned component configurations, assembled the audio system, checked electrical and signal connections, identified faults, tested system performance, and reflected on technical decisions. The control group received explanations and demonstrations covering the same general subject matter. The sequence of pretest, instructional activities, and posttest is shown in Table 2. The instructional setting and the short intervention period were considered when interpreting the findings.

Table 2. Research design and sequence of learning activities

Assessment before instruction	Instruction over two meetings within one month	Assessment after instruction
Experimental group (n = 15): pretest	Car audio-video installation through PjBL	Experimental group: posttest
Control group (n = 15): pretest	Conventional instruction and demonstration	Control group: posttest

The assessment contained 25 questions comprising 15 multiple choice items and 10 essay items. The objective questions covered audio system components, wiring, installation safety, and standard procedures. Each correct response was awarded 2 points, producing a maximum of 30 points. The essays required students to explain technical concepts, diagnose installation problems, evaluate options, and justify solutions. An analytical rubric allocated up to 2 points each for conceptual accuracy, completeness, and analysis, with 1 additional point for the proposed solution or conclusion. The essay section contributed a maximum of 70 points, giving a combined score of 100. Because the total included both technical knowledge and analytical responses, it represented performance on the complete assessment rather than a separate score for each critical thinking dimension. The instrument structure is summarized in Table 3.

Table 3. Assessment content and scoring criteria

Domain	Documented tasks	Scoring basis
Technical knowledge	Items 1–15: system components, wiring, installation safety	15 multiple-choice items × 2 points = 30
Conceptual and analytical responses	Items 16–25: explaining systems, troubleshooting, planning and evaluating installations	10 essay items × 7 points = 70
Critical-thinking indicators	Identify problems; analyze causes; evaluate information; propose solutions; draw conclusions	Essay responses interpreted using the documented indicator rubric

The essay section included practical scenarios such as identifying the causes of electrical interference when an engine is running, diagnosing an amplifier that fails to operate, assessing speaker impedance compatibility, and planning a safe system configuration. These tasks required students to relate technical evidence to explanations and proposed solutions. The accompanying observation sheet covered project planning, cooperation, procedural accuracy, troubleshooting, and reflection. Observation data described classroom processes, whereas the written assessment provided the scores used in the quantitative analysis.

Instrument review was planned using a content validation form with 25 criteria on a five point scale, covering relevance, clarity, technical accuracy, suitability for students, and the consistency of scoring criteria. The content validation form contained no completed expert ratings or validation decisions. Reliability coefficients and agreement estimates for essay scoring were also not documented. The findings therefore concern performance on the administered assessment; the validity and reliability of its scores require further empirical evaluation.

Descriptive analysis summarized sample size, minimum and maximum scores, mean, and standard deviation. The score distributions were examined using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Normalized gain (N-Gain) was used to describe improvement relative to the maximum possible score (Sukarelawan, Indratno, & Ayu, 2024). It was calculated by dividing the difference between posttest and pretest scores by the difference between the maximum possible score and the pretest score. The descriptive statistics combine the two instructional groups. A statistical comparison of the experimental and control conditions, including an estimate of the relative treatment effect, was not reported.

Results and Discussions

The descriptive results are presented in Table 4. Across all 30 students, the mean assessment score increased from 60.10 at pretest to 82.97 at posttest, a difference of 22.87 points. The standard deviation decreased from 10.246 to 4.672, indicating that the scores were less dispersed after instruction. Pretest values ranged from 40 to 81, while posttest values ranged from 75 to 93. These results describe the change observed in the complete sample.

Table 4. Descriptive statistics of assessment scores

Assessment	N	Minimum	Maximum	Mean	SD
Pretest	30	40	81	60.10	10.246

Posttest	30	75	93	82.97	4.672
Valid N (listwise)	30	—	—	—	—

Note. SD = standard deviation. Values summarize both instructional groups.

Table 5 presents the normality tests. The Shapiro–Wilk significance values were 0.610 for pretest and 0.210 for posttest, exceeding the conventional threshold of 0.05. In contrast, the Kolmogorov–Smirnov test indicated a significant departure from normality for posttest scores ($p = 0.026$). The two tests thus produced different interpretations for the posttest distribution. Because these diagnostics were calculated from combined scores, they do not establish whether the assumptions for comparisons between the two instructional groups were satisfied.

Table 5. Normality tests for pretest and posttest scores

Assessment	K–S statistic	df	K–S p	S–W statistic	df	S–W p
Pretest	0.117	30	0.200*	0.972	30	0.610
Posttest	0.171	30	0.026	0.954	30	0.210

Note. K–S = Kolmogorov–Smirnov with Lilliefors correction; S–W = Shapiro–Wilk. * The value 0.200 represents the lower bound of the reported significance.

The mean N-Gain was 0.563, corresponding to the moderate category (Table 6). This indicates a moderate improvement relative to the remaining possible score range at pretest. The value describes the overall sample and does not distinguish the gains attained by students in the experimental and control groups. Consequently, a relative advantage of PjBL cannot be established from this result alone.

Table 6. Summary of normalized gain

Outcome	N	Mean N-Gain	Classification
Combined assessment scores from pretest and posttest	30	0.563	Moderate

The increase in mean performance may reflect learning during the instructional period, but other influences also merit consideration. Familiarity with the assessment, differences in students' initial abilities, and experiences outside the two meetings could have contributed to the changes observed. The available descriptive results do not separate these possibilities from the effects of the project activities. Similarly, the absence of a direct comparison between groups cannot be interpreted as evidence that the two instructional approaches produced equivalent outcomes.

To place these findings in context, Table 7 summarizes 17 relevant empirical studies. The studies differ in subject matter, intervention design, student population, and the skills assessed. They help explain the educational relevance of authentic project activities while indicating why outcomes from different contexts cannot be compared solely on the basis of their reported gains.

Table 7. Comparison with empirical research on project learning

Study	Instructional setting / focus	Relevance to this study
Zhou (2023)	Automotive engineering teaching	Related technical authenticity; different practical tasks
Muslim et al. (2020)	Light-vehicle engine maintenance tools	Automotive project design, not audio-video systems
Samani et al. (2019)	Vocational critical thinking and problem-solving	Broad competencies; distinct assessment
Febrianti et al. (2023)	Entrepreneurship in vocational school	PjBL and critical thinking in another subject
Baidowi et al. (2023)	Vocational mathematics modules	Conceptual transfer across disciplinary settings
Rizal et al. (2024)	Vocational project-based e-module	Digital media and assessment differ
Arista et al. (2025)	Portfolio assessment in nail-art instruction	Performance scoring differs from technical tests
Taufiq (2025)	PjBL in vocational secondary education	Closest educational level; intervention content differs
Djatmiko et al. (2026)	LMS-supported PjBL in electronics	Critical-thinking disposition distinct from test performance
Rahim et al. (2024)	STEAM and welding technology	Authentic fabrication; different technical domain

Study	Instructional setting / focus	Relevance to this study
Hao et al. (2024)	Project-based business-English instruction	Reasoning measured in language-learning setting
Wahyudiati et al. (2022)	Project-based chemistry teacher education	Older learner population; related reasoning outcomes
Rengkuan et al. (2023)	Genetics project learning	Metacognition and subject-specific reasoning
Rohman et al. (2024)	Ethnoecological-STEM project tasks	Contextual problem-solving; different subject
Panjaitan et al. (2024)	Project learning in secondary physics	Critical thinking in a science context
Orji (2025)	Problem-based electrical/electronic instruction	Related task domain but distinct pedagogy
Sudarsono et al. (2022)	Integrated vocational PjBL for work readiness	Vocational project framework; distinct outcome

Note. The studies differ in population, instructional approach, and outcome assessment.

Research on automotive engineering and vocational practice demonstrates the potential of real technical problems to support learning (Zhou, 2023; Muslim et al., 2020). However, the cognitive demands of a project depend on how learners are asked to interpret evidence and explain their actions. Samani et al. (2019), Febrianti et al. (2023), and Taufiq (2025) provide related perspectives on reasoning within vocational instruction. In car audio video installation, component selection, electrical protection, signal routing, and diagnosis offer concrete opportunities for evaluating alternatives and defending technical choices. The instructional significance lies in making these decisions part of the learning task, not simply in completing the physical installation.

The comparison also reveals differences in the measurement of critical thinking. Research on learning modules (Baidowi et al., 2023; Rizal et al., 2024), portfolio assessment (Arista et al., 2025), and critical thinking disposition (Djatmiko et al., 2026) has used outcomes that are not directly equivalent. Studies of welding (Rahim et al., 2024), physics (Panjaitan, Simanjuntak, & Rajagukguk, 2024), genetics (Rengkuan, Leasa, & Sumampouw, 2023), and contextual STEM activities (Rohman, Marwoto, Nugroho, & Supriyadi, 2024) similarly involve different disciplinary demands. In this study, the essays provided opportunities to demonstrate analysis and justification, although the overall score also reflected performance on objective technical questions. Thus, the observed increase cannot be attributed to a particular reasoning dimension.

Differences in research design further limit direct comparisons of outcomes. Wahyudiati, Irwanto, and Ningrat (2022) investigated critical thinking and problem solving in teacher education, whereas Hao et al. (2024) examined project learning in a vocational language course. Orji (2025) evaluated problem based learning in electrical technology, which differs from the project approach examined here. Sudarsono et al. (2022) focused on readiness for work rather than the same critical thinking assessment. Reviews and cross national comparisons also show variation in instructional arrangements and outcome measures (Martini et al., 2024; Mardizal, Suryono, Nuswantara, Muhe, & Komari, 2023; Marta & Ambiyar, 2024; Triyasa, Yoto, & Nurjanah, 2025). These differences underline the importance of interpreting the present results within their specific educational and methodological context.

For classroom practice, the findings provide a basis for incorporating explicit reasoning into installation projects. Students can be asked to justify component specifications, identify possible causes of system noise, evaluate safe wiring arrangements, compare troubleshooting strategies, and explain the results of functional tests. Such activities reflect the emphasis on inquiry and reflection found in foundational PjBL research (Blumenfeld et al., 1991; Bell, 2010; Kokotsaki et al., 2016) and in later work on student learning and assessment (Guo et al., 2020; Loyens et al., 2023; López et al., 2023). Related evidence from Aswan, Aina, and Natalia (2024) and from industry collaboration studies (Naseer et al., 2025) provides further support for designing active learning tasks that connect theory with practical judgment.

The sample comprised only 15 students in each instructional group, limiting the precision of any comparison of instructional effects. The study also lacked a documented prospective calculation of the sample size needed to detect an educationally meaningful difference. Future investigations would benefit from defining a relevant target effect before recruitment and from retaining linked pretest and posttest records for each participant in both groups.

Several limitations should be considered. Because students were not randomly assigned, initial differences between the groups could have affected the results. Two instructional meetings over one month provided limited opportunities for sustained practice and reflection. In addition, the pooled analysis did not estimate the

difference between the PjBL and conventional instruction groups, while completed content validation results and reliability estimates were not documented. Future research should report results for each instructional group, examine initial comparability, assess scoring consistency, and include a longer period of implementation where feasible.

Conclusions

The mean assessment score of the 30 participating students increased from 60.10 to 82.97, while the standard deviation decreased from 10.246 to 4.672. The mean N-Gain was 0.563, indicating a moderate overall improvement during the study period. Because these figures combined the experimental and control groups, they cannot establish whether PjBL produced greater gains than conventional instruction. Car audio video installation provides a relevant setting in which technical learning can incorporate problem identification, evidence base analysis, evaluation of alternatives, and justified solutions. Further evaluation of its instructional effectiveness requires separate results from each group, documented evidence of assessment quality, and an appropriately designed statistical comparison. These considerations are particularly important when extending the findings beyond the students and setting examined in this study.

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