Journal of Engineering Science and Technology
Special Issue on ISCoE2024 Vol. 20 No. 3 (2025) 25 - 32

INTEGRATION OF GEOGEBRA AND WEB: AN INNOVATIVE SOLUTION FOR GUIDED DISCOVERY LEARNING ON TRIANGLE CONGRUENCE MATERIAL TO IMPROVE CONCEPTUAL UNDERSTANDING FOR PROSPECTIVE MATHEMATICS TEACHER STUDENTS

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Abstract

This study developed innovative online learning media integrating GeoGebra and web-based platforms for prospective mathematics teachers studying triangle congruence through guided discovery learning. The research employed a design-based research methodology, and effectiveness testing involved 69 students. The results showed that students achieved high conceptual understanding scores: 91.5% for Side-Side-Side (SSS) postulate, 95.8% for Side-Angle-Side (SAS), 92.8% for Angle-Side-Angle (ASA), and 92.8% for Angle-Angle-Side (AAS). These improvements occurred because the integration of GeoGebra and web platforms enhanced conceptual visualization and interactive learning, reinforcing guided discovery principles. This study highlights the positive impact of technology-enhanced learning on students' understanding of triangle congruence.

Keywords: Conceptual understanding, GeoGebra, Guided discovery learning, Triangle congruence, Web.

1. Introduction

Numerous studies have explored geometry [1, 2]. Then, one of the hottest studies is the optimization of GeoGebra and web platforms in guided discovery learning for triangle congruence, a fundamental yet challenging topic in geometry [3, 4]. This approach enhances prospective mathematics teachers' conceptual understanding through interactive exploration and visualization, fostering critical thinking, problem-solving, logical reasoning, communication, collaboration, and technological proficiency. Students solve problems in GeoGebra, record findings on a web platform, and store responses in a database for future reference. Previous research has examined GeoGebra-web integration for AI assessments [5], complex number understanding [6], mathematics software development, geometry assessment [7], and teacher training [8]. Studies on triangle congruence have also been conducted in non-digital learning environments [9-12].

This study developed an integrated GeoGebra-web learning medium to improve triangle congruence understanding through guided discovery learning. We used a design-based research method, which introduces a novel approach by combining GeoGebra, web-based learning, and guided discovery models to enhance mathematics education. Novelties of this study include (i) the development of an integrated GeoGebra-web learning platform. Unlike previous studies, this research introduces a fully integrated platform combining GeoGebra and web-based learning, enhancing student interaction, tracking, and engagement; (ii) Application of guided discovery learning in GeoGebra-web integration. While GeoGebra has been widely used in mathematics education, its integration with guided discovery learning models in triangle congruence is underexplored. This study bridges that gap; (iii) Database-backed learning system for real-time student interaction. A key innovation is a database-driven system where students' solutions are stored, reviewed, and re-evaluated, ensuring personalized learning experiences and progress tracking; (iv) Empirical validation of the effectiveness of technology-assisted triangle congruence learning. This study provides quantitative and qualitative evidence on how the GeoGebra-web integration enhances students' conceptual understanding, making it an effective digital learning tool for mathematics education.

2. Literature Review

Figure 1 illustrates the four criteria for determining triangle congruence:

(i) Side-Side-Side (SSS): If all three sides are equal, the triangles are congruent.
(ii) Side-Angle-Side (SAS): If two sides and the included angle are equal, the triangles are congruent.
(iii) Angle-Side-Angle (ASA): If two angles and the included side are equal, the triangles are congruent.
(iv) Angle-Angle-Side (AAS): If two angles and a non-included side are equal, the triangles are congruent.

Since triangles remain congruent despite shifts, rotations, or reflections [11, 13], knowing three out of six elements (sides and angles) is sufficient to determine triangle congruence [14-18].

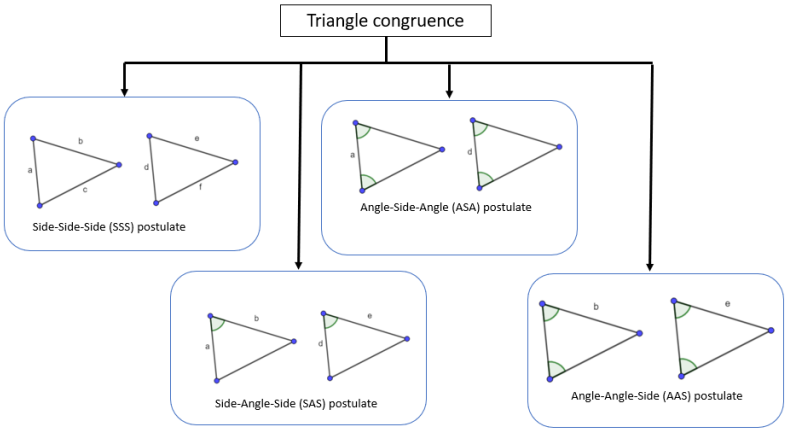

Fig. 1. Four criteria that can be used to prove the congruence of two triangles.

3. Method

This study used Design-Based Research (DBR) to develop and evaluate GeoGebra-web integrated learning media for prospective mathematics teachers studying triangle congruence. The DBR process included analysis, design, development, and evaluation [19]. We identified learning challenges at the Universitas Bengkulu, designed an interactive guided discovery platform, and validated it through expert review and practicality testing. The media was implemented in two classes (n=69 students) to assess its effectiveness in improving student understanding. This iterative DBR approach allowed continuous refinement based on real-world feedback, enhancing technology-based mathematics learning. The data was then analysed statistically using the same calculation as reported elsewhere [20-22].

4. Results and Discussion

This study developed an online GeoGebra application integrated with the web for guided discovery learning in triangle congruence. GeoGebra's web integration is rarely explored in learning due to the complexity of embedding scripts and aligning applications with specific learning models. This research addresses these challenges by enabling GeoGebra to be accessed seamlessly within a web platform.

Figure 2 presents the integration process, starting with creating a GeoGebra application at https://www.geogebra.org, generating a unique web address, and embedding it using "<iframe></iframe>". This allows students to interact with GeoGebra alongside learning instructions, data collection, and evaluation. Validation results indicate the integration media is highly valid in language, software engineering, and visual design, making it suitable for guided discovery learning. Material validity - including relevance, organization, evaluation, and clarity - was also rated very good. A practicality test (n=35) showed no implementation barriers, confirming its effectiveness.

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25
26  <iframe
    src="https://www.geogebra.org/classic/tw6kakrp?embed"
    width="90%" height="600" allowfullscreen
    style="border: 1px solid #e4e4e4;border-radius: 4px;"
    frameborder="0"></iframe>
27
```

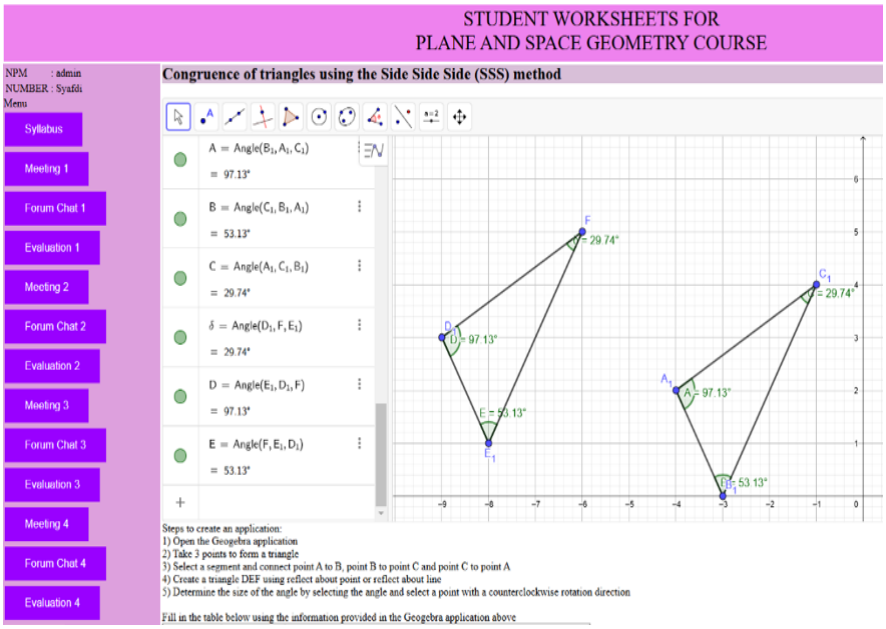

Fig. 2. Script and results of integration of GeoGebra and web.

Table 1 highlights a significant increase in student's conceptual understanding of triangle congruence among 69 Mathematics Education students at the Universitas Bengkulu. Achievement rates were 91.5% (SSS postulate), 95.8% (SAS), 92.8% (ASA), and 92.8% (AAS), demonstrating GeoGebra-web integration's role in improving conceptual mastery. Student concept understanding was measured through:

(i) Reconstructing concepts using GeoGebra visuals on the web.
(ii) Classifying congruence concepts based on SSS, SAS, ASA, and AAS postulates.
(iii) Presenting concepts systematically in GeoGebra and web formats.
(iv) Applying triangle congruence concepts in problem-solving tasks.

The guided discovery learning model enhances conceptual understanding by structuring investigations within GeoGebra and the web, allowing for unlimited access to learning [23, 24]. This approach yields better results than studies using cultural contexts to teach triangle congruence, where real objects may introduce inaccuracies due to imprecise angles and worn surfaces [9, 11, 25]. This also confirms the use of technology for supporting the teaching and learning process [26-30]. Finally, this study adds new information regarding the use of technology in improving students understanding in mathematics [31-35].

Table 1. Results of students' conceptual understanding in guided discovery learning on triangle congruence material.

Indicator	True	False	Percentage (%)
Students' conceptual understanding of triangle congruence indicators using the Side-Side-Side (SSS) postulate	65	6	91.5
Students' conceptual understanding of triangle congruence indicators using the Side-Angle-Side (SAS) postulate	68	3	95.8
students' conceptual understanding of triangle congruence indicators using the Angle-Side-Angle (ASA) postulate	64	5	92.8
Students' conceptual understanding of triangle congruence indicators using the Angle-Angle-Side (AAS) postulate	64	5	92.8

5. Conclusion

This study demonstrates that integrating GeoGebra and web-based learning within a guided discovery learning model significantly enhances students' conceptual understanding of triangle congruence. The developed interactive platform allows students to explore, visualize, and apply mathematical concepts in a structured manner, leading to high learning achievement. Validation results confirm the effectiveness and practicality of the integration, with no implementation barriers reported. Compared to traditional or culture-based approaches, this method offers greater accuracy, accessibility, and guided exploration, ensuring a more effective and engaging learning experience. These findings highlight the potential of technology-enhanced mathematics education in supporting deep conceptual learning.

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