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Museum-Based Virtual Tour Media in Geography Learning: Development and Its Implications for Students' Self-Directed Learning

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ABSTRACT

Purpose: This study aimed to develop geography learning materials through a museum-based Virtual Tour and to examine changes in Grade XI students' self-directed learning following its use. **Methods:** This study employed a Research and Development (R&D) approach using the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation. The participants were 46 Grade XI Social Sciences students at MA Mazroatul Ulum, selected through purposive sampling in a one-group pretest–posttest design without a control group. Data were collected using expert validation sheets, an achievement test to assess mastery of the geography materials, and a self-directed learning questionnaire administered before and after the intervention. Changes in self-directed learning scores were analyzed using the Wilcoxon Signed-Rank Test, as the pretest and posttest questionnaire data were not normally distributed. **Findings:** The analysis revealed a statistically significant difference in students' self-directed learning questionnaire scores before and after using the museum-based Virtual Tour ($Z = -5.934$, $p < .001$). All 46 students showed higher posttest scores, with 46 positive ranks and no negative ranks or ties. Because the study used a single group without a control condition, these results indicate an association rather than a causal effect, suggesting that the developed Virtual Tour is a promising medium for supporting self-directed learning through interactive, contextual, and flexible learning experiences. **Research Implications:** The findings suggest that museum-based Virtual Tours may serve as an alternative digital learning medium for geography, particularly when direct field studies or museum visits are constrained by time, cost, distance, or accessibility. Further studies using control groups are needed to confirm the observed changes. **Originality:** This study contributes by integrating geography learning materials, a museum-based Virtual Tour, and self-directed learning within a single learning medium, extending the use of Virtual Tours beyond visualization and learning outcomes toward the development of students' independent learning competencies.

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INTRODUCTION

The development of digital technology has brought significant changes to the education system in various countries. Digital transformation not only changes the way teachers deliver material, but also changes the characteristics of students' learning experiences that increasingly demand flexible, interactive, contextual, and *student-centered learning*. The integration of digital technology in learning is one of the strategies to improve the quality of education while preparing students to face the challenges of the 21st century that emphasizes critical thinking skills, digital literacy, creativity, collaboration, and independent learning. Various studies show that immersive technologies such as *virtual reality* (VR), *virtual field trips*, and *virtual tours* are able to create a more authentic learning experience than conventional learning media because it allows students to interact directly with representations of the real environment through digital media (Czimre et al., 2024;Masruroh et al., 2024).

In the context of geography learning, the use of digital technology is becoming increasingly important because the characteristics of geography emphasize understanding geosphere phenomena through spatial, environmental, and regional approaches. Geography material not only requires theoretical mastery of concepts, but also requires observation experience of real objects so that students are able to understand the relationship between natural phenomena, human activities, and environmental changes. However, the implementation of *field study activities* as the main character of geography learning often faces various obstacles, such as limited costs, time, access to locations, security, and certain geographical conditions. As a result, the learning process is still dominated by the use of textbooks, two-dimensional images, or presentations, so that many spatial concepts are difficult for students to understand in depth (Roelofsen & Carter-White, 2022;Czimre et al., 2024).

The limitations of field observation activities encourage the development of various digital learning media innovations that are able to present learning experiences that resemble real conditions. One of the innovations that has grown rapidly in recent years is the use of Virtual Tours based on 360° panoramas. Virtual tours allow students to explore a location virtually, observe objects from various perspectives, and obtain information independently through the integration of images, videos, audio, text, and other interactive features. In contrast to conventional visual media, Virtual Tours provide a more immersive learning experience so that it can increase curiosity, learning engagement, and students' ability to build knowledge based on the results of exploration carried out independently (Masruroh et al., 2024;Bengel & Peter, 2024).

The effectiveness of Virtual Tours in geography learning is also supported by various recent researches. Czimre et al. (2024) through a systematic review of 47 studies concluded that VR and Virtual Tour technology contribute positively to the visualization of geographical phenomena, the development of spatial skills, the increase of learning motivation, and the strengthening of inquiry-based learning. Meanwhile, Bengel & Peter (2024) show that the application of *virtual game-based field trips* in geography learning not only increases understanding of concepts, but also strengthens technology literacy and students' positive attitudes towards digital-based learning. The findings show that Virtual Tours are not just a visual medium, but an active learning tool that is able to integrate exploration, experience, and reflection in one digital learning environment.

In Indonesia, the use of Virtual Tours in geography learning also shows positive developments. Nisa et al. (2024) developed Virtual Geotour media on tectonism material in high school and found that the media has a high level of validity and is able to help students understand geography concepts that have been considered abstract due to the limitations of field observation. Another study by Masruroh et al. (2024) developed a 360° panorama-based Mobile Virtual Tour for environmental geography learning in universities. The results of the study show that the media is able to increase student involvement, provide a more realistic learning experience, and encourage students to explore the material independently without having to conduct direct field visits.

In addition to being used in environment-based geography learning, Virtual Tours also develop as a learning medium for cultural institutions, especially museums. The museum's transformation towards a digital ecosystem allows collections that were previously only accessible through direct visits can now be studied online through Virtual Museums. Research on the design of Virtual Museums shows that the process of exploring collections digitally can increase students' active participation, curiosity, and learning experience because they can access information according to their learning needs. On the other hand, Virtual Museums also provide teachers with the opportunity to integrate a variety of authentic learning resources into the learning process without being limited by space and time (Akgün & Çakmak, 2024;Hafida et al., 2024).

The use of museums as a learning resource in geography learning has great potential because museums hold various collections related to the dynamics of the earth, the diversity of landscapes, the development of civilization, and human interaction with the environment. The collection can help students understand geographical concepts in a more contextual way through the observation of authentic objects. However, the use of museums as a learning resource is still relatively limited due to the constraints of distance, time, visit costs, and limited integration of museums into the learning process in schools. The development of digital technology through Virtual Tours is one of the alternatives to overcome these limitations by presenting an online museum exploration experience without reducing the educational value of the museum (Kayaalp et al., 2024; Cronin-Golomb et al., 2024).

Museum-based virtual tours allow students to access various collections independently through 360° panoramas, high-resolution images, videos, audio, and interactive information. These characteristics are in line with a constructivist approach that places students as active subjects in building their knowledge through the process of exploration. Several studies have shown that the use of Virtual Museums can increase *student engagement*, learning experience, learning motivation, and concept understanding because students have the freedom to determine exploration paths according to their learning needs (Ariesta et al., 2024;Kayaalp et al., 2024). In addition, Virtual Tour technology also provides

flexibility for students to repeat the material at any time so that the learning process becomes more effective and student-centered (Masruroh et al., 2024;Czimre et al., 2024).

The characteristics of Virtual Tours that provide freedom in accessing and exploring materials also have the potential to increase *self-directed learning*. Learning independence is the ability of students to plan, manage, monitor, and evaluate their learning process independently. Students who have a good level of learning independence tend to be better able to determine learning goals, choose appropriate strategies, and be responsible for their learning outcomes. Research shows that an interactive, flexible, and exploration-based digital learning environment is able to improve *self-directed learning* abilities because learners are given the opportunity to control the learning process according to their own characteristics and needs (Kwak & Kim, 2024;Hafida et al., 2024).

Although research on Virtual Tours, Virtual Museums, and geography learning media has developed quite rapidly, previous studies have addressed different aspects of digital learning. For example, Czimre et al. (2024), through a systematic review of 47 studies, primarily reported the contribution of VR and Virtual Tour technologies to geographical visualization, spatial skills, learning motivation, and inquiry-based learning. Bengel and Peter (2024) examined virtual game-based field trips and found improvements in conceptual understanding, technology literacy, and students' attitudes toward digital learning. In Indonesia, Nisa et al (2024) developed Virtual Geotour media for tectonism material and focused on media validity and students' understanding of abstract geographical concepts, while Masruroh et al (2024) developed a 360° panorama-based Mobile Virtual Tour for environmental geography learning and emphasized student engagement, realistic learning experiences, and independent exploration. Meanwhile, studies on Virtual Museums have mainly examined student engagement, learning experiences, motivation, and concept understanding through digital exploration of museum collections (Ariesta et al., 2024; Kayaalp et al., 2024).

These studies demonstrate the potential of Virtual Tours and Virtual Museums as digital learning resources; however, their primary focus remains on learning outcomes, motivation, engagement, spatial skills, or learning experiences. They have not specifically addressed the development of a museum-based Virtual Tour that is intentionally designed to promote students' self-directed learning in geography education. Furthermore, existing geography-oriented Virtual Tour studies have generally focused on geographical phenomena or specific subject materials rather than integrating museum collections as contextual learning resources that connect physical, social, cultural, and environmental dimensions. Therefore, a research gap remains in developing and evaluating a museum-based Virtual Tour for geography learning that simultaneously integrates museum-based exploration, contextual geographical content, and self-directed learning.

Although research on Virtual Tours, Virtual Museums, and geography learning media has developed quite rapidly, most of the research still focuses on improving learning outcomes, learning motivation, or students' learning experiences. Research that specifically develops geography materials through museum-based Virtual Tour media with an orientation to increase learning independence is still relatively limited, especially in the context of geography learning in Indonesia. In addition, previous research has generally only developed learning media without integrating the potential of museums as a geography learning resource that is able to connect physical, social, cultural, and environmental aspects in an integrated manner (Nisa et al., 2024;Roelofsen & Carter-White, 2022).

Based on this description, an innovation is needed in the form of developing geography materials through museum-based Virtual Tour media that is able to provide a contextual, interactive, and flexible learning experience while encouraging students to become independent learners. The development of this media is expected not only to produce valid, practical, and effective learning products, but also to expand the use of museums as digital learning resources in geography learning. Thus, this research has novelty in the integration of Virtual Tours, museums as a source of geography learning, and learning independence in a learning media development model that is expected to be able to answer the needs of geography learning in the digital era (Masruroh et al., 2024;Czimre et al., 2024).

METHOD

This research uses the Research and Development (R&D) method with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model which aims to produce museum-based Virtual Tour media on geography materials and examine its feasibility and changes in students' learning independence (Branch, 2009). The ADDIE model was selected because it provides a systematic framework for identifying learning needs, designing and developing instructional media, implementing the developed product, and evaluating its feasibility and learning outcomes. The product developed in this study was a museum-based Virtual Tour for geography learning, which was evaluated in terms of its validity, practicality, and potential effectiveness in supporting students' self-directed learning. The Analysis stage consisted of needs analysis, curriculum analysis, learner analysis, and literature review. The geography materials focused on Indonesia's strategic geographical position and the potential of its natural resources. In the Design stage, learning objectives, content structure, learning activities, navigation flow, assessment procedures,

and storyboard were prepared. The research instruments, including expert validation sheets, student response questionnaires, self-directed learning questionnaires, and learning achievement tests, were also prepared at this stage.

The Development stage involved the production of the museum-based Virtual Tour based on the approved storyboard and learning design. The initial product was subsequently reviewed by expert validators. Material experts evaluated the accuracy, relevance, completeness, and presentation of the geography content, whereas media experts evaluated the interface, navigation, functionality, visual presentation, and usability of the Virtual Tour. Validation was conducted by two material experts and two media experts. The material experts were Geography Education lecturers holding doctoral degrees with more than 10 years of teaching and research experience, and the media experts were educational technology lecturers holding master's degrees with more than 8 years of experience in developing digital learning media. Each validator rated the product using a validation sheet consisting of 20 items on a 4-point Likert scale. The feasibility score was calculated as the percentage of the obtained score relative to the maximum possible score and interpreted using the following criteria: 81–100% = very feasible; 61–80% = feasible; 41–60% = fairly feasible; 21–40% = less feasible; and ≤ 20% = not feasible. Revisions were made based on the experts' recommendations before the product was implemented. The learning achievement test consisted of 20 researcher-developed items based on the learning objectives and geography materials. Each correct answer was scored 5 points and each incorrect answer 0 points, resulting in a maximum score of 100. The reliability of the test was assessed using Cronbach's Alpha and yielded a coefficient of 0.870.

The self-directed learning questionnaire was developed by the author based on the self-directed learning indicators proposed by Knowles (1975) and Zimmerman (2000), namely identifying learning needs, setting learning goals, choosing learning resources, implementing learning strategies, and evaluating learning outcomes. It consisted of 20 items (four items for each indicator) rated on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree, so that total scores ranged from 20 to 100. Construct validity was examined using the Pearson product-moment correlation between each item score and the total score. An item was considered valid when the calculated correlation coefficient (r-count) was greater than the critical value (r-table) at the 5% significance level. All items met this criterion and were therefore retained. Reliability was assessed using Cronbach's Alpha, and the coefficient exceeded the commonly used minimum threshold of .70, indicating that the items were internally consistent. Based on these results, the questionnaire was declared valid and reliable and was considered appropriate for measuring students' self-directed learning in this study.

The Implementation stage involved a trial of the revised Virtual Tour with 46 students of Grade XI Social Sciences at MA Mazroatul Ulum, consisting of classes XI IPS 1 and XI IPS 2, each totaling 23 students. The selection of subjects used purposive sampling, with the criteria that students were enrolled in Grade XI Social Sciences, had studied the relevant geography material, and participated in the complete research procedure. The implementation was conducted over two weeks in four sessions. In the first week, students received geography learning using instructional video media for two hours, followed by the learning achievement pretest and learning independence questionnaire for one hour on the following day. In the second week, students received learning using the developed museum-based Virtual Tour 360 for two hours, followed by the learning achievement posttest, learning independence questionnaire, and student response questionnaire for one hour on the following day.

Changes in students' scores were examined using a One-Group Pretest–Posttest Design. The pretest was administered after the initial video-based learning activity and before the implementation of the developed Virtual Tour, while the posttest was administered after the Virtual Tour learning activity**.** The validation data were analyzed descriptively using the percentage of the eligibility level, while the pretest–posttest data were analyzed using *the paired sample t-test* if the data were normally distributed or the Wilcoxon Signed-Rank Test if the data were not normally distributed. Normality was assessed using the Shapiro–Wilk test. Pretest and posttest scores of the self-directed learning questionnaire and the achievement test were summarized descriptively using the mean, median, standard deviation, interquartile range, and score range. For the Wilcoxon Signed-Rank Test, the effect size was calculated as $r = Z/\sqrt{N}$, where N is the number of participants. Because the study employed a one-group pretest–posttest design involving 46 students from a single school without a control group, the observed changes were interpreted as changes associated with the implementation of the developed media rather than definitive evidence of a causal treatment effect.

RESULTS

This research aims to develop geography materials through museum-based Virtual Tour media and examine changes in the learning independence of grade XI students following the use of these media. After the media development process through the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) stages is completed, data analysis is carried out to determine the characteristics of the research data and test the hypotheses that have been formulated. The analysis begins with a normality test to determine whether the data meets the assumption of normal

distribution so that appropriate statistical analysis techniques can be determined. Furthermore, because the data did not meet the assumption of normality, hypothesis testing was carried out using the Wilcoxon Signed-Rank Test to determine the difference in the level of learning independence of students before and after the use of museum-based Virtual Tour media. The results are presented according to the R&D process, including product development, expert validation, student responses, and changes in students' learning independence before and after implementation.

The developed product was a museum-based Virtual Tour 360 for geography learning covering Indonesia's strategic geographical position and the potential of its natural resources. The media was developed based on the learning objectives, learning materials, storyboard, and navigation design prepared during the design stage. The Virtual Tour provided students with interactive and contextual learning experiences through virtual museum exploration, geographical information, visual materials, and interactive navigation features.

The feasibility of the developed media was assessed through material and media expert validation. The material validation covered the accuracy, relevance, completeness, and presentation of the geography content, while media validation covered the interface, navigation, functionality, visual presentation, and usability of the Virtual Tour. The material expert validation obtained a score of 88.00%, categorized as very feasible, while the media expert validation obtained a score of 90.00%, also categorized as very feasible. These results indicate that the developed Virtual Tour met the predetermined feasibility criteria. Several suggestions provided by the experts, particularly regarding content presentation and navigation clarity, were incorporated into the final product before implementation.

Students' responses were also collected after the implementation of the Virtual Tour to evaluate its practicality and usability. The user-response questionnaire obtained an average score of 87.50%, categorized as very practical. Students generally reported that the Virtual Tour was easy to navigate, visually engaging, interactive, and helpful in understanding the geography materials. These findings provided additional evidence regarding the practicality of the developed media from the users' perspective.

Table 1 presents the descriptive statistics of the pretest and posttest scores. Scores on the self-directed learning questionnaire increased from a mean of 74.13 (SD = 9.39; median = 75.00, IQR = 10.00) in the pretest to a mean of 89.35 (SD = 7.20; median = 90.00, IQR = 10.00) in the posttest, an average change of 15.22 points. The observed scores ranged from 55 to 95 in the pretest and from 75 to 100 in the posttest. The achievement test, which was used to describe students' mastery of the geography materials and served as supplementary data rather than the primary outcome of the hypothesis test, yielded mean scores of 62.50 (SD = 11.20) in the pretest and 81.30 (SD = 9.40) in the posttest, with a possible score range of 0–100.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Instrument	Test	N	Mean	SD	Median	IQR	Min–Max
Self-directed learning questionnaire	Pretest	46	74.13	9.39	75.00	10.00	55–95
	Posttest	46	89.35	7.20	90.00	10.00	75–100
Achievement test	Pretest	46	62.50	11.20	60.00	15.00	40–85
	Posttest	46	81.30	9.40	80.00	15.00	60–100

Note. SD = standard deviation; IQR = interquartile range. Scores on the self-directed learning questionnaire could range from 20 to 100; achievement test scores could range from 0 to 100.

Normality tests are carried out to find out whether the pretest and posttest data are distributed normally. The test used the Kolmogorov–Smirnov and Shapiro–Wilk tests. Given that the number of study samples amounted to 46 students, the normality interpretation refers to the results of the Shapiro–Wilk test, because this test is more suitable for use in the number of samples less than 50.

Table 2. Normality Test Results

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Pretest	0.211	46	<.001	0.920	46	0.004
Posttest	0.184	46	<.001	0.916	46	0.003

Note. The data is declared to be normally distributed if the significance value (p) is >.05.

Based on Table 2, the results of the normality test using Shapiro–Wilk show that the pretest data obtained a significance value of 0.004, while the posttest data obtained a significance value of 0.003. Both values are smaller than the significance level of 0.05 ($p < .05$), so it can be concluded that both pretest and posttest data are not normally distributed. These results suggest that the data distribution does not meet the assumption of normality so parametric statistical analysis, such as *the paired sample t-test*, cannot be used. Therefore, hypothesis testing was continued using

the Wilcoxon Signed-Rank Test, which is a nonparametric test that is suitable for comparing two paired data that are not normally distributed. Thus, the use of the Wilcoxon test is considered appropriate to determine changes in the level of learning independence of students before and after using museum-based Virtual Tour media.

The hypothesis test was carried out using the Wilcoxon Signed-Rank Test to find out whether there was a difference in the level of students' learning independence before (pretest) and after (posttest) using museum-based Virtual Tour media. The test results are presented in Table 3.

Table 3. Wilcoxon Signed-Rank Test Results for Pretest and Posttest Scores

Comparison	Negative Ranks (*n*)	Positive Ranks (*n*)	Ties (*n*)	*Z*	*p*	*Effect Size*
Posttest – Pretest	0	46	0	-5.934	<.001	0.875

Note. A p value of < .05 indicates that there is a significant difference between pretest and posttest scores.

Based on Table 3, the results of the Wilcoxon Signed-Rank Test show that all students experienced an increase in scores after using museum-based Virtual Tour media. The effect size was $r = 0.875$ (calculated as $r = Z/\sqrt{N}$), indicating a large effect. The combination of the descriptive statistics and effect size indicates that the observed change was not only statistically significant but also substantial in magnitude.

Overall, the results of the R&D process indicate that the developed museum-based Virtual Tour met the feasibility criteria based on expert assessment, received positive responses from students, and was associated with an increase in students' learning independence scores. This is shown by the positive ranks of 46 students, while negative ranks and ties are both 0, which means that there are no students who experience a decrease in scores or get a fixed score after participating in learning. In addition, the test results produced a statistical value of $Z = -5.934$ and an asymptotic significance (2-tailed) of $p < .001$. The significance value is smaller than 0.05, indicating that there is a significant difference between pretest and posttest scores. Thus, the null hypothesis of no difference between pretest and posttest scores was rejected, indicating a statistically significant increase in the learning independence scores of grade XI students after the use of museum-based Virtual Tour media. Because the study used a one-group pretest–posttest design without a control group, this result is interpreted as a pre–post change associated with the implementation of the media rather than as evidence of a causal effect. Active, independent, and directed learning behaviors were not directly measured and are therefore treated only as possible explanations in the Discussion.

DISCUSSION

The results of the study show that the development of geography materials through museum-based Virtual Tour media was followed by a significant increase in the learning independence scores of grade XI students at MA Mazroatul Ulum. This is evidenced by the results of the Wilcoxon Signed-Rank Test which shows a value of $Z = -5.934$ with a significance level of $p < 0.001$, so that there is a significant difference between the pretest and posttest scores after students use the developed media. In addition, all students (46 people) experienced an increase in scores after treatment, which was shown by a positive rank score of 46 without negative ranks or ties. These findings indicate a significant pretest–posttest change in learning independence following the implementation of the museum-based Virtual Tour. However, because this study used a one-group pretest–posttest design, the observed change cannot be attributed exclusively to the Virtual Tour. These results show that museum-based Virtual Tour media is able to create a more meaningful learning experience and encourage students to be actively involved in the learning process. However, these aspects were not directly measured in the present study and therefore should be interpreted as possible explanations rather than direct findings. These findings indicate that the developed media not only functions as a medium for delivering information, but is also able to be a means that supports the development of students' learning independence through broader and more flexible exploration activities.

The findings are in line with the initial conditions found by researchers at the Mazroatul Ulum Supreme Court. Based on the results of observations during the geography learning process, students still show a relatively low level of learning independence. Most students still rely on the teacher's explanations when studying the material, lack the initiative to seek additional information from other sources, and tend to wait for directions in completing the assignment given. This condition shows that the learning process is still dominated by a *teacher-centered approach*, so that students' opportunities to develop learning skills independently are not optimal. After the museum-based Virtual Tour media was implemented, students' learning independence scores increased, while the observed classroom activities provided contextual indications of students' engagement with the media. These changes show that an interactive learning environment is able to encourage students to be more active and responsible for their own learning process. Nevertheless, the observed behavioral changes should not be interpreted as a direct causal effect of the Virtual Tour because they were not independently measured and the study did not include a control group.

The results of this research can be explained through the Theory of Constructivism pioneered by Piaget (1952) and later developed by Vygotsky (1978). Constructivist theory states that knowledge is not acquired through the process of passively receiving information, but rather is actively constructed based on the individual's experience and interaction with his or her environment. In the context of this research, museum-based Virtual Tour media provides opportunities for students to observe museum collections, browse information, connect observed objects with geographical concepts, and build their own understanding through the exploration process. Thus, students not only receive material from the teacher, but also play the role of subjects who actively construct knowledge. This result reinforces the constructivist view that an active and contextual learning experience will produce more meaningful understanding than learning that is only centered on the delivery of material by the teacher.

In addition to being supported by constructivism theory, the results of this study are also relevant to the Experiential Learning Theory developed by Kolb (1984). According to Kolb, effective learning occurs through four stages, namely *concrete experience*, *reflective observation*, *abstract conceptualization*, and *active experimentation*. Even though students do not make direct visits to the museum, museum-based Virtual Tour media is able to present a virtual learning experience that resembles real conditions through 360° panoramas, images, videos, and interactive information. The virtual experience provides an opportunity for students to observe geography phenomena in more depth, reflect on the information obtained, and then connect it with the geography concepts being studied. Thus, the use of Virtual Tours not only enhances conceptual understanding, but also strengthens learners' learning experiences through authentic environmental simulations.

The results of this study also support the Self-Directed Learning Theory introduced by Knowles (1975). Knowles explained that students who have learning independence are able to identify their learning needs, set learning goals, choose appropriate learning resources, implement learning strategies, and evaluate learning outcomes independently. During the use of museum-based Virtual Tour media, students gain the flexibility to determine the order of material exploration, re-access information that has not yet been understood, and adjust the learning speed according to their individual needs. These characteristics provide opportunities for students to manage the learning process more independently than conventional learning. Therefore, the increase in learning independence found in this study suggests that Virtual Tour media may facilitate the formation of more independent and responsible learning behaviors.

The results of this study are also in line with the Cognitive Theory of Multimedia Learning developed by Richard E. Mayer. The theory explains that the learning process will be more effective if information is presented through a combination of words, pictures, animations, audio, and visuals that complement each other so that it can optimize the working memory capacity of students. Mayer (2009) emphasized that multimedia learning allows students to build relationships between visual and verbal representations more effectively than textual information delivery. In this study, museum-based Virtual Tour media integrates 360° panoramas, images of museum collections, material narratives, and supporting information that allows students to understand geographical phenomena more concretely. The presentation of such material helps students connect geography concepts with real objects so that the learning process is no longer just memorized, but develops into a deeper conceptual understanding. This condition may be reflected in the increase in students' learning independence after using the developed media.

The results of this study also support the theory of Self-Regulated Learning proposed by Barry J. Zimmerman. According to Zimmerman (2000), students who have *self-regulated learning* skills are able to plan learning objectives, monitor the learning process, control the strategies used, and evaluate the learning outcomes obtained. Learning independence is one of the important indicators in the self-regulation process. During the use of museum-based Virtual Tour media, students not only receive information from the teacher, but also determine the order of material exploration, choose the museum object to be studied, and repeat the material if there are concepts that are not yet understood. These activities show that there is an increase in students' control over their own learning process so that they are more responsible for achieving learning outcomes. Thus, Virtual Tour media may not only support cognitive aspects, but also help develop students' self-regulation skills which is one of the important competencies in 21st century learning.

The findings of this study reinforce the research results of Masruroh et al. (2024) who developed *a 360° panorama-based Mobile Virtual Tour* for environmental geography learning. The study shows that the use of Virtual Tours is able to provide an immersive learning experience, increase student involvement, expand opportunities to explore geographical conditions, and encourage students to gain knowledge independently. The same condition was also found in this study. After the media is applied at MA Mazroatul Ulum, students no longer only depend on the teacher's explanations, but begin to actively explore the material through the features available in the media. Students can access information as needed, observe museum objects from various perspectives, and connect the information with the geography material being studied. This shows that the main characteristics of Virtual Tours, namely flexibility

of access, realistic visualization, and interactivity, are able to encourage the formation of more independent learning behaviors.

The results of this study are also consistent with a systematic study conducted by Czimre et al. (2024) regarding the use of *Virtual Reality* in geography learning. The study concluded that the use of Virtual Reality and Virtual Tour technology contributes to improving spatial thinking skills, learning motivation, student involvement, and quality of learning experience because students get the opportunity to explore the environment virtually as if they were in a real location. This study strengthens these findings by showing that the benefits of Virtual Tours are not only limited to improving cognitive abilities, but may also be associated with affective aspects in the form of increased learning independence. In other words, museum-based Virtual Tour media may not only help students understand geography material, but also foster more active and responsible learning habits. Unlike these outcomes, the present study focused on learning independence. This difference suggests that museum-based Virtual Tours may be relevant not only to cognitive or experiential outcomes reported in previous research, but also to students' capacity to manage their learning. Nevertheless, this study does not provide evidence that the Virtual Tour improves the cognitive outcomes identified by Czimre et al. (2024), because those outcomes were not measured here.

The findings of this study also show that museums have great potential as a source of geography learning when combined with digital technology. So far, museums are often used as locations for educational visits whose implementation depends on the availability of time, cost, and access to transportation. As a result, many schools have not been able to make optimal use of museums as part of the learning process. The presence of museum-based Virtual Tours is a solution to these problems because students can access museum collections at any time without having to visit in person. The digitization of the museum also allows the learning process to take place more flexibly while maintaining the educational value of the collection studied. These results are in line with the development of virtual museum applications that show that digital technology is able to increase access to museum information and strengthen the museum's function as a learning medium.

When compared to previous studies, there are differences that are the main contribution of this study. Most previous research has focused on the development of Virtual Tours to improve learning outcomes, learning motivation, spatial thinking skills, or learners' learning experiences. Instead, this study places learning independence as the main variable measured after media application. Thus, this study suggests that museum-based Virtual Tours may be relevant not only to academic aspects, but also to the development of students' learning character. This finding is important because the ability to learn independently is one of the essential competencies needed by students in facing 21st century learning that demands *lifelong learning*.

The novelty of this research lies in the development of media that integrates three main components, namely geography materials, museum-based Virtual Tours, and independent learning in one learning product. Previous research generally only developed Virtual Tour media as a means of visualizing geographical objects or *virtual field trips*. This research presents a different approach by utilizing museums as learning resources that are directly integrated into geography materials so that students obtain a more contextual learning experience. The integration provides opportunities for students to build their understanding through the exploration of museum objects that are relevant to the subject matter, as well as to train their learning skills independently. This contribution is the added value of research compared to previous studies.

The theoretical implications of this study are to strengthen the view of Piaget and Vygotsky's constructivism, *Kolb's Experiential Learning*, *Knowles' Self-Directed Learning* Knowles, *Mayer's* Cognitive Theory of Multimedia Learning*, and Zimmerman's Self-Regulated Learning* that learning that provides an authentic, interactive, and student-centered learning experience is able to improve the quality of the learning process while shaping learning independence. Meanwhile, the practical implications of this study show that museum-based Virtual Tour media can be an alternative to geography learning innovations in schools, especially for schools that have limitations in carrying out field observation activities or museum visits. This media allows teachers to present a more contextual learning experience without being constrained by distance, time, or cost, while students get the opportunity to learn more flexibly according to their respective learning speeds and needs. Thus, the development of museum-based Virtual Tour media has the potential to support the transformation of geography learning that is more innovative, effective, and oriented towards the development of students' competencies in the digital era. These practical implications should nevertheless be considered within the context of the study's limited sample and research design.

This study has several limitations. First, the absence of a control or comparison group means that the increase in learning independence cannot be attributed solely to the museum-based Virtual Tour. Other factors, such as maturation, teacher instruction, classroom activities, or exposure to the pretest, may have contributed to the observed change. Second, the participants were drawn from only one school, namely MA Mazroatul Ulum, which limits the generalizability of the findings to students in other schools and educational contexts. Third, the use of pretest and

posttest measurements may have introduced a testing effect, as students may have become more familiar with the questionnaire or the learning construct being assessed. Finally, the study examined changes over a relatively limited implementation period and therefore cannot determine whether the observed increase in learning independence would be sustained over time. Future research should involve a control or comparison group, participants from multiple schools, larger and more diverse samples, and longitudinal measurements to provide stronger evidence regarding the effectiveness and generalizability of museum-based Virtual Tour media.

Overall, the findings demonstrate a significant pretest–posttest difference in students' learning independence following the implementation of the museum-based Virtual Tour. The results provide initial evidence that this type of media may support learning independence in geography education. However, the absence of a control group and the limited sampling context require the findings to be interpreted as evidence of pre–post improvement rather than definitive evidence of a causal effect.

CONCLUSION

This research has successfully developed geography materials through museum-based Virtual Tour media using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The Wilcoxon Signed-Rank Test showed a significant difference between pretest and posttest scores ($Z = -5.934$, $p < .001$), with all students experiencing an increase in scores. These findings indicate that students demonstrated higher learning independence scores following the implementation of the developed media. However, given the one-group pretest–posttest design, the findings cannot be interpreted as definitive evidence of a causal effect**.**

The findings suggest that museum-based Virtual Tours may support learning independence through flexible and independent exploration of learning materials. Because conceptual understanding was not directly measured, no conclusion can be drawn regarding improvements in students' geography conceptual understanding. This research contributes to digital geography learning by integrating museum resources with Virtual Tour technology and focusing on learning independence. Further research should involve larger and more diverse samples, multiple schools, and a control or comparison group to provide stronger evidence of effectiveness and generalizability. Future studies may also examine other outcomes, such as conceptual understanding, motivation, and learning engagement.

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