



Development of Interactive Digital Teaching Materials for Geometric Transformation Based on Ethno-STEM of Jombang Culture to Enhance Students' Visual-Spatial Thinking Ability

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Abstract

Understanding geometric concepts often requires strong visual-spatial thinking skills, studies showed that internalizing visual-spatial thinking skills can be a solution in geometry learning. This study aims to develop interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombang culture* that are valid, practical, and effective in helping improve students' visual-spatial thinking ability. The cultural aspects highlighted in this study are the unique traditional batik and historic temples of Jombang Regency. The research employed the ADDIE development model consisting of five stages: analysis, design, development, implementation, and evaluation. Data collection techniques used observation, interview, questionnaire and test. Data analysis was carried out through quantitative and qualitative data. The results of the study showed that the developed materials demonstrated high validity with an average expert validation score of 85.90% (content, material, language, and learning aspects), high practicality with an average score of 91.31% (from practitioners and student responses), and moderate effectiveness indicated by a paired-sample t-test (sig. (1-tailed) = 0.000 < 0.05) and an average N-gain of 0.528. These findings suggest that the Ethno-STEM-based interactive materials are valid, practical, and effective for improving students' visual-spatial thinking skills in geometry learning.

Keywords: Geometry Transformation; Ethno-STEM; Interactive Digital Teaching Materials; *Jombang culture*; Visual-Spatial Thinking

Abstrak

Pemahaman konsep geometri sering kali menuntut kemampuan berpikir visual-spasial yang baik, penelitian menunjukkan bahwa menginternalisasi kemampuan berpikir visual-spasial dapat menjadi solusi dalam pembelajaran geometri.

Penelitian ini bertujuan untuk mengembangkan bahan ajar digital interaktif geometri transformasi berbasis Ethno-STEM budaya Jombang yang valid, praktis, dan efektif dalam membantu meningkatkan kemampuan berpikir visual-spasial siswa. Budaya yang diangkat berupa batik dan candi khas kabupaten Jombang. Metode penelitian ini menggunakan model pengembangan ADDIE yang meliputi tahap Analysis, Design, Development, Implementation, dan Evaluation. Teknik pengumpulan data menggunakan observasi, wawancara, angket, dan tes. Analisis data dilakukan melalui data kuantitatif dan kualitatif. Hasil penelitian menunjukkan bahwa produk yang dikembangkan memiliki validitas tinggi dengan persentase rata-rata keseluruhan dari penilaian ahli materi, bahan ajar, bahasa, dan pembelajaran sebesar 85,90%; kepraktisan tinggi dengan rata-rata penilaian dari validator praktisi dan respon peserta didik sebesar 91,31%; serta efektivitas sedang dalam meningkatkan kemampuan berpikir visual-spasial peserta didik, dibuktikan melalui uji paired sample t-test dengan nilai sig. (1-tailed) = 0,000 < 0,05 dan rata-rata N-gain sebesar 0,528. Dengan demikian, bahan ajar digital interaktif berbasis Ethno-STEM budaya Jombang dinyatakan valid, praktis, dan efektif untuk digunakan dalam pembelajaran geometri guna meningkatkan kemampuan berpikir visual-spasial siswa.

Kata Kunci: Bahan Ajar Digital Interaktif; Transformasi Geometri; Ethno-STEM; Budaya Jombang; *Visual-Spasial Thinking*

Introduction

Mathematics learning in schools is inseparable from students' daily lives. Mathematics as a universal science plays a crucial role in human development and underlies the advancement of modern technology while supporting various scientific fields and enhancing human thinking (Ramadhanti & Marlina, 2019). One branch of mathematics that is very close to everyday life is geometry (Andriliani et al., 2022). This makes geometry an important topic to learn and master. Geometry material emphasizes students to be able to visualize geometric objects in their minds (Fitriyani et al., 2023). Geometry requires students to visualize the shape, size, and relationship between geometric objects in order to understand the material, to facilitate the problem-solving process, and to apply concepts. Safari & Nurhida (2024) revealed the urgency of finding effective learning solutions for understanding geometry. One promising approach to address this issue is through the enhancement of students' visual-spatial thinking skills, which serve as a foundation for geometric reasoning and spatial problem solving.

Visual-spatial ability is how students use their imagination, use concepts in geometry material, use strategies in solving problems and find and use patterns (Haas, 2003). Improving the ability of visual-spatial thinking allows students to be able to visualize geometry material better. Students should have the ability of visual-spatial thinking in order to understand geometry (Harnum, 2022). This is because in understanding geometry material involves a study that is abstract and requires imagination. Therefore, to bridge the gap in training visual-spatial thinking ability,

teaching materials need to be designed that explicitly facilitate the development of this ability.

Teaching materials play a crucial role in helping students develop mathematical competencies in a coherent and systematic manner, enabling them to master both knowledge and skills comprehensively (Hutasoit & Gultom, 2023). Various forms of teaching materials can be used in the learning process (Muftianti, 2019). The use of technology and multimedia in interactive teaching materials makes it an interesting subject to study in this era of rapid advancement of technology. Interactive teaching materials utilize the use of technology and multimedia that allows users to actively participate in the learning process (Nurhairunnisah & Sujarwo, 2018). Teaching materials used in the learning process should also be designed in such a way that they are sourced from the environmental conditions of the students.

Local culture can be utilized as a learning resource that is relevant and closely connected to students' daily environments (Pathuddin & Raehana, 2019). One of the many varieties of local culture is the culture of Jombang Regency which is studied through mathematics or what is called ethnomathematics of Jombang (Rozi & Budiarto, 2022). Ethnomathematics of Jombang is an effort to explore, study, and understand mathematics contained in various aspects of the culture of Jombang Regency, East Java, Indonesia. Although there have been several studies related to Jombang ethnomathematics, until now the focus of research is still at the exploration stage, including the exploration of geometry in Jombang batik (Irfianti et al., 2018) and about *Jombang culture* in the perspective of mathematical literacy (Rozi & Budiarto, 2022). These researchers have not extended their work to the stage of developing a teaching material that can be applied in learning activities. Therefore, there is a great opportunity to continue this research to the next stage, namely developing teaching materials that can be applied directly.

Teaching materials are developed by considering the learning approach used. STEM (Science, Technology, Engineering, and Mathematics) approach is a relevant approach because it supports students' higher-order thinking skills and can connect various disciplines to real-world contexts (Rahmawati & Juandi, 2022). The collaboration of mathematics learning that links culture with STEM is known as learning based on the Ethno-STEM approach (Fanni et al., 2023; Sari et al., 2022). The study of local culture integrated with STEM can be included in mathematics learning. In the Ethno-STEM approach, the use of local culture is a special attraction for students along with the use of technology that can support the development of students' understanding and abilities (Risnawati, 2020).

Based on preliminary studies conducted at MTs Negeri 3 Jombang, it was found that the available teaching materials were limited to printed resources, consisting only of student worksheets and mathematics textbooks. In fact, the utilization of various teaching materials can be an option in presenting better and more interesting learning (Qiftiah et al., 2022). student worksheets and mathematics package books that are used in general display material with one-way communication. Teaching materials that display material with one-way communication make learning less interactive (Nurhairunnisah & Sujarwo, 2018). In addition, the teaching materials should support the abstraction of mathematical concepts, particularly those that rely on visual elements or require imagination, such as geometry. Based on the results of observations conducted by researchers at MTs Negeri 3 Jombang, it is known that students tend to experience difficulties in understanding problems related to the visualization of objects before and after undergoing geometric transformations, mainly in the sub-topics of rotation and dilation. Whereas there are various facilities that can be used to support the mathematics learning process such as LCD projector facilities, smart boards, computer laboratories, student laptops and internet access that can be used in the learning process. Students tend to have difficulty in understanding and solving problems related to the visualization of geometric transformation material. Educators also expressed the need for teaching materials that can be used in digital learning. Therefore, educators and students need a comprehensive interactive digital teaching material, both from material, sample problems, or practice questions so that learning becomes more optimal.

The limitations of previous research on the development of interactive digital teaching materials include the effort to improve understanding of mathematical concepts (Nurhairunnisah, 2017). However, this research focuses on general mathematical concept understanding, but does not specifically target visual-spatial thinking ability as the main learning outcome. The development of interactive teaching materials with an ethnomathematics approach based on Banten local culture (Trisnawati, 2022), Although this approach is relevant, it has not yet been fully integrated into a more comprehensive Ethno-STEM framework. The development of Ethno-STEM-based e-modules on Integral Rotating Object Volume material with ethnomathematics studies focusing on traditional Javanese musical instruments in the form of gamelan (Sari et al., 2022), material focuses on the Integral Volume Objects, not on geometric transformation material and not based on *Jombang culture*. So, there is still no research on the development of interactive digital teaching materials for geometric transformation material that focus on

facilitating students' visual-spatial thinking ability using the Ethno-STEM approach of *Jombangan culture*.

Considering the challenges and potentials described earlier, this study aims to develop interactive digital teaching materials for geometric transformation based on the Ethno-STEM approach integrating *Jombangan culture*. The developed materials are intended to be valid, practical, and effective in enhancing students' visual-spatial thinking skills.

Method

The research employed the ADDIE development model consisting of analysis, design, development, implementation and evaluation stages (Branch, 2009; Muruganantham, 2015). Researchers used the ADDIE development model with its parameters modified based on the demands and needs of the research. The stages of the ADDIE development model are shown in Figure 1.

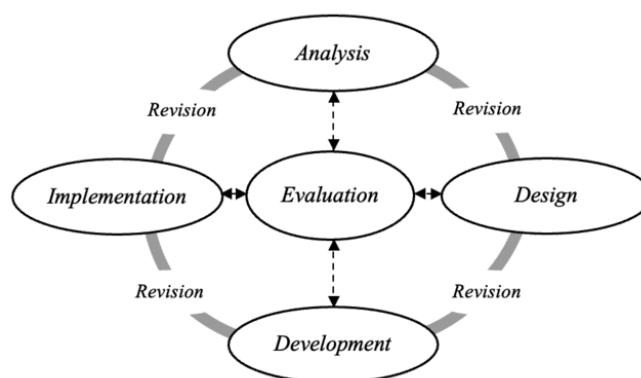


Figure 1. ADDIE Development Model

At the analysis stage, researchers conducted a needs analysis, task analysis and learning context analysis. At the design stage, researchers determined the content or field of study used, compiled content, designed interactive digital teaching materials, prepared developer components and prepared instruments. At the development stage, researchers developed interactive digital teaching materials, expert validation from 5 experts, and made revisions. At the implementation stage, researchers conducted field trials on 27 students, but before that small group trials were conducted on 5 students. The research subjects were ninth-grade students at MTs Negeri 3 Jombang, selected using purposive sampling. Meanwhile, the evaluation stage occurred at all stages of development both within a stage, between stages and after implementing which conclusions were drawn about a product that was valid, practical, and effective to improve students' visual-spatial thinking ability.

The data collection techniques used were observation, interview, questionnaire, and test using data collection instruments in the form of observation sheets, interview guidelines, validation sheets, practicality questionnaires, and visual-spatial thinking ability test sheets. Analysis of validity data was obtained from expert judgment of content, teaching material, language, and learning. Analysis of practicality was obtained from practitioner validator and student responses. The assessment used an instrument with a Likert scale of 1-4. The following calculation formula was used by researchers to determine the qualifications of validity and practicality scores:

$$P(s) = \frac{\sum x}{\sum x_{max}} \times 100\%$$

Where:

$P(s)$ = Percentage of sub variables

$\sum x$ = Total score of each sub variable

$\sum x_{max}$ = Total maximum score

Furthermore, the percentage of the calculation was transformed into descriptive data to draw conclusions on product validity and practicality qualifications using the qualification standards shown in Table 1 (Akbar, 2017).

Table 1. Validity and Practicality Qualifications

Percentage Rate (%)	Qualification	Description
$85.01\% \leq Score \leq 100\%$	Very valid/very practical	Usable without revision
$70.01\% \leq Score < 85\%$	Valid/practical	Usable with little revision
$50.01\% \leq Score < 70\%$	Less valid/less practical	Usable with many revisions
$01.00\% \leq Score < 50\%$	Not valid/not practical	Not usable

Determination of effectiveness is carried out using paired sample t-test (1-tailed) and n-gain of visual-spatial thinking ability test scores. Paired sample t-test (1-tailed) is used to determine whether there is a decrease or increase in students' pre-test and post-test scores. Then, n-gain is used to knowing the effectiveness criteria obtained. N-gain qualifications are shown in Table 2 (Hake, 1999).

Table 2. N-Gain Qualifications

N-Gain Value	Qualification
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Medium
$\langle g \rangle < 0.3$	Low

Results

The product developed in this study was an interactive digital teaching material for geometric transformation based on the Ethno-STEM approach that integrates *Jombangan* culture to enhance students' visual-spatial thinking skills. This research employed the ADDIE development model with the following stages.

Analysis

Researchers found in analysis stage that the mathematics teaching materials provided were limited to printed teaching materials in the form of student worksheets and mathematics textbooks. They also found that facilities that support the digital learning process have not been optimized such as the availability of LCD projectors, smart boards, computer laboratories, student laptops, and internet access. In addition, students experienced difficulties in understanding and solving problems related to abstracting/visualizing geometry transformation material. At the task analysis stage, researchers identified the main competencies that students must have during the learning process. Researchers analyzed the Core Competencies (*KI*) and Basic Competencies (*KD*) documents and then describe the Competency Achievement Indicators (*IPK*) according to the study of geometry transformation curriculum K13 (*Menteri Pendidikan dan Kebudayaan Republik Indonesia*, 2018). At the stage of analyzing the learning context, researchers analyzed the learning that supports to be applied in the field based on the needs analysis and the tasks that must be achieved by students. Researchers found information that the development of interactive digital teaching materials is needed at MTs Negeri 3 Jombang in order to overcome problems by utilizing the potential that supports learning. The Ethno-STEM approach can be the answer to overcoming existing learning problems.

Design

Researchers design and specify the basic description of interactive digital teaching materials by involving the use of outputs from the analysis stage to develop interactive digital teaching materials based on Ethno-STEM of *Jombangan culture* in geometry transformations material to improve students' visual-spatial thinking abilities. Researchers determined the study of geometry transformation in Jombangan cultural ethnomathematics which includes Rimbi Temple and Jombangan *batik* with Kayu Jati Gelondong Pattern, Tower Ringin Contong Pattern, Kharisma Kehidupan Pattern, Turonggo Sentulan Pattern, and Ceplok-Ceplok Jatipelem Pattern. At the stage of compiling the content of interactive digital teaching materials, researchers compiled materials, questions, and answers to

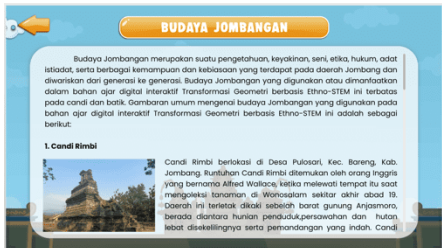
geometry transformation materials using the Ethno-STEM approach of *Jombang culture* to facilitate students' visual-spatial thinking abilities. Researchers then evaluated the results of the preparation that had been carried out to ensure the suitability of the content of interactive digital teaching materials with *KI*, *KD*, and *IPK* that had been determined. The developed content of this interactive digital teaching material consists of parts namely "Splash Screen", "Opening Page", "Preface Page", "Login Page", "*KD & IPK*", "Instructions for Use", "Culture Introduction", "Introduction Animation", "Main Menu", "Developer Profile", "Learning Menu", "Pre-requisite Material", "Mind Map", "Main Material", "Learning Activities", "Material Summary", "Exercise Menu", "Game Menu", "Evaluation Menu", and "Glossary & Bibliography". At the stage of designing interactive digital teaching materials, researchers created flowcharts, and storyboards based on the components of interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombang culture*.

When preparing the developer components, researchers carried out the process of downloading, registering accounts, and installing software used to develop interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombang culture* to improve students' visual-spatial thinking abilities. Researchers used a variety of software and websites to develop interactive digital teaching materials including Articulate Storyline 3, Adobe Photoshop, Adobe Illustrator, Desmos, GeoGebra Classic 6, WolframAlpha, Almost Fun, Wordwall, Clipchamp, Website 2 APK Builder Pro, and GitHub. At the stage of preparing instrument, researcher compiled an assessment instrument for interactive digital teaching materials for geometry transformations based on Ethno-STEM of *Jombang culture* to improve students' visual-spatial thinking abilities in the form of material expert validation sheets, teaching material expert validation sheets, language expert validation sheets, practitioner validation sheets, and student response questionnaires using a Likert scale of 1-4 accompanied by a column of criticism and suggestions. After the instrument was prepared, the researcher asked permission for the availability of experts to become validators.

Development

Researchers developed interactive digital teaching materials for geometry transformations based on Ethno-STEM of *Jombang culture* to improve students' visual-spatial thinking ability based on the design that has been done at the design stage. The development process resulted in a product shown in Table 3 below.

Table 3. Display of Ethno-STEM Based Interactive Digital Teaching Materials

Display	Description
	Opening page contains the title and there are several buttons that display: 1. Preface 2. Login page 3. Exit button
	Login page contains a welcome greeting to the user and asks the user to fill in the personal details. On the other hand, it also contains a button that displays: 1. Basic Competencies (KD) & Competency Achievement Indicators (IPK) 2. Instructions for use 3. Introduction to <i>Jombang culture</i>
	<i>Jombang culture</i> introduction page contains an introduction to the Jombang cultural context used as Ethno-STEM learning material.
	Introduction animation page contains animation as an apperception of learning before learning the entire content.
	Main menu page is a page that functions as an access page to the product features, such as: 1. Learning menu 2. Exercise menu 3. Game menu 4. Evaluation menu 5. Supporting features (learning objectives, instructions for use, developer profile, glossary and bibliography)



Learning menu page is a page that contains learning materials, such as:

1. Pre-requisite material
2. Mind map
3. Introduction material
4. Main material (translation, reflection, rotation and dilation)

Main material page is presented through the Ethno-STEM approach with visualizations that facilitate understanding. The main material page is divided into four sections namely Ethno-Science, Ethno-Technology, Ethno-Engineering and Ethno-Mathematics.

Learning activities page contains various learning activities designed to improve students' understanding and skills related to the material.

Material summary page contains the core information of the learning material in a short, concise and easy-to-understand form.

Exercise page contains practice questions with various types of questions including true-false, multiple choice and drag & drop.

Game page contains interactive games with the purpose of entertainment, learning and skill development.



Evaluation page contains self-evaluation questions after learning the learning material.

Evaluation results page contains the assessment results of the evaluation process which contains feedback, review of work results, print results and rework evaluation.

At the expert validation stage, researchers focused on evaluating the quality and suitability of the interactive digital teaching materials developed based on the Ethno-STEM approach of *Jombang culture*. The primary objective was to determine whether the teaching materials were of high quality and ready for use in the classroom or required for further improvements. To achieve this, the validation process involved a team of experts from various domains including content expert, teaching material experts, language experts, and learning experts. Teacher also provided insights into the practicality and usability of the materials in real classroom settings. Analysis of the validations results is shown in Table 4 below.

Table 4. Validation Results

Validator	Assessment Indicator	Percentage (%)	Qualification
Content Expert	1. Suitability of the material with Core Competencies (KI) and Basic Competencies (KD) 2. Accuracy of the material 3. Recency of the material 4. Completeness of material content coverage	82.14	Valid
Teaching Material Expert	1. Interface design 2. Content design of digital teaching materials 3. Clarity of text 4. Clarity and accuracy of multimedia use 5. Practicality and attractiveness	98.75	Very Valid
Language Expert	1. Language used is straightforward 2. Language used is communicative 3. Language used is dialogical and interactive	70.83	Valid

Learning Expert	1. Suitability of material presentation 2. Accuracy and suitability of supporting presentation 3. Appropriateness of Ethno-STEM learning with the material 4. Suitability of example with discussion 5. Coherence and conciseness of thought flow	91.88	Very Valid
Teacher	1. Practicality of the display of interactive digital teaching materials 2. Practicality of the presentation of interactive digital teaching materials 3. Benefits of using interactive digital teaching materials	91.00	Very Practical

Implementation

Researchers conducted a trial by applying interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombangan culture* to improve students' visual-spatial thinking ability to direct learning. No product deficiencies were found during the small group trial, but researchers must provide clear instructions for accessing and downloading interactive digital teaching materials so that students do not feel confused to access. At the field trial stage, researchers applied the interactive digital teaching materials for geometry transformation based on the Ethno-STEM of *Jombangan culture* to improve students' visual-spatial thinking abilities in learning geometry transformation to determine the practicality and effectiveness of the product by providing a student response questionnaire and test visual-spatial thinking ability. Researchers pay attention and improve from the notes that have been obtained when conducting small group trial. Then, conducted a field trial by providing learning for 3 meetings of geometric transformation material. Researchers distributed visual-spatial thinking ability tests in the form of pre-test and post-test to measure effectiveness of the product. The results of students' answers were analyzed to determine effectiveness of the product. Then, researchers also distributed a response questionnaire to measure the level of practicality based on student responses after the entire learning was carried out. Students who filled out the response questionnaire reached a percentage of 91.61% with the qualification "very practical".

Evaluation

Researchers conducted an evaluation of all data obtained based on a series of research activities that have been carried out; starting from the stages of analyzing, designing, developing and implementing. The data obtained in this evaluation are quantitative and qualitative data. At this stage, Researchers evaluated the product to determine the level of validity, practicality and effectiveness of the product. The product validity assessment was analyzed from assessment data and comments/suggestions from content, teaching materials, language and learning expert validators with the evaluation conclusion that the validity of the product reached an average percentage of 85.90% with the qualification "very valid". The assessment of product practicality was analyzed from assessment data and comments/suggestions from practitioner validators and learner responses with the evaluation conclusion that the practicality of the product reached 91.31%, with the qualification "very practical". Meanwhile, the assessment of product effectiveness was analyzed using paired sample t-test (1-tailed) and n-gain from students' answers in pretest and posttest of visual-spatial thinking ability. In the paired sample t-test test, the one-tailed p value was $0.000 < 0.05$, indicating that H_0 should be rejected. This result showed that the use of interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombangan culture* improves the visual-spatial thinking ability of MTs Negeri 3 Jombang students. N-gain test revealed that the average N-gain value reached 0.528 with moderate qualifications. This finding suggests that the use of product can improve the visual-spatial thinking ability of students with moderate qualifications.

Discussion

In the analysis stage, the researcher conducted a series of activities, including needs analysis, task analysis, and learning context analysis. The results indicated an urgent need to develop appropriate teaching materials to address the learning challenges identified. This finding is in line with (Hermiati & Julianti, 2023; Maulani & Zanthi, 2020; Putri, 2022) that most students still have difficulty in geometric transformation material. Through interviews with educators, it is known that the learning methods that are often applied are telling and discussions by utilizing teaching materials in the form of student worksheets and mathematics package books. Educators also revealed the need for interactive digital teaching materials to be used in the learning process. Interactive digital teaching materials can minimize learning limitations when using only one media, have media by design properties, optimize user interactivity, attractive user interfaces, with user control and flexibility (Oka, 2017; Prastowo, 2015; Sadjati et al., 2023). Then, researchers

analyzed the Core Competencies (KI) and Basic Competencies (KD) documents and then describe the Competency Achievement Indicators (IPK) according to the study of geometry transformation curriculum K13 (Menteri Pendidikan dan Kebudayaan Republik Indonesia, 2018). Based on the results of the analysis, there are sub-materials that must be mastered by students, namely translation, reflection, rotation, and dilation. Ethno-STEM approach was chosen in the development of this teaching material. The Ethno-STEM approach allows learning to be done more interestingly and contextually because it utilizes cultural elements or local wisdom in learning mathematics (Sari et al., 2022). In this study, *Jombang culture* is utilized (Rozi & Budiarto, 2022) because it is closely connected to the students' environment. Existing digital learning facilities can be optimally utilized through the Ethno-STEM approach because it can embrace the concept of integrating various scientific perspectives namely culture, science, engineering, mathematics, and technology into a learning field. As an effort to help students understand and solve the problem of geometric transformation material better, deepening the ability of visual-spatial thinking can be a solution (Elan et al., 2022; Octaviani et al., 2021). This is because in understanding the material transformation geometry involves a study that is abstract and requires imagining/visualization (Zainal, 2020).

In the design stage, determination of the *Jombang culture* is based on the suitability and relevance of the culture to the geometric transformation material, as well as the *Jombang culture* close to the environment of students according to Rozi & Budiarto (2022). Meanwhile, the determination of mathematical material in the form of geometry transformation is based on the suitability of KI & KD K13 curriculum, as well as based on the characteristics of the product being developed. Researchers mapped all KI & KD that are relevant to the Ethno-STEM-based geometry transformation material of *Jombang culture*. In compiling the content of interactive digital teaching materials, researchers collect and compile Ethno-STEM-based geometry transformation materials from valid sources (Kristanto et al., 2022; Rozi & Budiarto, 2022; Salamah, 2019; Subchan et al., 2018). Then, researchers present the material based on the steps of the Ethno-STEM approach, namely the Ethno-Science, Ethno-Technology, Ethno-Engineering and Ethno-Mathematics phases. In addition, researchers also compiled questions and answers given in the exercises, games and evaluation features. Components of this teaching materials refer to the form of e-module (Daryanto, 2013; Mariyana, 2016; Nisa, 2022). Flowchart and storyboard are used in this research to help facilitate the development process. Flowchart design serves to make it easier for researchers to know the overall flow or logical sequence of interactive digital teaching materials (Rohmatulloh & Zuhdi, 2020). On the other hand, storyboard design serves to draft

the concept and visual design of each page (slide) in the form of simple page charts that will be used as a guide in the development of each slide (Rohmatulloh & Zuhdi, 2020). Then, researchers prepared developer components to create Ethno-STEM-based interactive digital teaching materials on geometry transformation, while also developing validation instruments and student response questionnaires using a Likert scale and seeking expert validators' approval.

In the development stage, researchers develop products using developer components that have been prepared previously to produce whole products in the form of local web app, website and android application to accommodate the various types of gadgets used by students. Ease of user access to development products needs to be considered and adjusted by the developer (Melianti, 2023). The process of developing products consists of setting size and layout, making cover logo, making background, making interactive buttons, making characters, making voice over characters, making image content, making learning activity features, making game features, compiling interactive digital teaching material products and producing outputs in the form of local web app, website and android application. The researcher conducts a validation process as a form of product improvement so that it is suitable for testing at the next stage. The validation process is carried out by asking for help from experts who have a deep understanding related to certain competencies to get assessments and suggestions (Daryanto, 2013). Suggestions or comments and assessments from validators will be used as the basis for revising the product so that the development results are suitable for use in the field. The validation results for interactive digital teaching materials based on Ethno-STEM show that the content expert rated the material as valid (82.14%), the teaching material expert rated it as very valid (98.75%), the language expert rated it as valid (70.83%), the learning expert rated it as very valid (91.88%), and the teacher rated its practicality as very practical (91.00%).

In the implementation stage, the use of interactive digital teaching materials was implemented at MTs Negeri 3 Jombang class IX B for small group trial and field trial in class IX A. At the small group trial stage, researchers tested the product with limited students with the suggestion that the researchers must provide clear instructions for accessing and downloading interactive digital teaching materials so that students do not feel confused to access. From field trial in class IX A, it can be seen that students show a positive response to learning by being actively involved in the learning process and showing high interest in the material presented, especially in the presentation of culture in each existing sub-material. Easy access to learning activities that utilize digital technology also shows the efficiency of learning time in drawing or visualizing geometry objects that undergo

transformation. Students are also very interested and show high curiosity in the presentation of exercise features with various types of questions such as true-false questions, drag & drop and others. In utilizing the game feature, students compete in obtaining the highest score because a ranking feature is provided based on the correct answers of students. In the evaluation feature, students can clearly measure their understanding in geometry transformation material and get immediate feedback. The student response questionnaire results indicated a score of 91.61%, categorized as "very practical."

In the evaluation stage, the researchers evaluated and determined the level of validity, practicality and effectiveness of interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombangan culture* to improve students' visual-spatial thinking ability. this evaluation referred to the conversion table of product validity and practicality assessment developed by Akbar (2017). Then, the effectiveness refers to paired sample t-test (1-tailed) and n-gain test from pretest-posttest students' visual-spatial thinking ability. The validity assessment of the product reached 85.90% ("very valid"), its practicality scored 91.31% ("very practical"), and its effectiveness, analyzed through paired sample t-test and N-gain, showed significant improvement in students' visual-spatial thinking ability with a moderate N-gain of 0.528. Based on the assessment of expert validators, practitioners and students also through the ADDIE development procedure, it can be seen that the product of interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombangan culture* to improve students' visual-spatial thinking ability is very valid, very practical and effective to be applied in learning to improve students' visual-spatial thinking ability. This product contains material visualization, analysis and interpretation of geometric transformation concepts, abstracting transformation patterns and solving each problem with structured to support students' visual-spatial thinking ability. This finding aligns with research by Asri & Dwiningsih, (2022) who reported that teaching materials can be used as a medium for developing students' visual spatial intelligence. The use of technology in the form of software or math applications in the 21st century is a must to facilitate learning (Rafi & Sabrina, 2019). The use of software can serve as an effort to improve visual-spatial thinking ability (Pitriani, 2015; Sumarni & Prayitno, 2016). In line with other research that shows the need to train visual-spatial thinking skills so that students are able to understand the material and solve visualization problems well (Harnum, 2022; Hermiati & Julianti, 2023; Rafi & Sabrina, 2019).

The implications of this study are that it can contribute to the development of mathematics teaching materials in the form of interactive digital materials for

geometry transformation based on Ethno-STEM with a focus on facilitating students' visual-spatial thinking ability. In addition, this study provides references to guide the process of developing and implementing culturally relevant interactive digital teaching materials and providing an empirical basis for integrating the Ethno-STEM approach in mathematics learning. Meanwhile, the limitation of this research is the learning materials and culture raised in this product are limited to geometric transformation materials at the junior high school level with a focus on *Jombangan culture*. Based on the data explanation and the findings and limitations of the study, researchers suggest that the product of interactive digital teaching materials for geometry transformation based on Ethno-STEM of *Jombangan culture* to improve students' visual-spatial thinking skills can be developed with other materials, levels, and cultures.

Conclusion

The development of interactive digital teaching materials for geometric transformation based on the Ethno-STEM approach integrating *Jombangan culture* through the ADDIE development model has produced materials that are highly valid, highly practical, and moderately effective for improving students' visual-spatial thinking skills. The validity of the product was evaluated by experts in content, teaching materials, language, and learning, yielding an overall average score of 85.90%, categorized as very valid. The practicality was assessed by practitioner validators and student responses, resulting in an overall average score of 91.31%, categorized as very practical. The effectiveness of the materials was analyzed through a paired-sample t-test (1-tailed) and an N-gain test based on the pretest-posttest results of students' visual-spatial thinking skills. The t-test result showed a significance value of $0.000 < 0.05$, indicating that the use of the developed product significantly improved students' visual-spatial thinking skills. The N-gain score averaged 0.528, which falls within the moderate category. These findings indicate that interactive digital teaching materials for geometric transformation based on the Ethno-STEM approach of *Jombangan culture* are valid, practical, and moderately effective for enhancing students' visual-spatial thinking skills and can be effectively applied in geometry learning. This study has limitations in terms of material on geometric transformation, culture in the context of *Jombangan culture*, and experimental design methodology limited to pre-experiments. This opens up opportunities for further research by conducting experiments on a broader scale and developing digital interactive teaching materials based on Ethno-STEM with other materials, levels, and cultures.

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