Geospatial Technology E-Module Development for Strengthening TPACK Competency in Geomorphology Study

Bayu Wijayanto [1], Nofrion Nofrion [1], Sri Mariya [1],
Sumarmi Sumarmi [2], Dwiyono Hari Utomo [2], Budi Handoyo [2]

[1] *Faculty of Social Science, Universitas Negeri Padang, Padang, Indonesia*
[2] *Faculty of Social Science, Universitas Negeri Malang, Malang, Indonesia*

***Abstract* – Global educational issues highlight the importance of preparing for the demands of the 21st century by developing core competencies. Geography, as a core subject and theme of the 21st century, necessitates the integration of technology into higher education to enable prospective teachers to effectively utilize technological tools. A crucial aspect of enhancing prospective teachers' technological pedagogical content knowledge is the use of instructional modules. Currently, geography modules in higher education are perceived to lack sufficient geographical content. This study proposes a solution to improve prospective geography teachers' Technological Pedagogical and Content Knowledge (TPACK) by employing a techno-geospatial based e-module. Researchers decided to apply the Educational Research and Development method because of its focus on developing effective products in the context of educational activities. The findings reveal a significant difference in the n-gain scores between classes using the techno-geospatial based e-module and those that do not. Classes utilizing the e-module demonstrated a moderate level on the self-report measure of TPACK competency, whereas classes without the e-module were categorized as low.**

The techno-geospatial based e-module has proven to be both effective and feasible for enhancing prospective geography teachers' TPACK. This research contributes to the development of e-modules aimed at preparation for 21st-century skills.

***Keywords* – E-Module, Geomorphology, geospatial technology, TPACK.**

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Corresponding author: Bayu Wijayanto,
Faculty of Social Science, Universitas Negeri Padang, Padang, Indonesia
Email: bayuwijayanto@fis.unp.ac.id

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1. Introduction

The report, "Learning for the 21st Century" released a "Framework for 21st Century Learning," outlining four competencies or areas that individuals need to master, covering essential subjects, 21st-century themes, skills for learning and innovation, information, media, and technology proficiency, as well as life and career competencies [1]. Issues in global education highlight various aspects of preparation for 21st century education. These four competencies are intended to adapt education to the demands of the times. One aspect that is part of the core subjects and themes of the 21st century is geography.

Teachers need to possess a wide and deep understanding of instructional materials, content, teaching methods, and the use of technology. On a global scale, a teacher competency framework called TPACK is recognized. Subsequent studies have focused on developing approaches and strategies to improve teachers' TPACK knowledge and skills [2], [3], [4]. This has also involved the development of assessment and measurement instruments, teachers' and pre-service teachers' TPACK skills [5], as well as the exploration of lecturers' perceptions of future TPACK implementation [6], [7]. It is also important to note that previous research has only focused on teacher readiness related to online learning [8].

Studies on the TPACK competencies of prospective teachers are still relatively low. The technological knowledge and TPACK abilities of prospective teachers and graduate students are still low [9].

The study conducted [10] found that the level of literacy about technology, pedagogy, content knowledge, and TPACK was at a moderate stage. The use of technology is the main factor that provides the greatest support for the TPACK abilities of students who are undergoing education as prospective teachers [11].

Study programs in higher education must integrate technology in learning to help prospective teachers utilize technology, both hardware and software, in learning their respective disciplines [12]. One important aspect in improving the TPACK competence of prospective teachers is the module given in lectures. Modules are materials with a systematic arrangement so that students can learn independently. Students acquire TPACK by observing lecturers teaching in class and conducting independent learning with internet media [13]. The development of TPACK competencies through modules is still very limited. The development of TPACK competencies of prospective geography teachers based on geospatial technology needs to be done.

E-modules should be designed to facilitate independent learning, providing all essential materials and functioning autonomously without reliance on other media. They must also be adaptable to advancements in science and technology and user-friendly. The ideal solution to these needs e-modules that incorporate techno-geospatial content, are digitally optimized for effectiveness, promote digital literacy, and seamlessly integrate technology into teaching materials. Additionally, these e-modules should support asynchronous learning to enhance flexibility and engagement.

Techno geospatial is technology in geography learning as a tool that can support the achievement of learner competencies. One of the key components in the geospatial approach is the interaction between techno geospatial and PCK to support an effective learning environment [14].

The innovative aspect of this research lies in the proposed solution for enhancing the TPACK of future geography teachers: The use of e-modules based on techno-geospatial principles.

One of the courses that is expected to have e-modules is Geomorphology. The broad scope of study both theory and practicum and the course outcome of the course require students to understand concepts and skills, making the course expected to have e-modules. These problems also occur in other courses in the geography education curriculum. The issue with e-modules goes beyond their limited availability; it also includes the lack of e-modules that effectively integrate geospatial technology.

The results of preliminary observations on the modules used in geography lectures currently lack geography elements and have not been able to show and express the characteristics of geographic phenomena and translate geography education.

The existing module design only includes material and exercise questions in each discussion. The presentation of the material is verbal or narrative with examples in the form of pictures. Some lecturers write modules with certain materials that are not poured into an e-module that is characterized by geography by providing a techno geospatial base.

2. Methodology

The aim of this study is to design and develop a techno geospatial-based e-module to improve TPACK competencies in Geomorphology courses. Researchers decided to apply the Educational Research and Development method because of its focus on developing effective products in the context of educational activities. The research and development model used in this study is based on the framework proposed by [15], with modifications that streamline it to 7 out of the original 10 stages. The research flow is depicted in Figure 1.

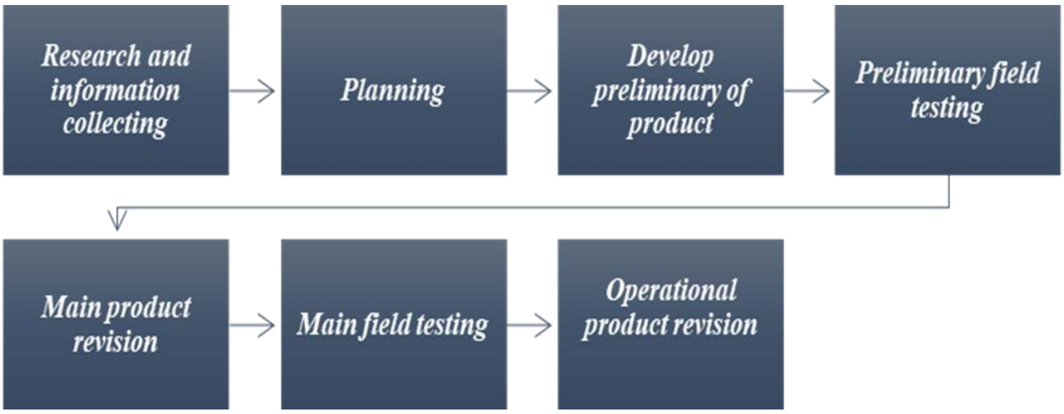


Figure 1. Borg and Gall Model [15]

2.1. Research and Information Collecting

Research and information collection consisting of literature studies and field studies. Literature studies were conducted using curriculum analysis and e-module analysis. Field studies were conducted using needs analysis. The needs analysis focuses on evaluating the current state of the learning process, including the conditions of instructional activities, observations of supporting laboratories and resources, as well as an assessment of both student and faculty needs.

2.2. Planning

Planning is the stage of preparing a research plan that includes developing the skills needed to carry out development research. At this stage, the formulation of objectives and subject matter as well as the research activity plan are outlined.

2.3. Develop Preliminary of Product

This step involves aligning the learning tools, specifically the semester learning plans, to ensure they meet the required objectives. The research instruments are described in Table 1.

Table 1. Research Instruments

No	Instrument	Objective	Time
1	Quality of e-modules (assessment by material, instructional design, media, and language experts)	Assessing the quality of the developed e-module (part of the feasibility test)	Preliminary field testing
2	Comprehension of an e-module (using the discourse main idea test)	Knowing the understandability of e-modules to be understood and used (part of the feasibility test)	Preliminary field testing
3	Self-report measure of TPACK Competency	Knowing the ability of geography students in the areas of technology, pedagogics, and content.	Pre-post Main field testing

2.4. Preliminary Field Testing

The e-module feasibility test consists of a quality test and an e-module comprehension test. The subjects of the comprehension test were 12 geography students at Universitas Negeri Padang.

The participants involved in the comprehension test were a different group from the participants who were the subjects in the main field test or operational field test in this development research.

The feasibility of e-modules based on techno geospatial is known from the analysis of the quality test and comprehension test of e-modules. The quality test and comprehension test were then determined by percentage and interpreted by considering the feasibility category. The assessment criteria for the e-module validation score are shown in Table 2.

Table 2. E-module validation score assessment criteria

No	Percentage	Criteria
1	$91 < x \leq 100$	Very Feasible
2	$76 < x \leq 90$	Feasible
3	$61 < x \leq 75$	Feasible Enough
4	$x \leq 60$	Less Feasible

1) Quality test of techno geospatial based e-modules: The quality evaluation of the e-module was conducted through expert validation, involving specialists in content, instructional design, multimedia, and language.
2) Techno geospatial-based e-module comprehension test: The comprehension test of the e-module content was conducted by testing the main idea of the discourse. The data from the comprehension test were analyzed using the following formula.

$$K = \frac{Score\ Obtained}{Maximum\ Score} x\ 100\% \quad (1)$$

2.5. Main Product Revision

After conducting the initial field test, the draft e-module adopting techno geospatial underwent revisions based on input from four experts, in line with the results of the e-module quality evaluation such as material, instructional design, media, and language.

2.6. Main Field Testing

This step is a product test that is carried out with a focus on aspects that include testing the effectiveness of techno geospatial-based e-modules on the TPACK competencies of geography students with pseudo experiments. The effectiveness test was carried out using inferential statistics first by meeting the requirements of normally distributed and homogeneous data (so normality and homogeneity tests are needed). The statistics that correspond to this test is the mean difference test. The normalized gain value obtained was then interpreted according to the criteria of [16].

Interpretation of the normalized gain values and n-gain effectiveness are shown in Table 3 and Table 4.

Table 3. Interpretation of normalized gain value

No	N-gain	Category
1	$<g> \geq 0{,}7$	High
2	$0{,}7 > <g> \geq 0{,}3$	Medium
3	$<g> < 0{,}3$	Low

Source: [16]

Table 4. N-gain effectiveness interpretation

No	Percentage	Category
1	< 40	Ineffective
2	40 – 55	Less Effective
3	56 - 75	Moderately Effective
4	>76	Effective

Source: [16]

Statistical analyses were performed to determine the significance of differences in TPACK competence outcomes between the experimental and control groups of geography students. The level of approval of the response to the techno geospatial-based e-module can be calculated using the equation:

$$\%approval \frac{number\ of\ scores\ obtained\ for\ each\ item}{number\ of\ ideal\ scores\ for\ all\ items} x100\%$$

2.7. Operational Product Revision

The revised part mainly includes the refinement of the techno geospatial-based e-module with the aim of ease of learning implementation and achievement of the objectives of using the developed e-module, namely increasing TPACK competence.

3. Results

This section presents research findings based on each stage of the development model. The results are organized according to the development steps to ensure a coherent explanation.

3.1. Research and Information Collecting

This step includes two aspects that are researched, the first is a literature study consisting of curriculum analysis and e-module analysis, the second is related to field studies in the form of needs analysis.

1) Literature Studies: The curriculum development in the Geography Education program necessitates an update to the modules used in lectures. An analysis of the semester learning plan (RPS) for the Geomorphology course reveals that the current learning approach does not incorporate geospatial technology. The existing modules are still in printed format. To address these issues, the proposed solution is the use of e-modules that incorporate geospatial technology, are digitally optimized for effectiveness, promote digital literacy, and integrate technology into the teaching materials.
2) Field Studies: Observations in the General Geomorphology class at Padang State University showed high student enthusiasm, reflected in an 89% attendance rate. Lecture progress was monitored through attendance records and e-learning logs. E-modules offer efficiency and flexibility, as they are accessible on students' devices and support rich visual content like videos, animations, and 3D models—well-suited for geography education.

Analysis of TPACK competencies of prospective geography teachers based on experience using geospatial technology obtained the results in Table 5.

Table 5. Results of independent sample t-test for TPACK differences based on experience in using geospatial technology

Subscale	Using Geospatial Technology	Mean	SD	p
TK	No	18,386	3,505	< ,001
	Yes	21,568	3,427	
PK	No	20,773	4,697	< ,001
	Yes	23,193	4,458	
CK	No	15,273	3,338	< ,001
	Yes	17,972	2,879	
TPK	No	15,568	3,571	< ,001
	Yes	17,438	3,538	
TCK	No	15,795	3,547	< ,001
	Yes	17,415	3,107	
PCK	No	15,682	3,694	< ,001
	Yes	17,074	3,283	
TPACK	No	15,432	3,729	< ,001
	Yes	17,040	3,417	

Table 5 explains the data analysis of experience using geospatial technology on TPACK competence.

The analysis shows that there are significant differences in all TPACK subscales based on the experience of using geospatial technology ($p<0.05$). Prospective geography teachers who are accustomed to using geospatial technology in doing assignments have higher TPACK competencies when compared to prospective teachers who do not use geospatial technology in the process of doing assignments. The mean value between the two on each subscale shows a fairly high difference.

3.2. Planning

The purpose of developing techno geospatial-based e-modules is to assist prospective geography teacher students in achieving the learning objectives of the general Geomorphology course.

The development of techno geospatial-based e-modules is used to improve the TPACK competencies of prospective geography teachers.

E-modules integrated with techno geospatial improve the skills of prospective teachers in accessing several geospatial applications such as BlenderGIS, QGis, Google Earth, and several techno geospatial websites such as Gistaru, Sigap, Magma Indonesia, INA Geoportal, World Atlas, Earth Observatory, and Open Street Map. Thus, the e-module shows a pattern of material delivery supported by geospatial technology as supplementary visualization.

3.3. Development of Preliminary Form of the Product

1) Techno Geospatial-Based E-Modules

a) Opening Section

i. Title: The title of the techno geospatial-based e-module product developed is "Geomorphology: techno geospatial-based landform studies". The title provides an overview of the material discussed. The cover presentation is a visualization of the title and content of the material. There are visualizations with elements of landforms and geospatial technology on the cover. In addition, the cover is also emphasized by the use of the word "E-Module", complemented by the author's name.

ii. Table of Contents: The table of contents is made more interesting without losing its informative elements. The table of contents has a hyperlink feature that makes it easier for learners to find topics contained in the e-module. Making the table of contents by considering the theories of constructivism and information processing theory. Figure 2 presents the appearance of the table of contents in the techno geospatial-based e-module.

Figure 2. Table of contents display on techno geospatial-based e-module

iii. Information Map: The information map is important to be included as one of the components. The information map presents the relationship between the topics discussed in the e-module. The presentation of the information map on the e-module is made in the form of a hierarchical diagram. The purpose of compiling this component is to be the key in determining the e-module framework in accordance with information processing theory. The interrelationship between materials provides an overview to students in understanding the content. Figure 3 presents the information map included in the techno geospatial-based e-module.

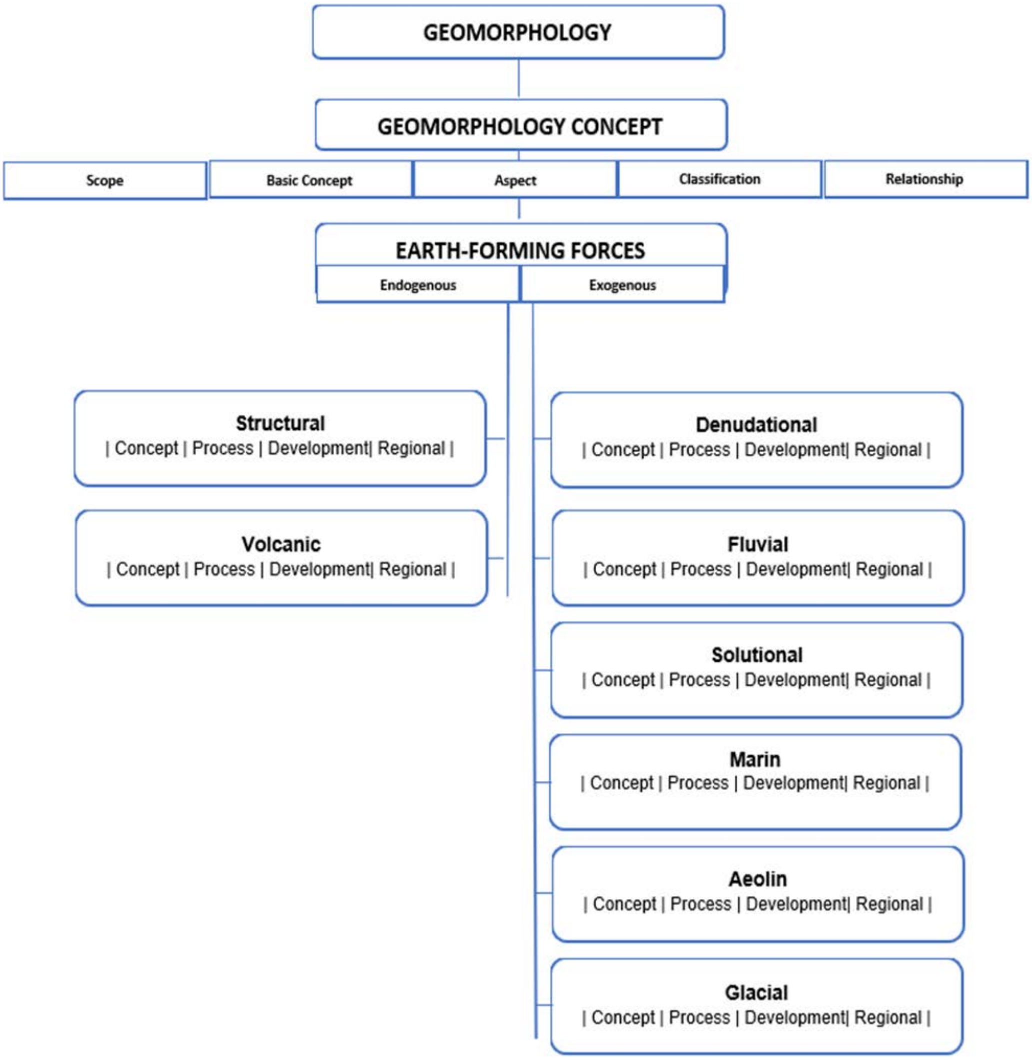


Figure 3. Diagram of material relationship in techno geospatial based e-module

Visualization helps in the organization of information. According to information processing theory, organizing information into meaningful structures is a key step in knowledge formation. Visualization helps students organize information and build relationships between concepts. Visualization can stimulate bottom-up and top-down information processing. At the bottom-up level, students can understand visual details and construct meaning gradually. At the top-down level, visualization can help activate existing cognitive schemas and facilitate connections with prior knowledge.

iv. Objective: The purpose of the e-module is to help students know the course outcomes in the general Geomorphology course. The main objective of this e-module is to introduce geography education students as prospective geography teachers to the main concepts and theories of Geomorphology. This objective is the general objective of the e-module which is described in the objectives of each chapter.

v. Preliminary Test: The initial assessment is crucial for gauging students' baseline knowledge. The initial test is related to general Geomorphology material. The initial test consisted of 20 questions in multiple choice format. Giving the initial test is related to the theory of constructivism. Constructivism theory recognizes that a person has prior knowledge, beliefs, and experiences that shape the way they understand the world. Giving an initial test can be an effective tool in implementing a constructivist approach, allowing lecturers to respond to students' individual needs and understanding as well as creating a learning environment that emphasizes active knowledge building. The distribution of questions in the preliminary test is described in Table 6.

Table 6. Distribution of problem items on the preliminary test

No	Content	Total
1	Geomorphology Concept	2 Item
2	Earth Surface Forming Forces	2 Item
3	Structural	2 Item
4	Volcanic	3 Item
5	Denudational	3 Item
6	Fluvial	3 Item
7	Marin	3 Item
8	Solutional	2 Item

b) Core Section (for each material)

i. Introduction: An introduction can provide context that helps students process information more effectively. It creates a foundation for the delivery of subsequent information, facilitates better understanding and follows the principles of information processing theory.

ii. Objective: The objectives outlined in this section are the objectives of each material or chapter. In accordance with the theory of constructivism, the delivery of goals is intended to provide direction to find solutions or understanding of a topic, activating students' cognitive processes in designing strategies to achieve these goals.

iii. Material Description: In the context of information processing theory, visualization helps simplify the complexity of information and allows the brain to more effectively process and understand the material. The determination of geospatial applications and websites is adjusted to the characteristics of the material. The utilization of geospatial technology is presented in Table 7.

Table 7. List of geospatial technology utilization

No	Chapter	Format	Apk/Web
1	Geomorphology Concept	Video	Google Earth
		Video	Google Earth
2	Earth-forming forces	Video	Natural Earth
		Video	World Atlas
3	Structural	3D Model	Blender
		Video	YouTube
4	Volcanic	3D Model	Blender
		Video	Magma Indonesia
5	Denudational	Video	Open Street Map
		Video	Blender GIS
		Video	YouTube
6	Fluvial	Video	Google Earth
		Video	YouTube
7	Marin	Video	Google Earth
		Video	Contextual
8	Solutional	Video	YouTube
9	Aeolian	Video	Earth Observatory
		Video	Google Earth
10	Glacial	Video	YouTube
		3D Model	Blender

The sequence of materials is arranged systematically by utilizing geospatial technology as tools to support the TPACK competencies of prospective geography teachers. The choice of geospatial technology, whether for applications or websites, is tailored to align with the specific characteristics of the material.

iv. Formative Test: The formative test consists of ten multiple choice items and four description questions. Through the use of formative tests that are in line with the principles of constructivism, lecturers can facilitate more active, relevant and personalized learning.

v. Task: The assignments were done collaboratively by the prospective geography teacher students. Table 8 presents the integration of geospatial technology in the assignment.

Table 8. Geospatial technology integration on assignment

No	Chapter	Geospatial Technology
1	Geomorphology Concept	Google Earth Pro
2	Earth Surface Forming Forces	Ina Geoportal
3	Structural	Blender-GIS
4	Volcanic	MAGMA Indonesia
5	Denudational	SIGAP KLHK
6	Fluvial	Google Earth Pro & QGIS
7	Marin	Research Based Outdoor Learning
8	Solutional	Gistaru ATR/BPN
9	Aeolin	Whitebox tools
10	Glacial	Google Earth Engine/Timelapse

vi. Summary: The process of reading summaries invites students to synthesize and reorganize information. Constructivism emphasizes the importance of students constructing their own knowledge through rearranging and organizing information, and summary reading is a step in this process.

c) Closing Section

i. Glosarry: Glossaries can be used as a tool to develop knowledge. Information processing theory suggests that learning involves the growth of knowledge that can be integrated into existing knowledge structures.

ii. Final Test: The material tested in the final test is related to general Geomorphology material. The final test consists of 20 questions in multiple-choice format. Although the final test is generally considered a summative assessment, formative elements can be included, such as providing feedback throughout the semester or providing opportunities for correction and re-understanding. Distribution of question items on the final test is described in Table 9.

Table 9. Distribution of question items on the final test

No	Chapter	Total
1	Geomorphology Concept	2
2	Earth Surface Forming Forces	2
3	Structural	3
4	Volcanic	3
5	Denudational	1
6	Fluvial	1
7	Marin	3
8	Solutional	2
9	Aeolin	2
10	Glacial	1

iii. Index: Providing an index allows readers to create a personal context by finding information that is most relevant to their needs or interests. This is in line with the concept of constructivism, which values personal experience as the basis for knowledge construction.

iv. References: The bibliography consists of book sources and scientific articles that have been published both at the national and international levels. Reference writing uses the American Psychological Association (APA) standard. Providing a bibliography allows readers to explore sources that support their own learning, taking an active role in developing their understanding.

The conceptual model of techno geospatial-based e-module development consists of 7 categories or 19 sub-categories. These categories include organization with sub-categories of organization and format category consisting of sub-categories of content and assignment. The organization and format categories refer to the Department of Education 2008. The third category is relevance which consists of sub categories of relationships between chapters and further reading that refer to the theory of constructivism.

The fourth category is the TPACK framework components. The fifth category is techno geospatial which consists of sub-categories of websites and applications. The sixth category is quality with sub-categories of material, instructional design, media, and language. While the seventh category is comprehension with sub-categories of main ideas of discourse.

In summary, the conceptual model of techno geospatial-based e-modules is presented in Figure 4.

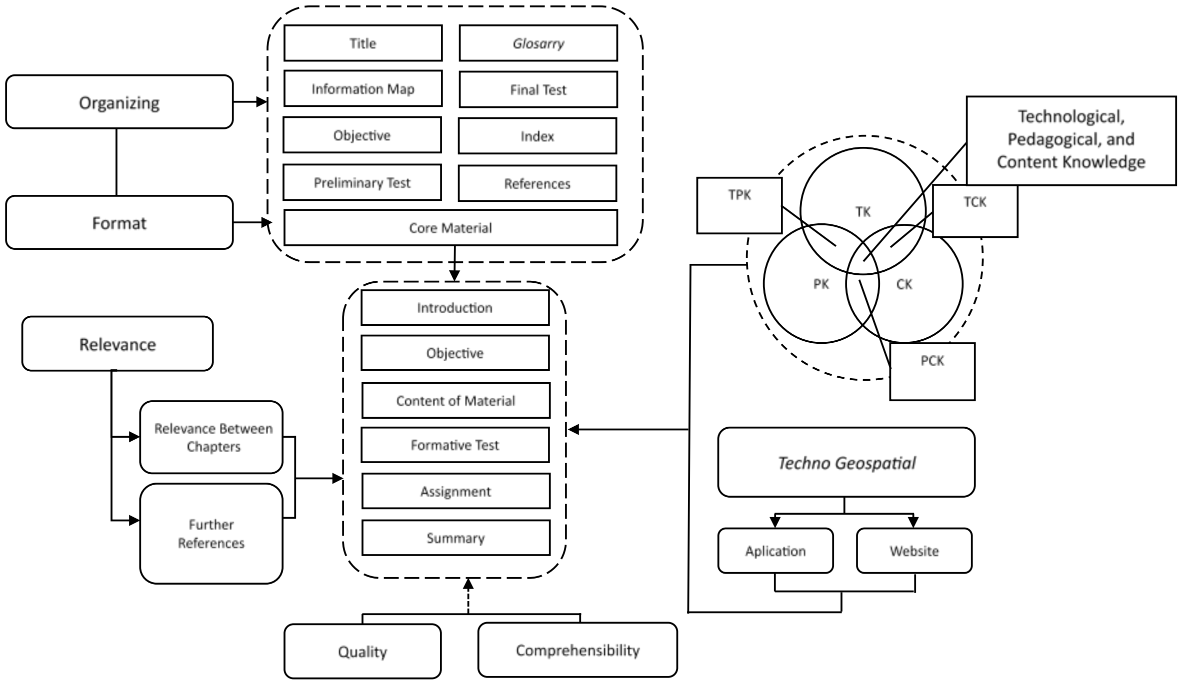


Figure 4. Conceptual model of techno geospatial-based e-module

2) Instrument

At this stage, the preparation of several instruments needed in RnD is carried out, namely instruments to measure the quality of e-modules and the understandability of e-modules used during the initial field test.

a) Validity of the TPACK Competency Self-Report Measure Instrument: The validity test was conducted by TPACK expert validators in the field of geography. The results of expert validation stated that the survey items were constructively appropriate for measuring self-report measures of TPACK competence of prospective geography teachers. Table 10 presents the data from the TPACK instrument validation results.

Table 10. TPACK instrument validation data

No	Aspect	Score
1	Suitability of questions with research objectives	4
2	Clarity of instrument instructions	4
3	Clarity of the purpose of the question	3
4	The possibility that the instrument can be completed	3
5	The suitability of the language used in the question in accordance with Indonesian language rules	4
6	Sentences do not contain double meanings	3
7	Sentence formulation is simple and easy to understand	3
Average		3,43

Based on Table 10, the self-report measure instrument of TPACK competence received a score of 3.43 on a scale of 4. Thus, the instrument can be used in the data collection process of TPACK competence of prospective geography teachers.

b) Reliability of the TPACK Competency Self-Report Measure Instrument

Table 11. Reliability of the self-report measure of TPACK competence

No	Component	***Alpha Cronbach's***
1	Technological Knowledge	0.840
2	Pedagogical Knowledge	0.920
3	Content Knowledge	0.870
4	Technological Pedagogical Knowledge	0.912
5	Technological Content Knowledge	0.861
6	Pedagogical Content Knowledge	0.903
7	TPACK	0.920

Table 11 displays the results of the reliability test for the self-report measure of TPACK competence. The reliability coefficient, assessed using Cronbach's alpha, evaluates the consistency of a set of items within the study. All survey components had Cronbach's alpha values exceeding the general recommended value of 0.7. Therefore, all items on the self-report measure of TPACK competence were found to be reliable.

3.4. Preliminary Field Testing

1) Quality Test

The quality of the geospatial technology-based e-modules plays a critical role in this research and development process. To evaluate the quality of the developed e-module, the researchers conducted a comprehensive quality assessment, involving four experts from different fields: geography content, instructional design, learning media, and language.

Table 12. Material expert validation test results

No	Indicator	Score	Suggestion
1	The suitability of the material with the course outcome	4	The accuracy of the images in the e-module needs to be sharpened, and communication should use language that is easier to understand.
2	The accuracy of the content	3,57	
3	Supplementary learning materials	3,83	
4	Up-to-date material	4	
Average		3,85	

Table 12 presents the average rating of 3.85 (out of a maximum score of 4) for the techno-geospatial-based e-module, as assessed by material experts. This indicates that the material aspect of the e-module is highly aligned with the course objectives, demonstrates accuracy, includes relevant supplementary materials, and reflects up-to-date content. As a result, the e-module meets the necessary criteria to be considered a valuable learning resource.

Table 13. Instructional design expert validation test results

No	Indicator	Score	Suggestion
1	Presentation	3,79	Suitability of formative tests and assignments according to the characteristics of the material
2	Instructional	3,83	
3	Characteristics	3,78	
Average		3,80	

Table 13 shows the average score of the assessment of techno geospatial-based e-modules by instructional design experts is 3.80 with a maximum score of 4. This means that the instructional design aspects of techno geospatial-based e-modules have a very high level of presentation, suitability for learning, and e-module characteristics, so they are eligible for use as learning support.

Table 14. Media expert validation test results

No	Indicator	Score	Suggestion
1	Software introduction-Ease of use	4	Increase visualization, pay attention to student needs, face validity, show the novelty of e-modules, e-module principles, self-learning settings.
2	Software introduction-Display	3,46	
3	E-module dimensions	4	
4	E-module cover design	3,91	
5	E-module layout	3,80	
Average		3,83	

Table 14 shows the average rating of 3.83 (out of a maximum score of 4) for the techno-geospatial-based e-module, as evaluated by media experts. This indicates that the media aspects of the e-module—such as software usability, interface design, size, cover design, and content layout—are highly effective, making the developed product well-suited for use as a learning tool.

Table 15. Results of the language expert validation test

No	Indicator	Score	Suggestion
1	Straightforward	3,67	Increase visualization to support information completeness
2	Communicative	4	
3	Interactive and dialogic	4	
4	Suitability for the learner's developmental level	4	
5	Clarity and coherence of the reasoning or flow of ideas	4	
6	Use of terms, symbols, and icons	3,5	
Average		3,86	

Based on Table 15, the average score of the techno geospatial-based e-module assessment by linguists is 3.86 with a maximum score of 4. This means that the language aspect of the techno geospatial-based e-module has met the requirements as material with a good sentence structure in language. Based on these results, the developed product is qualified to be used as learning support.

2) Comprehension Test: The comprehension test was conducted on a limited basis by giving it to 12 geography students at Universitas Negeri Padang. The comprehension test of the techno geospatial-based e-module was carried out with the discourse main idea instrument.

Table 16. Discourse main idea test

Chapter	Percentage	Category
I	87,00	High
II	85,83	High
III	83,17	High
IV	84,00	High
V	78,83	High
VI	80,75	High
VII	77,92	High
VIII	80,17	High
IX	77,08	High
X	75,17	High
Average	80,99	High

From the results of the evaluation of the main idea of the discourse, presented in Table 16, it can be seen that the analysis of the main idea of the discourse in each part of the techno geospatial-based e-module reaches the high category. This is reflected in the average percentage value of each component, which exceeds 60 based on Rankin and Culhane's (1992) criteria. Overall, the average percentage value for all components is also in the high category, reaching 80.99.

In the supporting sentence test, students were asked to read and write down information that supports the main idea of each discourse. The recapitulation of the test analysis can be found in Table 17.

Table 17. Supporting sentence test

Chapter	Percentage	Category
I	87,08	High
II	84,83	High
III	82,83	High
IV	83,67	High
V	79,50	High
VI	78,67	High
VII	76,50	High
VIII	78,67	High
IX	77,00	High
X	75,67	High
Average	80,44	High

Table 17 presents the data from the test analysis of the supporting information for the main idea in each component, which shows results in the high category. Similarly, the average percentage value for all components is also in the high category, reaching 80.44. The results of the evaluation of the clarity of the techno geospatial-based e-module on the discourse main idea test and the discourse main idea supporting information test on landform study can be found in Figure 5.

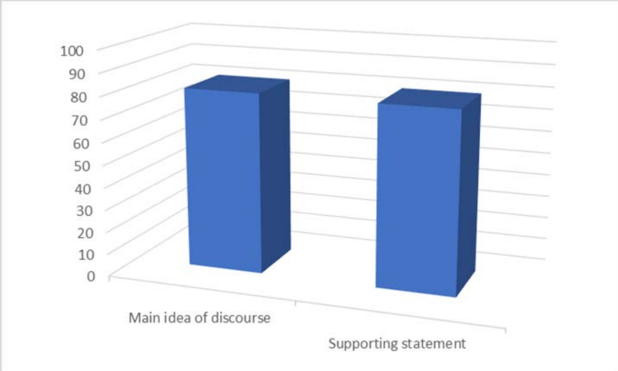


Figure 5. Average percentage of comprehension test

The results of the evaluation of understanding conducted on students related to the main idea of discourse and supporting information show that the average percentage value is in the high category. The conclusion of the comprehension evaluation of the entire e-module design that has been developed is that the material can be well understood by geography students. A good level of comprehension can be stated if the material can be easily understood by the reader.

The evaluation of understanding shows that there are still some terms that are not recognized by students, which may affect the understanding of the paragraph. Therefore, it is necessary to revise the book to make it more understandable to readers, especially students or prospective geography teachers. Information regarding the description of terms that have not been recognized by students can be found in Table 18 based on the results of the comprehension evaluation.

Table 18. Unrecognized terms

No.	Unrecognized terms
1	*Scoria*
2	*Coastal dunes*
3	*Residu*
4	*Stratigrafi*
5	*Dikes*
6	*Washload*
7	*Diaklas*

The comprehension test found that there were sentences that were difficult for students to understand, so revisions were needed to the techno geospatial-based e-module that had been developed. Information related to the description of sentences that become obstacles in student understanding can be found in Table 19.

Table 19. Sentences that are difficult to understand

No.	Sentences are difficult to understand
1	Geomorphology is about the processes that change the Earth's surface, the study of how erosion (land subsidence) and uplift (land elevation) work together over the long term. (chapter 2)
2	The result of the subduction resulted in the appearance of volcanoes on Flores Island and the formation of the Melange on Timor (chapter 3).
3	Therefore, the cause is the process of organisms, namely animals, plants and humans (chapter 5).
4	This landscape is formed by the formation of wind processes (aeolin) and the combination of weathering with water flow (chapter 9).

3.5. Main Product Revision

Overall, the results of the quality test by four validators stated that the techno geospatial-based e-module developed was classified as very good and very feasible, improvements were still needed based on suggestions and input from the validators as part of the product improvement process. A description of the suggestions and improvements given by the validators is presented in Table 20.

Table 20. Description of quality test suggestions and Improvements

No.	Component	Suggestion	Revision result
1	Material	The accuracy of the images in the e-module needs to be sharpened, and communication should use language that is easier to understand.	• Using images that are more in line with the explanation of the material. • Change the language to be easier to understand.
2	Instructional Design	The suitability of formative tests and assignments according to the characteristics of the material.	• Formative tests are customized based on the material per chapter.
3	Media	Increase visualization, pay attention to student needs, face validity, show new things from e-modules	• Adding further reading sections and links between chapters. • Providing a background on the e-module content page.

Based on the results of the understandability test, the techno geospatial-based e-module draft is included in the high category, which means that the e-module draft is very feasible to use.

The following is a description of the improvement of unrecognized terms and sentences that are difficult to understand based on the results of the understandability test in Table 21.

Table 21. Description of improvements to unrecognized terms and difficult to understand sentences

No.	Unrecognized term	Revision
1	*Scoria*	Add the word/term to the glossary section. So that readers will find an explanation and understand the word/term.
2	*Coastal dunes*	
3	*Residu*	
4	*Stratigrafi*	
5	*Dikes*	
6	*Washload*	
7	*Diaklas*	
No	**Sentences that are difficult to understand**	**Revision**
1	Geomorphology is about the processes that change the Earth's surface, including how erosion occurs (land reduction) and uplift (land elevation) work together over the long term (chapter 2).	Geomorphology involves understanding how erosion (soil erosion) and uplift (land rise) work together to change the Earth's surface over the long term.
2	The result of the subduction resulted in the appearance of volcanoes on Flores Island and the formation of the Melange on Timor (chapter 3).	The result of the subduction led to the appearance of volcanoes on Flores Island and the formation of the Melange on Timor.
3	Therefore, the cause is the process of organisms, namely animals, plants and humans (chapter 5).	The agents of biological weathering processes are organisms, including animals, plants and humans.

3.6. Main Field Testing

This step is a test process carried out on products that have been revised in the previous step. This test was conducted by looking at the effectiveness of techno geospatial-based e-modules with pseudo experiments. The operational field test was conducted in four classes consisting of one experimental class and one control class. The classes used as research samples were classes A, B, and D as experimental classes and class C as a control class. Class A with 30 students was named experimental class 1, class B with 29 students was named experimental class 2, and class D with 16 students was named experimental class 3.

This effectiveness test uses a nonequivalent control group. Pretest was conducted to determine the initial data of technological, pedagogical, and content knowledge of prospective geography teachers. After that, treatment was given by implementing learning by utilizing techno geospatial-based e-modules to prospective geography teacher students in the experimental class. While in the control class, learning is carried out without using techno geospatial-based e-modules.

After the treatment, researchers gave a posttest to determine the technological, pedagogical, and content knowledge of geography after learning using techno geospatial-based e-modules.

1) Experimental Class Learning Results:

The results of the pretest and posttest self-report measures of TPACK competence in the experimental class can be seen in Table 22.

Table 22. Results of pretest and posttest self-report measures of TPACK competence of experimental classes

Class	***Pretest***			***Posttest***		
	Minimum Score	**Maximum Score**	**Average**	**Minimum Score**	**Maximum Score**	**Average**
Experiment 1	68,33	81,11	73,89	85,00	92,78	89,72
Experiment 2	68,33	77,78	72,49	85,00	90,56	87,93
Experiment 3	71,67	80,56	74,41	84,44	88,89	86,67

Based on the data in Table 22, it can be seen that there is a significant increase in the self-report measure of TPACK competence between the average value before treatment and after treatment.

The increase occurred significantly in each TPACK component. The following is the average value per TPACK component of the Experimental Class on the self-report measure of TPACK competence.

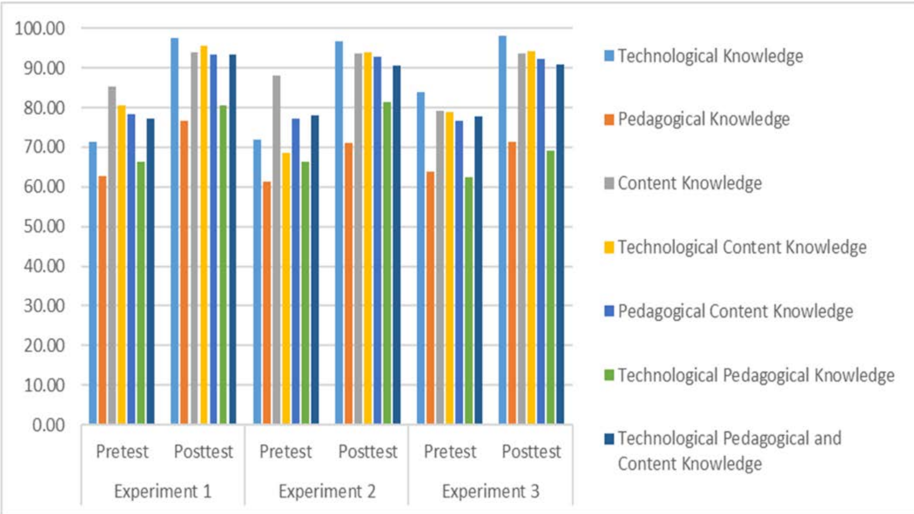


Figure 6. Average score per competency of TPACK self-report measure experiment class 1, 2, 3

Based on Figure 6, it is known that all TPACK components on the self-report measure increased significantly in all experimental classes. The technological knowledge component is the component that has the highest posttest value. The technological content knowledge component has the second highest posttest value. Meanwhile, pedagogical knowledge was the component with the lowest posttest value.

During the four meetings in the operational field test, prospective geography teacher students also filled out formative tests in chapters 3, 4, and 5. The following are the results of the operational field test formative tests in the experimental class presented in Figure 7.

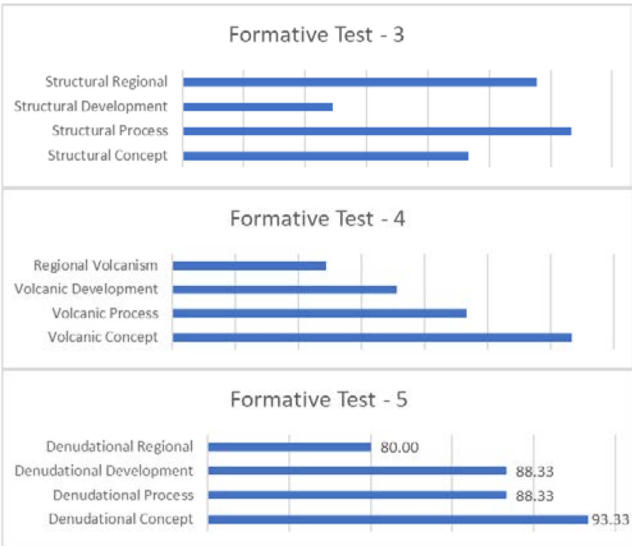
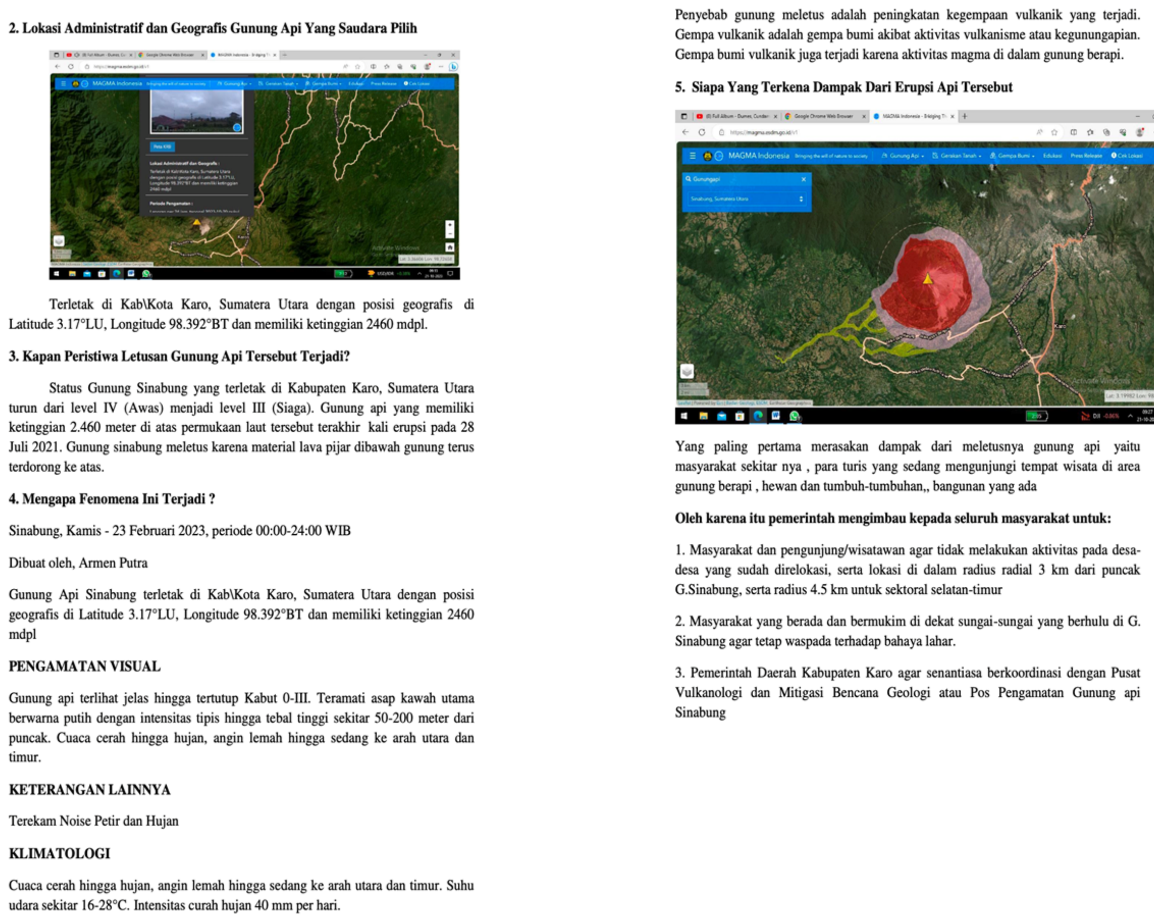


Figure 7. Formative test results of operational field test of experimental class

Based on Figure 7, it can be seen that the formative test results in the operational field test obtained an average result of 86.81 for formative test 3, an average of 86.25 for formative test 4, and 87.50 for formative test 5. These results indicate the success of learning content in the experimental class.

Here is an example of working on the assignment in the techno geospatial-based e-module by one of the prospective geography teacher students. Example of Assignment Results are shown in Figure 8.


2. Lokasi Administratif dan Geografis Gunung Api Yang Saudara Pilih

Terletak di Kab\Kota Karo, Sumatera Utara dengan posisi geografis di Latitude 3.17°LU, Longitude 98.392°BT dan memiliki ketinggian 2460 mdpl.

3. Kapan Peristiwa Letusan Gunung Api Tersebut Terjadi?

Status Gunung Sinabung yang terletak di Kabupaten Karo, Sumatera Utara turun dari level IV (Awas) menjadi level III (Siaga). Gunung api yang memiliki ketinggian 2.460 meter di atas permukaan laut tersebut terakhir kali erupsi pada 28 Juli 2021. Gunung sinabung meletus karena material lava pijar dibawah gunung terus terdorong ke atas.

4. Mengapa Fenomena Ini Terjadi ?

Sinabung, Kamis - 23 Februari 2023, periode 00:00-24:00 WIB

Dibuat oleh, Armen Putra

Gunung Api Sinabung terletak di Kab\Kota Karo, Sumatera Utara dengan posisi geografis di Latitude 3.17°LU, Longitude 98.392°BT dan memiliki ketinggian 2460 mdpl

PENGAMATAN VISUAL

Gunung api terlihat jelas hingga tertutup Kabut 0-III. Teramati asap kawah utama berwarna putih dengan intensitas tipis hingga tebal tinggi sekitar 50-200 meter dari puncak. Cuaca cerah hingga hujan, angin lemah hingga sedang ke arah utara dan timur.

KETERANGAN LAINNYA

Terekam Noise Petir dan Hujan

KLIMATOLOGI

Cuaca cerah hingga hujan, angin lemah hingga sedang ke arah utara dan timur. Suhu udara sekitar 16-28°C. Intensitas curah hujan 40 mm per hari.

Penyebab gunung meletus adalah peningkatan kegempaan vulkanik yang terjadi. Gempa vulkanik adalah gempa bumi akibat aktivitas vulkanisme atau kegunungapian. Gempa bumi vulkanik juga terjadi karena aktivitas magma di dalam gunung berapi.

5. Siapa Yang Terkena Dampak Dari Erupsi Api Tersebut

Yang paling pertama merasakan dampak dari meletusnya gunung api yaitu masyarakat sekitar nya , para turis yang sedang mengunjungi tempat wisata di area gunung berapi , hewan dan tumbuh-tumbuhan,, bangunan yang ada

Oleh karena itu pemerintah mengimbau kepada seluruh masyarakat untuk:

1. Masyarakat dan pengunjung/wisatawan agar tidak melakukan aktivitas pada desa-desa yang sudah direlokasi, serta lokasi di dalam radius radial 3 km dari puncak G.Sinabung, serta radius 4.5 km untuk sektoral selatan-timur

2. Masyarakat yang berada dan bermukim di dekat sungai-sungai yang berhulu di G. Sinabung agar tetap waspada terhadap bahaya lahar.

3. Pemerintah Daerah Kabupaten Karo agar senantiasa berkoordinasi dengan Pusat Vulkanologi dan Mitigasi Bencana Geologi atau Pos Pengamatan Gunung api Sinabung

Figure 8. Example of assignment results

2) Control Class Learning Result:

The results of the pretest and posttest self-report measures of TPACK competence of the control class are presented in Table 23.

Comparison of pretest and posttest self-report measure scores in the control class that did not use techno geospatial-based e-modules can be seen in Figure 9.

Table 23. Results of pretest and posttest self-report measure of TPACK competence of control class

Class	*Pretest*			*Posttest*		
	Minimum Score	Maximum Score	Average	Minimum Score	Maximum Score	Average
Control	68,33	81,11	74,39	73,89	83,89	78,91

Figure 9. Comparison of pretest and posttest self-report measure of TPACK competency of control class

Based on the data in Figure 9, there was an increase in the mean scores of the pretest and posttest, but the increase was not significant, or in other words, there was only a slight increase in both tests. The average value per TPACK component on the self-report measure of TPACK competence is presented in Figure 10.

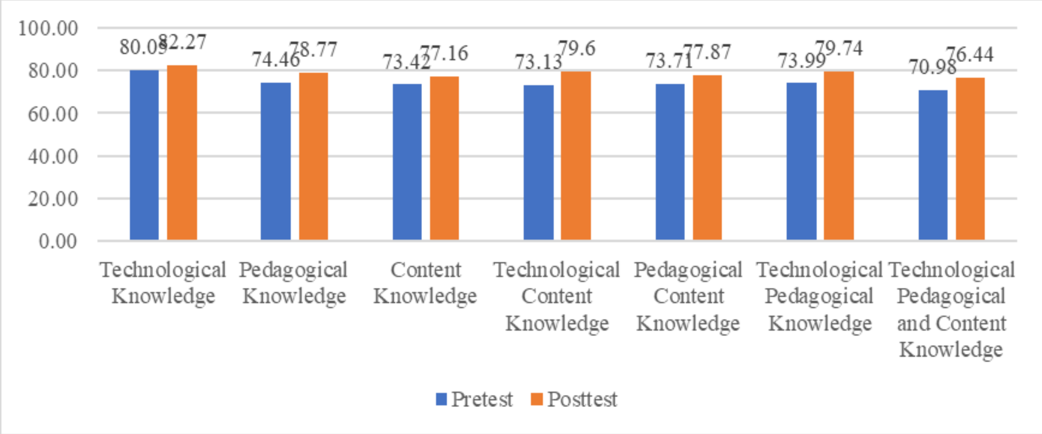


Figure 10. Average score per component of TPACK self-report measure for control class

Based on Figure 10, it is known that all TPACK components on the self-report measure have increased. The increase was not significant. The technological knowledge component is the component that has the lowest increase with a difference of only 2.22.

3) Normalized Gain Test:

Based on the results of the pretest and posttest in the experimental class and control class, the average gain value was obtained. The increase in self-report measure of TPACK competence of prospective geography teachers and in each class has a difference.

Table 24. N-Gain data of self-report measure of TPACK competence of experimental and control classes

No	Class	N	N-Gain Average	Category
1	Experiment 1	30	0,61	Medium
2	Experiment 2	29	0,56	Medium
3	Experiment 3	16	0,48	Medium
4	Control	29	0,17	Low

From Table 24, it can be seen that there are differences in the average value of gain. Experimental classes that use geospatial techno-based e-modules obtained an average gain value of 0.61 in experimental class 1 with a medium category, 0.56 in experimental class 2 with a medium category, and 0.48 in experimental class 3 with a medium category, while the control class that did not use geospatial techno-based e-modules only obtained an average gain value of 0.17 with a low category.

4) Statistical Assumption Test

Table 25. Normality test results of self-report data on TPACK competency measures

Data	Kolmogorov-Smirnov (Z)		H_0	Conclusion	
	Statistik	Sig.		Normality	Statistical test
Experiment 1	0,103	0,200	Accepted	Normally Distributed Data	Parametric: Independent-Sample t test
Experiment 2	0,156	0,069	Accepted		
Experiment 3	0,213	0,050	Accepted		
Control	0,158	0,062	Accepted		
	Shapiro-Wilk				
	Statistik	Sig.			
Experiment 1	0,967	0,467	Accepted		
Experiment 2	0,926	0,042	Rejected		
Experiment 3	0,923	0,192	Accepted		
Control	0,935	0,074	Accepted		

As shown in Table 25, the Sig. (2-tailed) value for the n-gain of experimental classes 1, 2, and 3, as well as the control class, is greater than the 0.05 significance level, indicating that the null hypothesis (H0) is accepted.

In other words, the data follows a normal distribution. The hypothesis test employed is the parametric Independent-Sample T-test.

Table 26. Homogeneity test results of self-report measure of TPACK competence

Data	Statistik Levene	Df 1	Df 2	Sig.	H_0	Homogeneity	Statistical test
Experiment 1 Experiment 2 Experiment 3 (With Control Class)	1,778 3,373 2,009	1 1 1	57 5643	0,188 0,072 0,164	Accepted	Data variance is homogeneous	Parametric: Independent-Sample t test

Based on Table 26, it can be seen that the results of the Test of Homogeneity of Variance for experimental classes using techno geospatial-based e-modules and control classes that do not use techno geospatial-based e-modules obtained a significance value of 0.188 for experimental class 1, 0.072 for experimental class 2, 0.164 for experimental class 3, so H0 is accepted because it is greater than α = 0.05. The calculation results show that the data variance is homogeneous, thus the hypothesis test used is the parametric Independent-Sample T-test.

5) Statistical Test:

Referring to the results of normality and homogeneity testing of the n-gain self-report measure of TPACK competence in the experimental and control classes, the next step is hypothesis testing on the data obtained. Normality and homogeneity tests determine the use of statistical tests used in hypothesis testing. Hypothesis testing was carried out with the help of SPSS version 22 for windows and Microsoft Excel 2019. The hypothesis tested is as follows:

Ho: No difference in TPACK self-reports between users and non-users of techno geospatial e-modules.

Ha: There is a difference in TPACK self-reports between users and non-users of techno geospatial e-modules.

Hypothesis decision making is if the significance level α < 0.05 and the value of t count> from t table then Ha is accepted and Ho is rejected.

Table 27. Independent-sample t-test results hypothesis 2

Data	t	df	Sig. (2-tailed)
N-Gain of Experiment Class 1 and Control Class	26,727	57	0,000
N-Gain of Experiment Class 2 and Control Class	27,242	56	0,000
N-Gain of Experiment Class 3 and Control Class	16,933	43	0,000

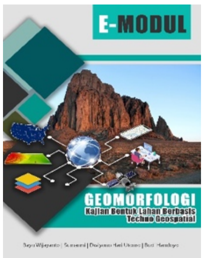
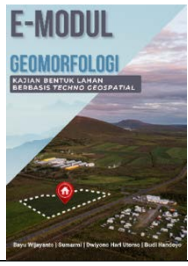
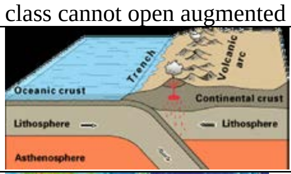
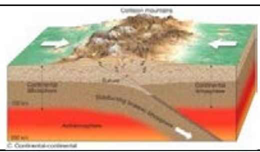
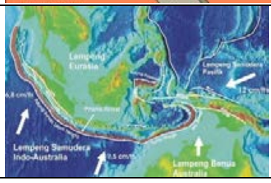
The results of hypothesis testing using SPSS software version 22 for windows in Table 27 of the Independent-Sample t test results show that the experimental class 1 the calculated t value is 26.727 with a degree of freedom (df) of 57 (t Table = 2.002465) and a sig value. (2-tailed) of 0.000. Experimental class 2 the magnitude of the t value is 27.242 with degrees of freedom (df) of 56 (t Table = 2.003241) and a sig value. (2-tailed) of 0.000. Experimental class 3 the t value is 16.933 with a degree of freedom (df) of 43 (t Table = 2.016692) and a sig value. (2-tailed) of 0.000.

The significance level α=0.05, it can be seen that the sig. (2-tailed) is smaller than α or 0.05> 0.000. This means that the results of hypothesis testing are H0 rejected and Ha accepted. It can be concluded that there is a difference in the self-report measure results of prospective geography teachers in classes that use techno geospatial-based e-modules with classes that do not use techno geospatial-based e-modules.

3.7. Operational Product Revision

Based on the results of the main field test, there are several things that need to be revised on the techno geospatial-based e-module as a result of input from observers and team teaching related to the cover, obstacles in the device used by students, and clarity of images, as well as changes in pedagogical aspects. At this stage, revisions were made to the techno geospatial-based e-module product presented in Table 28.

Table 28. Operational product revision list

No	Aspect	Before Revision	After Revision
1	Cover		
2	Device	Device limitations in the experimental class cannot open augmented reality.	The augmented reality visualization is converted into a 3D model.
3	Chapter 1 Picture		
4	Chapter 2 Picture		
5	Component of *technological pedagogical knowledge*	It is necessary to add activities or assignments that lead to the preparation of prospective geography teachers in the technological pedagogical knowledge component.	Adding learner activities to the technological pedagogical knowledge component, namely in chapter 2 of the assignment section: As a prospective geography teacher, you are required to be able to utilize technology in learning, one of which is in developing learning media on Geomorphology studies.

4. Discussion

Lesson plans, which are included in the curriculum documents, show that technology is not integrated into learning. This suggests a new finding that there is a gap between the competencies that prospective geography teachers or geography education students should have and the learning activities. This finding is supported by previous research that identified the lack of teacher resources as a limitation in the application of geospatial technology in education [17], [18]. Scholars set out the necessary aspects of a modern learning system after studying the current global exposure and the forced acceleration caused by the pandemic in 2020 [19]. Globally, the use of ICT in education has grown rapidly [20]. Prospective geography teachers who understand geospatial technology have better cognitive capacity [21]. Prospective geography teachers who are able to combine technical skills with pedagogical and field knowledge are those who meet the expectations of today's education [22].

Geospatial techno-based e-modules link topics by providing an integrated perspective of landforms on the Earth's surface through the use of geospatial technology. Research on applying geospatial technologies to explore Earth and environmental sciences in classroom settings has demonstrated their effectiveness in enhancing students' understanding of complex scientific concepts related to Earth and the environment [23].

Geospatial technology such as online three-dimensional (3D) maps can be used to more easily understand the environment on earth. Geospatial technology such as online three-dimensional (3D) maps can be used to more easily understand the environment on earth [24], [25].

Geography learning requires students to actively engage in demonstrating, manipulating, analyzing, and synthesizing spatial data to build their knowledge, rather than simply passively receiving information [26]. Geospatial technology provides a more interactive approach to learning in geography [27], learners can use geospatial technologies to explore, query, manage, manipulate, analyze, and interpret spatial data across various geographic scales, with educators and technology serving as guides to facilitate and enhance their learning outcomes [28].

Several studies have developed e-modules using Flip PDF Professional as the software [29], [30]. Techno geospatial-based e-modules are developed using newer software with more features than Flip PDF Professional, namely Flip PDF Corporate Edition. The most widely used geospatial technology feature in techno geospatial-based e-modules is the use of Google Earth. Research from [25], [31] stated that the use of Google Earth in teaching geography increases geography awareness, critical thinking, analysis and questioning skills.

Students need teaching materials that are effective, flexible, interesting, and not boring, equipped with images, animations, videos, and audio [32]. The quality of geospatial technology books needs to be considered because it can affect the understanding of the material described [33]. The results of the evaluation of comprehension carried out on students related to the core of the discourse and explanations that support the core of the discourse show that the average percentage is at a high level.

From primary education programs to higher education programs, there are many lessons related to the use of computers and the internet at various levels [34]. Students are millennials who have the ability to quickly keep up with technological changes [11]. Geography education at university aims to produce creative and innovative future teachers in geography [35]. It is important to understand how to plan and implement teaching programs to balance students' pedagogical and technological knowledge. As many educational programs are inefficient, student teachers have difficulty connecting technology, pedagogy and content knowledge with each other [36].

Current education is marked by technological updates, with augmented reality (AR) as an innovative technique [37] that bridges the physical environment and the virtual world by converting everyday objects into 3D digital elements that can be interacted with through mobile devices. Geospatial technology is particularly useful for geography education but also plays an important role in other subjects [38]. Geospatial technology can be incorporated into geography, but also other fields of science or social science [38]. Geospatial technology offers a range of dynamic mapping tools that can be utilized as effective learning resources in educational environments [17].

The comparison of the increase in n-gain value is quite far between classes that use techno geospatial-based e-modules and classes that do not use techno geospatial-based e-modules. The n-gain scores for all classes using techno-geospatial-based e-modules on the self-report measure of TPACK competence fall within the medium category. In contrast, classes that did not use these e-modules were classified in the low category. Teacher candidates who recognized the significance of TPACK in all classroom activities involving technology highlighted the growing integration of technology in school curricula, the crucial role of technology in globalization, and the negative impact of insufficient technological and pedagogical knowledge on the learning process [39]. The use of technology can positively impact the effectiveness and outcomes of geography learning [40].

The technological knowledge component is the component that has the lowest increase. Teachers need to be both confident and proficient in using technology effectively with their students [33]. To encourage teachers to integrate technology into the classroom, it is essential to offer strong support and guidance, such as providing examples of technology-enhanced lesson plans and content-specific, technology-integrated teaching strategies [41]. TPACK must be owned and mastered in order to be effective in learning [42]. The use of technology helps to make abstract geography concepts more concrete and accessible. As a result, geography teachers have a responsibility to innovate in their teaching methods, making the subject more engaging and tangible for students [12].

The use of geospatial technology has proven effective in supporting geography learning [43]. Prospective geography teachers who have good TPACK competencies are an important need [44] because they can effectively integrate technology into their teaching [45]. Geospatial technologies are causing a digital revolution in geography education and making it possible to better understand the world and find solutions to geographic problems by enhancing their 21st century skills [46].

5. Conclusion

The techno geospatial-based e-module that has been developed is proven to be very feasible and effective in improving the TPACK competencies of prospective geography teachers. The findings contribute to techno geospatial-based e-module development techniques to prepare for 21st century skill needs. This study also contributes to the development of geography science. Digital technology provides numerous opportunities to enhance geography education, with geospatial technology playing a key role in improving the teaching of geography. Measuring the TPACK competencies of prospective geography teachers can improve future teacher education and professional development of geography teachers. Several institutions provide various GIS workshops for teachers. Most of these workshops focus on improving teachers' GIS technology skills. Pedagogical training integrated with learning and field experience through appropriate instructional design and constructionist activities to advance teachers' and prospective teachers' TPACK competencies is necessary. Teachers should change their teaching style from traditional learning approaches to effective ones with the use of technology. Without proper teacher professional development, the application of geospatial technology to students in the classroom, especially in high-needs school settings, is unlikely to succeed.

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References:

[1]. Marzano, R. J., & Heflebower, T. (2012). *Teaching & assessing 21st century skills. The Classroom Strategies Series*. Marzano Research Laboratory.

[2]. Chai, C. S., et al. (2011). Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, *57*(1), 1184-1193. Doi: 10.1016/j.compedu.2011.01.007

[3]. Mouza, C., et al. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education*, *71*, 206–221. Doi: 10.1016/j.compedu.2013.09.020

[4]. Tondeur, J., et al. (2017). A comprehensive investigation of TPACK within pre-service teachers' ICT profiles: Mind the gap!. *Australasian Journal of educational technology*, *33*(3). Doi: 10.14742/ajet.3504

[5]. Akyuz, D. (2018). Measuring technological pedagogical content knowledge (TPACK) through performance assessment. *Computers & Education*, *125*, 212-225. Doi: 10.1016/j.compedu.2018.06.012

[6]. Baya'a, N., & Daher, W. (2015). The development of college instructors' technological pedagogical and content knowledge. *Procedia-Social and Behavioral Sciences*, *174*, 1166-1175. Doi: 10.1016/j.sbspro.2015.01.733

[7]. Reyes Jr, V. C., et al. (2017). Integrating ICT into teacher education programs from a TPACK perspective: Exploring perceptions of university lecturers. *Computers & Education*, *115*, 1-19. Doi: 10.1016/j.compedu.2017.07.009

[8]. Scherer, R., et al. (2018). The importance of attitudes toward technology for pre-service teachers' technological, pedagogical, and content knowledge: Comparing structural equation modeling approaches. *Computers in Human Behavior*, *80*, 67-80. Doi: 10.1016/j.chb.2017.11.003

[9]. Koyuncuoglu, Ö. (2021). An Investigation of Graduate Students' Technological Pedagogical and Content Knowledge (TPACK). *International Journal of Education in Mathematics, Science and Technology*, *9*(2), 299-313. Doi: 10.46328/ijemst.1446

[10]. Ammade, S., Mahmud, M., Jabu, B., & Tahmir, S. (2020). TPACK Model Based Instruction in Teaching Writing: An Analysis on TPACK Literacy. *International Journal of Language Education*, *4*(1), 129-140.

[11]. Malichatin, H. (2019). Analisis Kemampuan Technological Pedagogical and Content Knowledge mahasiswa calon guru biologi melalui kegiatan presentasi di kelas. *Journal Of Biology Education*, *2*(2), 162. Doi: 10.21043/jbe.v2i2.6352

[12]. Mensah, B., et al. (2022). Technology integration into the teaching and learning of geography in senior high schools in Ghana: A TPACK assessment. *Social Education Research*, 80-90. Doi: 10.37256/ser.3120221218

[13]. Septiyanti, M., Inderawati, R., & Vianty, M. (2020). Technological Pedagogical and Content Knowledge (TPACK) perception of English education students. *English Review: Journal of English Education*, *8*(2), 165-174. Doi: 10.25134/erjee.v8i2.2114

[14]. Hammond, T., et al. (2019). Shoulderto-shoulder: Teacher professional development and curriculum design and development for geospatial technology integration with science and social studies teachers. *Contemporary Issues in Technology and Teacher Education*, *19*(2), 279-301.

[15]. Gall, M. D. (2002). *Educational Research: An introduction* (7th ed.). Allyn & Bacon.

[16]. Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American journal of Physics*, *66*(1), 64-74. Doi: 10.1119/1.18809

[17]. Hammond, T. C., et al. (2018). "You know you can do this, right?": developing geospatial technological pedagogical content knowledge and enhancing teachers' cartographic practices with socio-environmental science investigations. *Cartography and Geographic Information Science*, *45*(4), 305-318. Doi: 10.1080/15230406.2017.1419440

[18]. Hong, J. E., & Stonier, F. (2015). GIS in-service teacher training based on TPACK. *Journal of Geography*, *114*(3), 108-117. Doi: 10.1080/00221341.2014.947381

[19]. Daineko, Y. A., et al. 2022). Development of a Mobile e-Learning Platform on Physics Using Augmented Reality Technology. *Int. J. Interact. Mob. Technol.*, *16*(5), 4-18. Doi: 10.3991/ijim.v16i05.26961

[20]. Abd Halim, N. D., et al. (2022). Designing Game-Based Learning Kit with Integration of Augmented Reality for Learning Geography. *International Journal of Interactive Mobile Technologies (iJIM)*, *16*(2), 4–16. Doi: 10.3991/ijim.v16i02.27377

[21]. Verma, K., & Estaville, L. (2018). Role of geography courses in improving geospatial thinking of undergraduates in the United States. *International Journal of Geospatial and Environmental Research*, *5*(3).

[22]. Huang, K. H. (2018). Integrating spatial technology into fieldtrips within elementary geography education. *GI_Forum 2018*, *6*(2), 214-226. Doi: 10.1553/giscience2018_02_s214

[23]. Bodzin, A. M. (2011). The implementation of a geospatial information technology (GIT)-supported land use change curriculum with urban middle school learners to promote spatial thinking. *Journal of Research in Science Teaching*, *48*(3), 281-300. Doi: 10.1002/tea.20409

[24]. Koc, T., & Topu, F. B. (2022). Using three-dimensional geospatial technology in primary school: Students' achievements, spatial thinking skills, cognitive load levels, experiences and teachers' opinions. *Education and Information Technologies*, *27*(4), 4925-4954. Doi: 10.1007/s10639-021-10810-x

[25]. Patterson, T. C. (2007). Google Earth as a (not just) geography education tool. *Journal of Geography*, *106*(4), 145-152. Doi: 10.1080/00221340701678032

[26]. Huang, K. H. (2011). A GIS-interface web site: Exploratory learning for geography curriculum. *Journal of Geography*, *110*(4), 158-165. Doi: 10.1080/00221341.2011.542474

[27]. Favier, T. T., & van der Schee, J. A. (2014). The effects of geography lessons with geospatial technologies on the development of high school students' relational thinking. *Computers & Education*, *76*, 225-236. Doi: 10.1016/j.compedu.2014.04.004

[28]. Xiang, X., & Liu, Y. (2017). Understanding 'change'through spatial thinking using Google Earth in secondary geography. *Journal of Computer Assisted Learning*, *33*(1), 65-78. Doi: 10.1111/jcal.12166

[29]. Komikesari, H. (2020). Development of e-module using flip pdf professional on temperature and heat material. *Journal of Physics: Conference Series, 1572*(1). Doi: 10.1088/1742-6596/1572/1/012017

[30]. Nurjayadi, M., Sadono, R., & Afrizal. (2021). Development of e-module structure and protein function with flip PDF professional application through online learning. *AIP Conference Proceedings*, *2331*(1), 040029. AIP Publishing LLC. Doi: 10.1063/5.0041891

[31]. Blank, L. M., et al. (2016). Factors affecting student success with a Google Earth-based earth science curriculum. *Journal of Science Education and Technology*, *25*(1), 77-90. Doi: 10.1007/s10956-015-9578-0

[32]. Rini, D. P., Aminatun, T., & Saputra, A. A. (2023). Development of e-module based on socio-scientific issues of environmental change topic. *AIP Conference Proceedings*, *2540*(1), 060007. AIP Publishing LLC. Doi: 10.1063/5.0106499

[33]. Hong, J. E. (2017). Designing GIS learning materials for K–12 teachers. *Technology, Pedagogy and Education*, *26*(3), 323-345. Doi: 10.1080/1475939X.2016.1224777

[34]. Uçar, M. B., Demir, C., & Hiğde, E. (2014). Exploring the self-confidence of preservice science and physics teachers towards technological pedagogical content knowledge. *Procedia-Social and Behavioral Sciences*, *116*, 3381-3384. Doi: 10.1016/j.sbspro.2014.01.768

[35]. Mitchell, J. T. (2018). Pre-service teachers learn to teach geography: A suggested course model. *Journal of geography in higher education*, *42*(2), 238-260. Doi: 10.1080/03098265.2017.1398719

[36]. Erdogan, A., & Sahin, I. (2010). Relationship between math teacher candidates' technological pedagogical and content knowledge (TPACK) and achievement levels. *Procedia-Social and Behavioral Sciences*, *2*(2), 2707-2711. Doi: 10.1016/j.sbspro.2010.03.400

[37]. Aziz, N., et al. (2022). Augmented Reality Fraction Apps for Low Vision Alpha Generation Based on Affective Design Principles. *TEM Journal*, *11*(3). Doi: 10.18421/TEM113-04

[38]. Mašterová, V. (2023). Learning and teaching through inquiry with geospatial technologies: A systematic review. *European Journal of Geography*, *14*(3), 42-54. Doi: 10.48088/EJG.V.MAS.14.3.042.054

[39]. Doering, A., Koseoglu, S., Scharber, C., Henrickson, J., & Lanegran, D. (2014). Technology integration in K–12 geography education using TPACK as a conceptual model. *Journal of geography*, *113*(6), 223-237. Doi: 10.1080/00221341.2014.896393

[40]. Janko, T., & Knecht, P. (2013). Visuals in geography textbooks: Categorization of types and assessment of their instructional qualities. *Review of International Geographical Education Online*, *3*(1), 93-110.

[41]. Fisher, T. (2016). Developing the educational use of information and communications technology: Implications for the education of geography teachers. *Issues in Geography Teaching*, 50–66

[42]. Mahdum, M. (2015). Technological pedagogical and content knowledge (TPACK) of English teachers in Pekanbaru, Riau, Indonesia. *Mediterranean Journal os Social Sciences*, *6*. Doi: 10.5901/mjss.2015.v6n5s1p168

[43]. Jo, I., & Hong, J. E. (2018). Geography education, spatial thinking, and geospatial technologies: Introduction to the special issue. *International Journal of Geospatial and Environmental Research*, *5*(3).

[44]. Yıldırım, S., & Ünlü, M. (2021). Evaluating in-service GIS training for geography teachers based on G-TPACK model. *Lnternational Journal of Geography and Geography Education*, (44), 112-123. Doi: 10.32003/igge.958881

[45]. Canbazoglu Bilici, S., Guzey, S. S., & Yamak, H. (2016). Assessing pre-service science teachers' technological pedagogical content knowledge (TPACK) through observations and lesson plans. *Research in Science & Technological Education*, *34*(2), 237-251. Doi: 10.1080/02635143.2016.1144050

[46]. Muñiz Solari, O., Demirci, A., & van der Schee, J. A. (2015). Geospatial technologies and geography education in a changing world: Geospatial practices and lessons learned. *Advances in Geographical and Environmental Sciences*. Doi: 10.1007/978-4-431-55519-3