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Fostering Conceptual Understanding of Dilation in Geometry through Motion Graphics: A Didactical Design Research Approach

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Abstrak
Penelitian ini bertujuan untuk mengembangkan desain didaktis berbasis media motion graphic guna meningkatkan pemahaman konseptual siswa pada materi transformasi geometri, khususnya dilatasi. Penelitian ini menggunakan pendekatan Didactical Design Research (DDR) yang terdiri dari tiga tahap: analisis didaktis prospektif, analisis metapedadidaktis, dan analisis retrospektif. Subjek sebanyak 10 siswa kelas XII di salah satu SMK bidang teknik komputer dan jaringan. Instrumen yang digunakan mencakup rancangan desain didaktis dan pedoman wawancara semi-terstruktur. Hasil penelitian menunjukkan bahwa sebagian besar siswa mengalami peningkatan dalam memahami konsep dilatasi seperti titik pusat dan faktor skala, serta mampu mengaitkan konsep dengan konteks kehidupan sehari-hari. Namun, hambatan belajar seperti kesalahan prosedural, kesulitan mengekspresikan ide dalam struktur matematika, dan miskonsepsi simbolik masih ditemukan. Revisi desain dilakukan dengan menambahkan contoh kontekstual dan lembar kerja siswa untuk membantu strukturisasi jawaban dan meningkatkan keterhubungan konsep. Penelitian ini merekomendasikan integrasi media visual yang bermakna dan pendampingan dengan alat bantu belajar untuk mengoptimalkan pembelajaran geometri secara konseptual.
Kata Kunci: desain didaktis; dilatasi; hambatan belajar; motion graphic; pemahaman konsep

Abstract
This study aims to develop a motion graphic-based didactical design to enhance students' conceptual understanding of geometric transformations, focusing on dilation. The research employed a Didactical Design Research (DDR) framework consisting of three phases: prospective didactical analysis, metapedadidactical analysis, and retrospective analysis. The study involved 10 twelfth-grade students from a vocational high school in the Computer and Network Engineering field. Instruments included a didactical design document and a semi-structured interview guide. Results indicated that most students improved their understanding of dilation concepts such as center and scale factor and were able to relate these concepts to real-life situations. However, learning obstacles such as procedural errors, difficulties in expressing ideas in mathematical structure, and symbolic misconceptions were still observed. The design was revised by incorporating contextual examples and student worksheets to support structured responses and conceptual linkage. This study recommends the integration of meaningful visual media and learning scaffolds to optimize conceptual learning in geometry.
Keywords: conceptual understanding; didactical design; dilation; learning obstacles; motion graphic

I. INTRODUCTION

Education plays a pivotal role in shaping individuals who are intelligent, creative, and possess noble character (Sholikhah et al., 2018; Surani & Wahyuni, 2023). Within mathematics education, geometry is essential for developing spatial reasoning, logical thinking, and the ability to apply concepts to real-world situations (Budiarto & Artiono, 2019; Ningsih et al., 2023). As a core component of mathematics, geometry enables students to understand spatial relationships and provides valuable tools for problem-solving across disciplines (Cesaria et al., 2021; Muharram, 2021).

Learning outcomes serve as a foundation for further learning processes, directly influencing students' development (Haqq et al., 2018; Nurjanah & Juliana, 2020; Ismaniar, Sumarni, & Riyadi, 2024). These outcomes are not limited to knowledge acquisition but also include skills that empower students to solve problems related to the learned material (Achdiyat & Utomo, 2018; Hafidz, 2019; Hajizah & Salsabila, 2024). Among academic disciplines, mathematics stands out due to its applicability in daily life and its function as a tool for recognizing patterns and solving problems (Musyrifah et al., 2022; Zaki et al., 2024).

Geometry, a vital branch of mathematics, aims to equip students with the ability to understand geometric elements and their interrelationships in order to solve spatial problems. It is said that everything imaginable inherently contains geometric elements (Rosita et al., 2019; Cesaria et al., 2021; Muharram, 2021). Geometry enables students to explore and understand the world through shapes and structures and offers rich opportunities for reasoning, communication, and critical thinking (Primasatya & Jatmiko, 2018; Susanto & Mahmudi, 2021). The reasoning skills developed through geometry, particularly spatial and dimensional reasoning, are essential for mathematical problem-solving (Sholihah & Afriansyah, 2017; Budiarto & Artiono, 2019; Pitriyani, Sundayana, & Maryati, 2024).

Research indicates that students often face significant obstacles in learning geometric transformations, which can be categorized as ontogenical, epistemological, and didactical. Ontogenical obstacles include low motivation, unfamiliarity with formulas, problem misinterpretation, and insufficient conceptual understanding; epistemological obstacles involve misconceptions in applying transformations, especially in contextual problems or those involving multiple points; and didactical obstacles arise from instructional factors such as rapid material delivery or inadequate textbook explanations (Rahadi et al., 2024; Haqq & Toheri, 2019).

These challenges highlight that many students struggle due to limited conceptual comprehension and inadequate mastery of prerequisite knowledge, such as arithmetic and Cartesian diagrams, despite conceptual understanding being essential for effectively applying mathematical concepts in both academic and real-world contexts (Khairunnisa et al., 2022; Putra et al., 2018a).

Given these challenges, there is a critical need for instructional innovations that enhance teaching effectiveness and

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efficiency. One such approach is Didactical Design Research (DDR), which systematically plans, develops, and evaluates instructional designs to address specific learning obstacles (Nindiasari et al., 2016; Noto et al., 2018; Oktarina et al., 2020; Pramuditya et al., 2021; Supriyadi et al., 2023). DDR emphasizes phenomenological understanding of the teaching-learning process, including students' learning obstacles, learning trajectories, and instructional limitations (Mulyana et al., 2014; Rohimah, 2015; Komala et al., 2021; Wardani et al., 2024). DDR involves three phases: (1) analysis of didactical situations prior to instruction, (2) metapedadidactic analysis (exploring the didactic triangle), and (3) retrospective analysis that compares planned and actual learning scenarios (Putra et al., 2017; Jatisunda & Kania, 2020).

Central to DDR is the concept of the didactic triangle, comprising the relationships between teacher and student (pedagogical), student and content (didactical), and teacher and content (anticipatory didactical-pedagogical) (Sulistiawati et al., 2015; Putri, Sujadi, & Fitriana, 2024), where optimal learning requires dynamic, flexible situations that consider students' cognitive readiness and present accessible, meaningful content (Intansari, 2019; Husamah & Setyaningrum, 2013).

While previous studies have used static images, printed diagrams, and conventional videos to teach geometric transformations, these media often lack the ability to show continuous change, emphasize temporal spatial relationships, and maintain engagement, whereas motion graphics provide dynamic, sequential, and visually rich presentations that make abstract processes tangible, enable step-by-step visualization, and highlight key mathematical properties (Kusumadinata et al., 2019; Wiana et al., 2018).

To address conceptual challenges in geometric transformations, this study proposes integrating motion graphic media into the DDR framework, as motion graphics—animated visual aids depicting processes, sequences, and abstract concepts with engaging visuals often synchronized with audio—can enhance students' ability to conceptualize and internalize transformations such as translation, rotation, reflection, and dilation (Rahadi et al., 2020a; Kusumadinata et al., 2019; Wiana et al., 2018; Wicaksana et al., 2024).

Motion graphics have several characteristics that support learning: they are predominantly two-dimensional but can simulate three-dimensional motion, and they are non-interactive but linear, guiding students through structured representations. These features make motion graphics an effective tool for helping students visualize and understand complex spatial relationships.

The proposed didactical design aims to anticipate specific learning obstacles. For instance, when students struggle to understand the concept of rotation, motion graphic videos will visually demonstrate how an object rotates around a point. Similarly, to overcome difficulties in applying transformation concepts to problem-solving, motion graphic-based problems will be used to reinforce understanding through visualization (Rahadi et al., 2020a; Mamonto et al., 2024).

Building upon earlier DDR studies addressing learning obstacles in geometry (Nindiasari et al., 2016; Noto et al., 2018), this study advances prior work by focusing specifically on dilation for vocational high school students, integrating motion graphics to enhance both conceptual and procedural understanding, and embedding contexts relevant to students' vocational field to promote transfer of knowledge to practical applications.

This study aims to develop a motion graphic-based didactical design to enhance conceptual understanding of dilation among vocational high school students majoring in Computer and Network Engineering, emphasizing its relevance for both academic and vocational contexts.

Therefore, this study seeks to develop a didactical design that incorporates motion graphic media to enhance students' conceptual understanding of geometric transformations. It aims to provide an instructional model that is responsive to students' learning trajectories and cognitive development, ultimately improving learning outcomes in geometry.

II. Method

This study employed a qualitative descriptive approach aimed at developing a didactical design for teaching geometric transformations, grounded in the analysis of student learning obstacles. The qualitative approach was chosen due to its ability to describe complex educational phenomena in depth and to capture contextual richness in learning processes that cannot be expressed numerically (Ulfatin, 2022). The descriptive-analytic method allowed the researcher to examine patterns of behavior, reasoning, and student responses in natural classroom settings (Gunawan, 2022).

The research utilized the Didactical Design Research (DDR) framework, which comprises a systematic process for creating and refining instructional designs based on student responses and anticipated learning trajectories. DDR consists of three primary phases: (1) Prospective Didactical Analysis or analysis of the didactical situation prior to instruction, (2) Metapedadidactic Analysis during instruction, and (3) Retrospective Analysis after instruction (Jahnke et al., 2017; Haryanti & Wahyuni, 2019; Sudarja et al., 2018).

In the Prospective Didactical Analysis phase, a hypothetical didactical design was formulated. The design outlined: a learning trajectory for teaching geometric transformations, predicted student responses, anticipated learning obstacles (ontogenic, epistemological, and didactical), planned instructional interventions to overcome these obstacles.

This phase also included the preparation of a motion graphic-based instructional media, which served as a central tool to visually convey geometric transformation concepts such as dilation. The design was based on findings from prior research, which had revealed that students struggle with both the conceptual and procedural aspects of geometric transformations due to gaps in prerequisite knowledge and lack of intuitive visualization (Rahadi et al., 2024; Haqq & Toheri, 2019).

The second phase, Metapedadidactic Analysis involved implementing the hypothetical didactical design in an actual classroom setting. The instructional process was conducted with a focus on observing the emerging didactical situations, student interactions, and their cognitive responses to the use of motion graphic media during the geometry lessons. The observations also focused on identifying how students' understanding evolved during instruction and whether anticipated difficulties actually occurred.

In the final phase (Retrospective Analysis), a comprehensive comparison was made between the predicted student responses and the actual responses observed during the implementation. This comparison enabled the researcher to assess the effectiveness of the initial design and to determine whether the planned anticipations were accurate. Based on this evaluation, a revised didactical design was developed to address the identified gaps and improve the instructional strategy for future iterations.

The subjects of the study were ten twelfth-grade students from a vocational high school in Cirebon, Indonesia. These participants were chosen based on prior identification of learning obstacles in geometric transformation topics. The focus group represented a range of understanding and common misconceptions observed in previous diagnostic assessments. The small sample size (n = 10) was intentionally chosen because this was a preliminary trial study aimed at exploring learning obstacles in depth, refining the motion graphic-based didactical design, and assessing feasibility prior to broader implementation. This size allowed for detailed observation of each participant’s learning process, which would have been impractical with a larger group within the given time frame.

The study employed two main instruments: a detailed didactical design document, including predicted student reactions and instructional strategies; a semi-structured interview guide to gather feedback on the implementation and understand students’ learning experiences. Examples of interview questions and worksheet tasks are provided in Appendix A to illustrate the focus of data collection on conceptual understanding and procedural fluency in dilation.

A triangulation technique was employed to enhance the validity and reliability of the data. This technique combined: observations, to record student behavior and interaction during lessons; interviews, conducted in an open-ended, unstructured manner to allow students to articulate their experiences and difficulties; documentation, including lesson plans, student worksheets, and motion graphic materials, which were analyzed to assess implementation fidelity and learning progression. This combination of methods allowed for comprehensive data capture from multiple perspectives.

Ethical approval for the study was obtained from the Research Ethics Committee of Universitas Swadaya Gunung Jati. Prior to participation, informed consent was obtained from all students, ensuring voluntary participation and confidentiality of all collected data.

Data analysis followed the framework by Miles and Huberman (1992), comprising: (a) raw data collected through observation, interviews, and documents were filtered to focus on relevant findings. The researcher identified key patterns, common difficulties, and emerging themes, particularly in relation to the hypothesized learning trajectory and anticipated obstacles; (b) processed data were then systematically organized using matrices and visual aids to highlight relationships between teaching strategies, student responses, and conceptual understanding; (c) final conclusions were drawn by correlating empirical findings with the initial hypotheses and research questions. These were continually tested against raw data and cross-verified to ensure internal validity and consistency.

Given that the study involved a small number of participants from a single school, the findings should be interpreted with caution. The results may not be generalizable to all vocational high school settings; however, they offer valuable insights for refining the didactical design before scaling up to larger and more diverse populations.

III. Result and Discussion

A. Result

The didactical design developed for the dilation topic consists of three structured didactical situations aimed at building students' conceptual understanding through real-life contexts and interactive media. These situations are summarized in Table 1, which outlines the sequence and objectives of the activities.

Table 1.
Didactical Situations on Dilation

No	Didactical Situation
1	Students discuss a motion graphic video showing real-life phenomena to introduce the dilation concept.
2	Students solve problems related to determining the image of objects under dilation with given center and scale.
3	Students identify the scale and center of dilation based on transformed figures shown in the video.

In the first situation, students related dilation to selfie photos and zooming functions, as seen in Figure 1, which presents the illustration from the motion graphic video used to spark discussion.

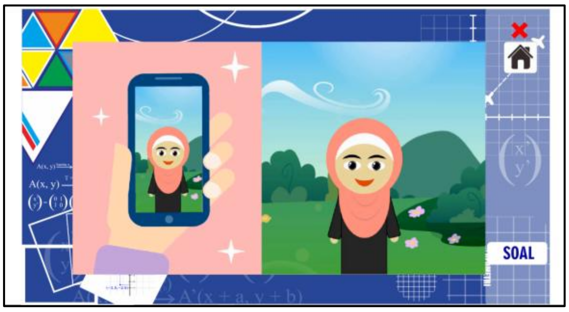

Figure 1. Used to Connect Abstract Dilation Concepts with Familiar Activities (Zooming A Photo)

Students responded well to this approach, which contains excerpts from their classroom dialogue.

Student: "Oh, so dilation means enlarging or shrinking, right?"

Teacher: "Correct. But what exactly is enlarged or reduced?"

Student: "The object, like in that selfie photo. It's resized to a smaller scale."

Teacher: "Yes, using a specific scale. Also, there's a center point for dilation."

Student: "So it's like zooming in and out, right?"

The second situation (Didactical Situation 2) asked students to determine the dilated image of a triangle given a center at O (0,0) and a scale factor of 2. Students were able to locate image points correctly, as depicted in Figure 2, and explained their reasoning through oral responses documented.

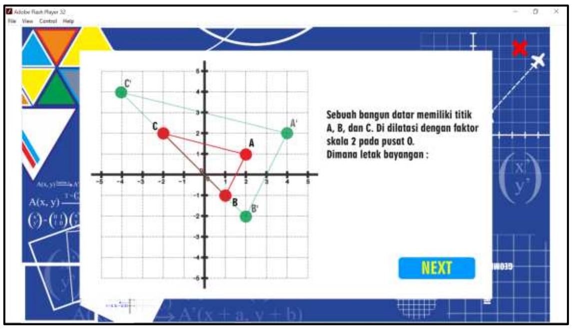

Figure 2. Helped Students Apply Scale Factor Rules from A Fixed Center

Teacher: "Try to draw the enlarged triangle from the video!"

Student: "Point A moves to (4,2), and point B to (2,2)."

Teacher: "Why is that?"

Student: "Because it's doubled from the center point."

In the third situation (Didactical Situation), students were asked to determine the scale of dilation from the visual representation. Students compared object and image sizes to deduce the correct scale factor, as shown in Figure 3.

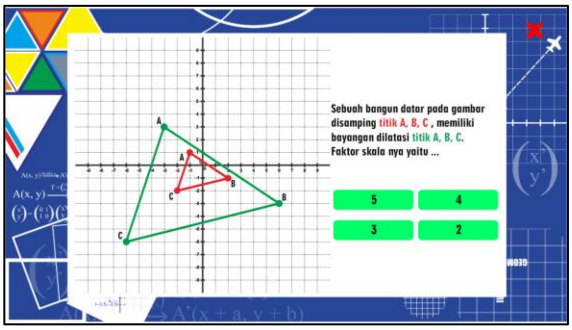

Figure 3. Prompted Analytical Reasoning to Deduce Scale Factor from Visuals

To evaluate conceptual understanding after the implementation, an essay test was administered. One question asked students to provide real-life examples of dilation and explain their reasoning. Student responses are categorized in Table 2.

Question:

There are many real-world examples of dilation that we encounter in everyday life. Mention three examples that reflect the concept of dilation and explain why you chose those examples!

Table 2.
Student Responses to Essay Question on Real-Life Dilation Examples

No	Student Answer (Examples and Reasoning)	Frequency
1	Balloon, selfie photo, telescope – justified with consistent scale and center	7
2	Microscope, map, binoculars – examples provided without clear justification	2
3	No answer	1

Students in category 1 demonstrated solid understanding, expressing how dilation occurs with respect to scale and center, echoing concepts from the video. Some students in category 2 struggled to verbalize their reasoning, although their examples were conceptually aligned with dilation. Others admitted to copying peers' responses due to confusion.

From the results of this retrospective analysis, several learning obstacles were identified: incorrect use of mathematical symbols, misinterpretation of questions, failure to relate abstract concepts to daily life, Inaccurate classification of examples, procedural errors, lack of structured written responses.

These findings guided subsequent revisions to the didactical design, such as incorporating structured worksheets and enriching real-life contextual explanations.

B. Discussion

The results of this study indicate that the integration of a didactical design supported by motion graphic media significantly improved students' understanding of geometric dilation. The didactical situations allowed students to experience learning through stages, aligned with Van Hiele's levels of geometric thinking, progressing from visualization to formal reasoning (Amalliyah et al., 2021; Mulyadi & Muhtadi, 2019; Susanto & Mahmudi, 2021).

In the initial design phase, students engaged with concrete examples, which helped bridge abstract mathematical concepts with everyday experience, consistent with the view that geometry learning becomes more meaningful when contextualized with real-world phenomena (Cesaria et al., 2021; Susanto & Mahmudi, 2021). These tasks not only supported conceptual understanding but also facilitated gradual development through visualization, classification, and problem solving.

The use of motion graphic media enhanced student engagement and conceptualization, allowing learners to see dynamic representations of dilation processes. This medium proved effective, especially for Generation Z learners, as reported in earlier studies (Kusumadinata et al., 2019; Nawawi, 2020; Rahadi et al., 2020a, 2020b). Students were able to identify transformations visually, which reinforced their verbal and written reasoning.

The metapedadidactical analysis confirmed that most of the anticipated student responses occurred as predicted. However, unforeseen responses also emerged, offering insights into how future iterations of the design might be adjusted. This iterative process aligns with the nature of didactical design research, where unexpected student reactions provide feedback for improvement.

The retrospective analysis revealed persistent difficulties in procedural fluency and conceptual application. Some students struggled to relate abstract mathematical concepts to real-life examples, a challenge also found in previous studies (Laili & Puspasari, 2018). Procedural errors, such as incorrect application of formulas or failure to interpret questions correctly, align with findings by Murtiyasa & Wulandari (2020), who noted similar issues in students' procedural skills.

While these results align with studies emphasizing the benefits of dynamic visual media (Kusumadinata et al., 2019; Wiana et al., 2018), they contrast with findings by Putra et al. (2018b) and Mahmud & Fitriani (2021), who reported limited impact of visualization tools when students lacked sufficient prerequisite knowledge. In the present study, the targeted nature of the motion graphics—designed specifically to address known learning obstacles in dilation—may have been a critical factor in their effectiveness. This suggests that the success of visual technology integration depends heavily on its alignment with learners' cognitive readiness and anticipated misconceptions.

Despite these obstacles, the overall performance in essay responses suggests a positive shift in conceptual understanding. Students were able to apply concepts of dilation, provide justifications, and interpret visual cues, though with varied levels of sophistication. As emphasized by Putra et al. (2018b) and Sariningsih (2014), students' mathematical understanding strengthens when they develop strategies, apply operations, and use symbols effectively.

As a follow-up, the didactical design was revised by incorporating additional real-life examples and learner worksheets. These revisions aim to enhance structured response construction and deeper integration of concept and context (Khalifah et al., 2022). Worksheets serve as scaffolding tools, promoting systematic thinking and clearer mathematical expression.

IV. Conclusion

This study demonstrates that a motion graphic-based didactical design within the Didactical Design Research (DDR) framework can effectively enhance vocational high school students' conceptual understanding of geometric dilation. The integration of dynamic visual representations with structured instructional sequences addressed known learning obstacles, supported students' progression through Van Hiele's levels of geometric thinking, and encouraged meaningful connections between abstract concepts and real-world applications.

The iterative process, informed by prospective, metapedadidactic, and retrospective analyses, allowed for refinement of the design to better meet students' cognitive needs. The findings contribute to the growing evidence that targeted, media-supported instructional designs can be particularly effective for students in vocational education contexts, especially when aligned with their vocational specializations.

For broader implementation, future scaling of the design should consider developing a modular version adaptable to different class sizes, training teachers in both the pedagogical and technical aspects of motion graphic integration, and creating a repository of motion graphic resources aligned with national curriculum standards. These strategies would facilitate adoption in various school contexts while maintaining design fidelity.

Further research is recommended to investigate the long-term retention of students' conceptual understanding after exposure to motion graphic-based instruction, as well as to examine its applicability across different cultural and educational settings. Comparative studies in diverse regions and school types could provide insights into how cultural contexts influence both the reception and effectiveness of such designs.

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