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The Comparative Effectiveness of Computer-Aided Instruction (CAI) on Learning Outcomes in Electronics Maintenance and Assembly for Senior High School and Vocational School Graduates

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A B S T R A C T

This study aims to examine the comparative effectiveness of Computer-Aided Instruction (CAI) on learning outcomes in electronics maintenance and assembly between Senior High School (SMA) and Vocational High School (SMK) graduates. This research employs a quasi-experimental design with a pretest-posttest approach involving two groups of students from different educational backgrounds. The CAI learning model was implemented to assess its impact on improving student achievement. The results indicate that the use of CAI significantly enhances student learning outcomes, particularly in the competencies of electronics maintenance and assembly. Moreover, SMK graduates demonstrated higher learning achievement compared to SMA graduates after the implementation of the CAI model. These findings suggest that CAI is not only effective in improving learning outcomes but also relevant for application in vocational education settings. Teachers and students responded positively to the use of this model, indicating a high level of practicality in technology-based learning implementation.

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INTRODUCTION

Vocational education aims to prepare individuals for entry into the workforce. This preparation involves educating and training individuals so they are capable of performing their duties and responsibilities effectively in a professional setting. In this context, vocational education plays a crucial role in enhancing a person's knowledge, skills, and attitudes. To remain relevant, vocational education must adapt to the ongoing changes and developments in the world of work, especially as job roles continue to evolve in line with advances in science and technology.

One of the vocational education institutions in Makassar that offers technical programs is the Vocational High School (SMK), which implements the national curriculum as mandated by the government. In this school, subjects related to electronics maintenance and assembly are essential components of the vocational education process. The curriculum emphasizes mastery of technology-based competencies and practical skills. However, student learning outcomes in subjects related to electronics maintenance and assembly remain suboptimal. This condition highlights the need for more effective and adaptive learning models that align with technological advancements and the demands of the labor market. One potential alternative is the use of Computer-Aided Instruction (CAI), which is considered effective in enhancing students' conceptual understanding and technical skills. This study aims to compare the effectiveness of the CAI learning model on the learning outcomes of students from different educational backgrounds—specifically Senior High School (SMA) and Vocational High School (SMK) graduates—in the field of electronics maintenance and assembly in Makassar.

Initial findings suggest that the low learning outcomes in the subject of electronics maintenance and assembly may be largely due to students' limited study and practice time outside of regular classroom hours. This issue is further supported by a teacher's statement indicating that the lack of available computers and the absence of internet facilities hinder students' engagement with learning media. In fact, this subject plays a crucial role in supporting students' mastery of technology and practical skills in the field of electronics. Therefore, improving student performance in this subject is essential. There is a need for alternative learning strategies that can overcome these limitations while also promoting more independent and structured student engagement. One effective and feasible solution is the implementation of Computer-Aided Instruction (CAI). This learning model is considered capable of enhancing student achievement, especially for both Senior High School (SMA) and Vocational High School (SMK) graduates who come from different educational backgrounds in the technical field in Makassar.

CAI (Computer-Aided Instruction) is a computer-based learning approach intentionally designed and developed to study specific subjects. CAI programs serve as individualized learning tools and provide an activity that can enhance learning outcomes. The advantages of using CAI in education include: First, CAI can be used individually, allowing each student to study the subject matter independently without relying on others. This approach promotes personalized

learning, ensuring that students can progress at their own pace, according to their individual needs and understanding (Kulik, 2003; Mayer, 2005; Van Merriënboer & Sweller, 2010).

This type of learning encourages students to be more active, enhances their independence, and boosts their confidence. Second, CAI is flexible; students can learn anytime and anywhere (self-paced). Once students have access to a CAI program, they can study the subject matter in class, outside of class, at school, beyond the school premises, or wherever and whenever they choose. This flexibility greatly supports students who wish to improve their understanding of the subject they are studying through repetitive exercises using CAI. Third, CAI can be used for remedial teaching. One of the key characteristics of a competency-based curriculum (CBC) is mastery learning. In mastery learning, students who have not yet mastered the competencies outlined must repeat the lessons (remedial teaching) until they achieve the desired learning outcomes. CAI is an excellent tool for remedial teaching. Fourth, the use of CAI enhances students' motivation. Motivation increases because students learn out of their own desire and awareness, using engaging individual learning media (Alessi & Trollip, 2001; Clark & Mayer, 2016; Anderson, 2018).

Based on the various advantages of using Computer-Aided Instruction (CAI), it is expected that the implementation of CAI as a learning medium will improve student learning outcomes in electronics maintenance and assembly. However, to confirm its effectiveness, this needs to be tested through further research. Therefore, this issue will be examined through an experiment with the research title "*The Effectiveness of Computer-Aided Instruction (CAI) on Learning Outcomes in Electronics Maintenance and Assembly for Senior High School (SMA) and Vocational High School (SMK) Graduates in Makassar*."

LITERATURE REVIEW

Computer-Aided Instruction (CAI) has become an increasingly popular approach in modern education, especially in technical and vocational training environments. CAI refers to the use of computer-based software and applications designed to deliver instructional content and enhance the learning experience. It supports individualized learning, interactive multimedia content, and flexible access to educational materials (Alessi & Trollip, 2001).

Research indicates that CAI has a significant positive effect on students' learning outcomes, particularly in science and technology-related subjects. Kulik and Kulik (1991) found that students using CAI generally scored higher on standardized achievement tests compared to those receiving traditional instruction. Similarly, Mayer (2005) emphasizes the cognitive benefits of multimedia learning, stating that properly designed computer-based instruction can improve retention, understanding, and transfer of knowledge.

In the context of vocational education, particularly electronics maintenance and assembly, CAI provides several advantages. It allows learners to visualize complex systems, simulate troubleshooting processes, and repeat practice activities without depending on expensive or limited physical

equipment (Clark & Mayer, 2016). These features are essential for skill mastery in electronics, where precision and repetition are critical.

Moreover, CAI aligns well with competency-based education (CBE) models, which are central to vocational training. Through adaptive feedback and self-paced modules, students can achieve mastery learning by repeatedly engaging with the content until the expected competency is reached (Van Merriënboer & Sweller, 2010).

Several studies have also noted the relevance of learner background in the effectiveness of CAI. Students from general academic backgrounds (e.g., senior high school) and those from technical backgrounds (e.g., vocational high school) may exhibit different levels of familiarity and proficiency with hands-on technical content. As such, comparative studies are needed to evaluate how CAI affects learners from these different educational pathways.

This study is built upon existing research by exploring how CAI can be utilized in teaching electronics maintenance and assembly, and whether its effectiveness varies between graduates of SMA and SMK in the context of vocational education in Makassar..

METHODOLOGY

This study employs a quasi-experimental research design and follows a quantitative approach. Specifically, it utilizes the Nonequivalent Control Group Design, which involves both an experimental group and a control group receiving pretests and posttests. The experimental group is taught using Computer-Aided Instruction (CAI), while the control group undergoes traditional instruction. In this context, conventional teaching is not considered a treatment, but rather serves as a comparison to evaluate the impact of the CAI-based learning approach.

Quasi-experimental research is widely applied in the field of education, whereas true experimental research is more commonly utilized in scientific studies. A quasi-experimental method can be defined as a research approach used to determine the effect of a specific treatment on a given outcome under controlled conditions (Sugiyono, 2007). In this study, the sampling technique employed is *cluster random sampling*, where intact groups—students already assigned to their respective classes—are randomly selected. As a result, the characteristics of subjects in the experimental group and those in the control group are not identical, which is typical in quasi-experimental designs involving intact groups.

The instrument used for data collection in this study is an achievement test. The test includes both written (objective) tests to assess cognitive domains and performance-based (practical) tests to evaluate psychomotor skills. These tests are administered during both the pretest and posttest stages for both the experimental and control groups. Once the test items are fully developed and structured, they are reviewed by subject matter experts to evaluate their content validity. Following expert validation, the test is pilot-tested to assess its validity, reliability, level of difficulty, discrimination index, and the effectiveness of the distractors.

A good research instrument is one that demonstrates reliability. A reliable instrument consistently produces stable results when used repeatedly to measure the same variable. In this study, the reliability coefficient of the test instrument was calculated using the Kuder-Richardson Formula 20 (KR-20). Instrument reliability is expressed through a numerical coefficient derived from this formula. According to experts (Lubis, 2013), a minimum reliability coefficient of 0.8 is considered acceptable. Based on the analysis of the pilot test data, the instrument achieved a reliability coefficient of 0.925, indicating that the instrument is highly reliable.

The discrimination index of a test refers to its ability to distinguish between high-performing and low-performing students. This capability is indicated by the discrimination index value. A good test is one that achieves at least a moderate level of discrimination. The index values obtained from the calculation are then compared with standard classification criteria to determine their quality. Additionally, analysis of multiple-choice items from the pilot test data can also be used to evaluate the effectiveness of distractors. In a four-option multiple-choice test, one of the options is the correct answer, while the remaining three serve as distractors. These distractors are designed to mislead students who do not fully understand the material, thereby helping to differentiate student performance levels.

RESULT AND DISCUSSION

The normality test in this study was conducted using the Kolmogorov-Smirnov (K-S) test, with the assistance of SPSS version 20. The K-S test was applied at a significance level of $\alpha = 0.05$. If the significance value exceeds 0.05, the data are considered to be normally distributed. Normality testing was performed on both pretest and post-test data for the experimental and control groups. Based on the results, the pretest data for students taught using Computer-Aided Instruction (experimental group) showed a significance value of 0.396 (> 0.05), and the control group (taught using conventional methods) showed a significance value of 0.200 (> 0.05). Therefore, it can be concluded that the pretest data for both the experimental and control groups were normally distributed.

The post-test data analysis for students in the computer-Aided Instruction (CAI) group (experimental class) and those in the conventional teaching group (control class) revealed that the significance values for both groups were 0.115 and 0.250 respectively, both exceeding the threshold of 0.05. Based on these results, it can be concluded that the post-test data for both the experimental and control groups follow a normal distribution.

The pretest data analysis for students in both the Computer-Aided Instruction (experimental class) and the conventional teaching (control class) groups showed that the significance value was 0.450 (> 0.05). This indicates that the null hypothesis (H_0) is accepted, meaning the variances between the two groups are equal (homogeneous). The post-test data analysis for students in both the computer-Aided Instruction (experimental class) and conventional teaching (control class) groups showed a significance value of 0.230 (> 0.05).

This result indicates that the null hypothesis (H_0) is accepted, meaning the variances between the two groups are equal (homogeneous).

The findings of this study indicate that Computer-Aided Instruction (CAI) significantly enhances learning outcomes in the subject of Electronics Maintenance and Assembly for senior high school (SMA) and vocational high school (SMK) graduates in Makassar. This aligns with the principle that learning is a process that leads to changes in individuals, particularly in terms of knowledge, skills, and attitudes commonly referred to as learning outcomes. These outcomes represent behavioural changes that occur as a result of the learning experience.

The purpose of assessing learning outcomes is to determine whether students have understood the material presented and to evaluate the effectiveness of the teaching methods used. In this study, the assessment was conducted to measure the impact of CAI on students' ability to comprehend and apply concepts related to electronics maintenance and assembly.

The assessment was carried out using appropriate and accurate test instruments to ensure that the measured outcomes reflected the educational objectives. The tests included objective written assessments to evaluate cognitive abilities and performance-based assessments to measure students' psychomotor skills.

One of the indicators of student success in the learning process is achieving good learning outcomes. The better the implementation of the learning process, the better the students' learning outcomes will be. On the other hand, if the learning process is less effective, the students' learning outcomes will tend to be low. Low learning outcomes can be influenced by several factors, including: 1) Internal factors, which are factors within the students themselves, such as a lack of interest in learning and practicing outside of class hours, resulting in students being less active and independent in understanding the material; 2) External factors, which are factors from outside the students themselves, such as strategies, methods, and learning media that do not fully support modern learning approaches. In the context of Electronics Maintenance and Assembly subjects, the use of less engaging learning media may cause students to be less interested in actively participating. Therefore, an approach that can increase student involvement is needed, one of which is through the use of technology-based learning media, such as Computer Aided Instruction (CAI).

Learning media has evolved over time. This development is reflected in the variety of learning media available today, which are used to convey information, making the learning process more effective and efficient. Advances in science and technology, particularly in the field of education, have led to the development of new teaching methods. The use of computer-assisted learning media has gained significant attention due to its capabilities and the way it facilitates learning activities, allowing students to directly interact with the content programmed into the computer. This is referred to as Computer Assisted Instruction (CAI).

CONCLUSIONS AND RECOMMENDATIONS

The use of CAI can make it easier for students to learn anywhere and anytime, review material they have not fully understood, complete exercises, and identify their weaknesses. These exercises are designed by the teacher and are equipped with answer keys and necessary explanations. As a result, CAI can enhance students' learning motivation, creativity, and self-confidence. It also encourages greater student engagement in the learning process (student active learning) and fosters student-centered instruction. This approach is considered a new paradigm in education. The findings of this study can be summarized as follows:

1. The pretest scores of the experimental group, which used Computer-Assisted Instruction (CAI), were similar to the pretest scores of the control group, which used conventional learning methods in the subject of Electronics Maintenance and Assembly for Senior High School (SMA) and Vocational High School (SMK) graduates in Makassar.
2. The post-test learning outcomes of the experimental group, which used Computer-Assisted Instruction (CAI), were higher than the post-test learning outcomes of the control group, which used conventional learning methods in the subject of Electronics Maintenance and Assembly for Senior High School (SMA) and Vocational High School (SMK) graduates in Makassar.

FURTHER STUDY

This research still has limitations so further research is still needed on this topic.

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