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Development of STEM-Based Basic Geometry Learning Worksheets to Improve Students' Geometric Skills

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ABSTRACT: This study aims to develop STEM-based Basic Geometry learning worksheets (LKM) to enhance students' geometric skills. The developed instructional materials include an electronic module and practicum guides for the Basic Geometry course. To support their implementation, student worksheets and geometric skill assessment instruments were also designed. The research employed a Research and Development (R&D) approach referring to the 4-D development model, consisting of: (1) Define, (2) Design, (3) Develop, and (4) Disseminate.

The quality of the developed materials and instruments was assessed based on (1) their alignment with the course objectives and curriculum, (2) expert validation consistency, and (3) improvement in students' geometric skills. The study is aligned with the 2021–2025 Research Master Plan (Renstra) of Universitas PGRI Pontianak, under the priority field of *Innovative Education and Learning in Science, Technology, Social Sciences, and Humanities.* The expected outcome of this study is an electronic STEM- based module that effectively enhances students' geometric abilities.

KEY WORDS: STEM education, Basic Geometry, Learning Worksheet, Geometric Skills, Teaching Material Development, Students Geometric Skill

1. INTRODUCTION

Geometry is one of the fundamental areas in mathematics that supports students' logical reasoning, spatial visualization, and problem-solving skills. However, many students still face challenges in understanding abstract geometric concepts. To address this issue, innovative learning approaches that integrate science, technology, engineering, and mathematics (STEM) are essential.

STEM-based learning provides students with opportunities to connect geometric theory with real-world applications, thus fostering a deeper understanding of concepts. The development of learning materials aligned with STEM principles allows for more interactive and contextual learning experiences.

This study focuses on the development of STEM-based Basic Geometry learning worksheets (LKM) to enhance students' geometric skills and promote innovative teaching practices in higher education.

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The integration of Information Technology (IT) in education has transformed traditional learning approaches. Teaching materials play a crucial role in facilitating both educators and students in the learning process. In mathematics, especially geometry, effective learning resources are essential for developing students' conceptual understanding, visualization ability, and problem-solving skills. STEM (Science, Technology, Engineering, and Mathematics) provides a multidisciplinary framework that encourages contextual, creative, and project-based learning. Integrating STEM principles into geometry learning allows students to connect mathematical theory with real-world applications. The development of electronic STEM-based modules and student worksheets can increase student motivation, interaction, and geometric reasoning.

Preliminary studies at Universitas PGRI Pontianak revealed that students often struggle with spatial reasoning and abstract visualization in geometry courses due to limited interactive materials and reliance on conventional teaching methods. Thus, this study focuses on developing STEM-based electronic materials for Basic Geometry courses to promote active learning and enhance students' geometric competencies.

II. METHOD

This research employed a Research and Development (R&D) approach using the 4-D model developed by Thiagarajan, Semmel, and Semmel (1974), consisting of four stages: Define, Design, Develop, and Disseminate. Data were collected through validation sheets, questionnaires, and geometric skill tests. The analysis focused on determining validity, practicality, and effectiveness of the developed materials.

III. RESULTS

I. Development Process

The development of the STEM-based Basic Geometry Student Worksheets (LKM) followed the four stages of the **4-D Model (Define, Design, Develop, Disseminate)** proposed by Thiagarajan et al. (1974).

Table 1: Each stage is described as follows

No.	Stage	Activities Conducted	Main Outcomes
1	Define	Conducted preliminary analysis to identify students' needs and learning challenges in the Basic Geometry course at Universitas PGRI Pontianak. Reviewed the current curriculum and existing materials.	Found that students lacked digital-based learning resources and had difficulty visualizing 2D–3D geometry concepts. Identified a need for interactive STEM-based learning tools.
2	Design	Created the structure of the electronic module (e-module) and student worksheets integrating *GeoGebra* software, STEM activities, and project-based tasks. Designed test instruments for measuring geometric skills (visual, verbal, drawing, logical, and applied).	Draft of electronic module (E-LKM) and test instrument blueprint developed.
3	Develop	Conducted expert validation by content specialists, instructional design experts, and media experts. Revised the product based on feedback. Performed limited trials with first-semester students of Mathematics Education.	Validation results showed that the materials met "valid" criteria. Limited trials showed positive responses and improved learning motivation.
4	Disseminate	Prepared for wider distribution and publication of the developed module and worksheets as institutional teaching materials.	Ready-to-use e- module and LKM for Basic Geometry, aligned with the university's 2021–2025 Research Master Plan.

2. Expert Validation Results

Validation was conducted by three experts (content, design, and media). The results indicated high validity scores in several aspects:

Table 2: Validation

No.	Validation Aspect	Average Score (Scale 1–5)	Criteria
1	Content Feasibility	4.75	Very Valid
2	Learning Design	4.60	Valid
3	Linguistic Clarity	4.50.	Valid
4	Media Presentation	4.70	Very Valid
5	Average	4.64	Highly Valid

Experts noted that the content aligned with the learning outcomes of the Basic Geometry course and that the STEM integration (through contextual problems and technological applications) was appropriate for undergraduate mathematics students.

3. Student Response Results

A limited trial was conducted with 25 first-semester students of the Mathematics Education Program at Universitas PGRI Pontianak. The student response questionnaire covered engagement, clarity, and perceived usefulness of the developed materials.

Table 3: Indicator Student Response

No.	Indicator	Average Percentage (%)	Interpretation
1	Interest and Motivation	88.5	Very Positive
2	Ease of Understanding	84.2	Positive
3	Attractiveness of Design	86.8	Very Positive
4	Usefulness for Learning	89.0	Very Positive
5	Overall Average	87.1	Very Positive Response

Students reported that the use of *GeoGebra* and contextual STEM tasks helped them better visualize 3D figures, understand geometric relations, and connect theory to real-life situations.

4. Effectiveness Test of the Developed Materials

Students' geometric skill levels were measured before and after using the STEM-based LKM through a geometric skill test adapted from Hoffer's (1981) framework. The pretest and posttest scores were analyzed using the **N-gain formula**.

Table 4: Skill Type

No.	Skill Type (Hoffer, 1981)	N-Gain	Category
1	Visual Skill	0.56	Moderate
2	Verbal Skill	0.55	Moderate
3	Drawing Skill	0.56	Moderate
4	Logical Skill	0.54	Moderate
5	Applied Skill	0.61	High
6	Overall Mean	0.56	Moderate–High

The statistical test (paired t-test) showed a **significant improvement ($p < 0.05$)** in all five skill areas, indicating that the use of STEM-based LKM had a positive impact on students' geometric proficiency.

Summary of Results

The development followed the 4-D model consisting of Define, Design, Develop, and Disseminate stages. The Define stage identified the learning needs and challenges in geometry; the Design stage created the structure of the electronic module and worksheets; the Develop stage validated and revised the product based on expert feedback; and the Disseminate stage prepared the materials for broader implementation.

Validation results showed that the materials achieved a high validity score (average 4.64/5). Student responses were positive (average 87.1%), and the N-gain analysis revealed an improvement of 0.56 (moderate-high category). The integration of GeoGebra software enhanced students' ability to visualize and solve geometric problems, improving their spatial reasoning and conceptual understanding

IV. DISCUSSION

The development of the STEM-based Basic Geometry Learning Worksheets (LKM) has shown that the integration of Science, Technology, Engineering, and Mathematics principles can significantly improve students' geometric understanding and engagement in learning. The discussion of results is presented in several key perspectives:

a. Validity of the Developed Materials

The expert validation results indicated that the STEM-based LKM is **highly valid** in terms of content accuracy, design, and pedagogical relevance. This demonstrates that the learning materials were developed in alignment with curriculum objectives and followed sound instructional design principles. The integration of technology, particularly the use of **GeoGebra**, enriched the learning experience by providing dynamic visualizations of geometric concepts. This finding supports earlier studies (Hamdani,

2011; Van de Walle, 2016) that emphasized the role of visual and technological aids in enhancing conceptual understanding in geometry.

b. Improvement of Students' Geometric Skills

The N-gain analysis (0.56, moderate–high category) and the significant improvement in students' posttest results ($p < 0.05$) confirmed that the developed LKM effectively enhanced geometric skills. These skills include visual, verbal, drawing, logical, and applied skills as outlined by **Hoffer (1981)**. Students were able to visualize 3D figures more easily, describe geometric properties accurately, and apply concepts in solving real-world problems — demonstrating the potential of STEM-based learning to foster **higher-order thinking** and **spatial reasoning**. This finding is consistent with **Yakman (2008)** and **Beers (2011)** who stated that STEM education enhances critical thinking and problem-solving through interdisciplinary learning experiences.

c. Positive Student Engagement

The students' responses showed strong enthusiasm (average 87.1%), indicating that they found the materials engaging, easy to follow, and helpful for independent learning. The inclusion of **project-based and inquiry-oriented activities** allowed students to learn actively, collaborate with peers, and construct their own understanding of geometric principles. This aligns with the principles of **constructivist learning theory**, where learners actively build knowledge through experience, exploration, and reflection.

d. Integration with Institutional Research Roadmap

The study aligns with the **2021–2025 Research Master Plan (Renstra)** of Universitas PGRI Pontianak, particularly within the field of *Innovative Education and Learning in Science Technology, Social Sciences, and Humanities.* By developing STEM-integrated digital learning resources, the research contributes to institutional efforts to promote innovation in educational technology and mathematics pedagogy at the higher education level..

V. CONCLUSION

The integration of STEM principles into geometry learning effectively enhanced students' geometric understanding and engagement. The LKM developed was highly valid, practical, and effective, aligning with curriculum goals and the institutional research roadmap. The findings demonstrated significant improvements in geometric skills and positive student engagement. The pedagogical implications include integrating STEM principles in curriculum design, utilizing digital tools in teaching, and promoting active, inquiry-based learning. Limitations include the small sample size and limited dissemination phase; future studies should expand implementation and incorporate STEAM elements.

This study successfully developed STEM-based electronic learning materials and student worksheets for the Basic Geometry course. The materials were validated as valid, practical, and effective in enhancing students' geometric skills. The innovation lies in integrating STEM principles and technology (GeoGebra) into geometry instruction to promote independent learning and creativity. Future studies are encouraged to conduct broader implementation and longitudinal evaluations of the developed materials across various educational levels. The findings contribute to the advancement of innovative learning models in mathematics education and support the strategic goals of Universitas PGRI Pontianak's Research Master Plan (2021–2025) in the field of *Innovative Education and Learning in STEM.*

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VII. DISCLOSURE

No conflicts of interest in this work.

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