Development of E-Module Based on Geospatial Technology to Improve TPACK Competencies of Geography Pre-Service Teacher: A Needs Analysis Review

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Abstract – 21st-century education affected pre-service teachers to have TPACK competencies. One way to support pre-service teacher to have TPACK competencies is through teaching materials. The development of e-modules, particularly those of geospatial technology, was prompted by the poor quality of the instructional materials utilized in geography classes. Therefore, a need analysis is required before designing and developing the e-modules. This research evaluated a need analysis based on the PRISMA 2020 guidelines. This research aimed to explain the need analysis related to: 1) curriculum documents, 2) the lecturing process, 3) the availability of laboratories, and 4) the student's need for e-module based on geomorphology course. The data was collected from 186 university students who were preparing as pre-service geography teachers. The results indicated that pre-service geography teachers required e-modules to support the course and achieve TPACK competencies. The developed e-modules are expected to support in geomorphology lectures through the use of geospatial data, websites, and applications.

Keywords – E-Module, geospatial technology, TPACK, pre-service teacher.

1. Introduction

Education in the 21st century identifies four basic skills: creativity, critical thinking, communication, and collaboration. Collaboration, digital literacy, critical thinking, and problem-solving utilized with technology are the fundamental skills of 21st-century learning. Geography is one of the competencies found in 21st century themes. The knowledge of teacher must be comprehensive and holistic in terms of content/material, pedagogy/educational science, and technology. In a global context, a pattern of teacher competency known as technical, pedagogical, and content knowledge (TPACK). Teaching and learning are subjects ought to be changed due to the growth of digitization and the need for professional usage of digital technologies [1].

The main focus of the higher education curriculum is to prepare pre-service teachers to be able to teach based on technology and digital media. The development of TPACK for pre-service teachers is essential for creating learning that integrates technology and digital media [2]. TPACK is an important supporting factor for determining geography competency [3]. Meanwhile, studies on the TPACK competency of pre-service teachers are still minimal. Pre-service teachers and graduate students remain to have limited technological knowledge and TPACK skills [4], [5]. Literacy level of lecturers in technology, pedagogy, content knowledge (TPACK) is at a moderate level [6]. The usage of various forms of technology is the component that contributes the most to the pre-service teachers' TPACK competency [5].

Teachers and pre-service teachers in the field of geography need to improve their technology, pedagogy, content knowledge (TPACK) competency. It is crucial that teacher preparation programs implement strategies for guiding and supporting the development of technology-based pedagogy so that it becomes an important component of pre-service teachers' professional development [7].
Information and Communication Technology (ICT) must be integrated into university study programs to assist pre-service teachers in applying various technologies, hardware, and software in order to learn their relevant disciplines [8], [9]. The electronic module (e-module) is an important aspect of increasing the TPACK competence of pre-service teachers in geography [10], [11].

E-module is one of the learning materials that should be present in higher education [11]. Generally, the geography curriculum in Indonesia does not yet have an e-module. The geomorphology course is one of the expected subjects to have an e-module. Because of the broad scope, both in theoretical and practical, this course is expected to have e-modules as a resource for students' individual learning that aligned with the subject area and course outcomes. Geospatial technology presents challenges in teaching students about the geosphere phenomenon. The problem with e-modules is not only the limited access [12], but also the lack of contents that integrate with geospatial technology.

Computer-based learning, multimedia resources, networks, and communication systems that facilitate learning are the main components of digital technology [13], [14]. Using geospatial technology tool is the method suggested in this study to improve geography pre-service teachers' TPACK. The term "geospatial technology" refers to a technology that can promote the development of student competences and is used in the subject of geography learning. The combination of geospatial, technological, pedagogical, and content knowledge (TPACK) to provide an effective geography learning environment is one of the core aspects in the geospatial method [15]. As a result, creating an online course using geospatial technology is necessary to satisfy the needs of prospective geography teachers or students. This can be done by conducting need analysis for the course. However, the research that covers the needs analysis of geospatial technology for e-module development, particularly in improving the TPACK competency of geography pre-service teachers, is still limited. The researcher believes that responding to questions based on field data is critical before designing e-modules contained with geospatial technology to improve the TPACK competency of geography pre-service teachers and promote 21st-century education. Therefore, the following questions about the development of e-modules based on geospatial technology were the focus of this study: 1) curriculum documents and lesson plans for geomorphology courses; 2) learning process and laboratory availability; 3) student-teacher opinions regarding teaching medias used in current lectures; 4) technology integration in learning; 5) expected lecturing format in studying geomorphology; 6) the importance of TPACK for geography pre-service teachers; and 7) the integration of geospatial technology in geomorphology course and the various features of e-modules. The needs analysis procedure begins with the identification and evaluation of the needs which are going, followed by the determination of expectations [14]. This is one of the most significant phases since it proposes the research topics that will be used to design the module [14]. The research will also examine the literature on e-modules for need analysis or similar terms. The objective of a systematic literature review (SLR) is used to determine the need analysis of technology-based teaching material. In actuality, there is no systematic literature review (SLR) that combines the demand analysis of e-modules based on geospatial technology with TPACK competency.

2. Literature Review

The semester credit system (SKS) is used in academic lectures provided at universities. The course to prepare geography pre-service teachers can take between 12 and 24 credits per semester. Credits are a measurement of the amount of work that a student is expected to complete and a form of appreciation for the amount of progress that a student makes in their academic development. Each credit consisted of in-person lessons, structured assignments, and independent work. Students can use synchronous or asynchronous e-module to engage in direct learning, structured assignments, and independent activities outside the university.

According to the literature review, TPACK competencies are developed through training for teachers and teacher candidates. Several studies recommend that teachers and pre-service teachers use technology that is integrated into learning [16], [17]. The suggested improvements have focused on building trust through exposure, teaching and administrative modelling, effective evaluation, and technology-integrated curriculum [7]. The results of the literature review show that there has never been any use of e-modules to develop TPACK competencies. Improving the educational process through the use of information and communication technology is the focus of educational technology, including the integration of various digital media into learning to change the learning process [18].

In Indonesia, the availability of e-module in the lecturing process is still limited. A preliminary study conducted at several universities, including Universitas Negeri Padang, Universitas Negeri Semarang, Universitas Siliwangi, Universitas Syiah Kuala, Universitas Samudera, and Universitas Sebelas Maret, revealed that the availability of e-module was very limited.
Integrating technology in the modern era requires an e-module. An e-module that contains geospatial technology, is packaged digitally to be effective, supports digital literacy, integrates technology in teaching media, in the form of visual, audiovisual, static, or dynamic, and supports asynchronous learning. A lecturer who utilizes an e-module to teach a particular subject must get a pedagogical understanding of the underlying learning principles and be able to apply them to the subject of science matter [19].

3. Method

This research uses the Research and Development (R&D) methodology and Systematic Literature Review (SLR). A more detailed explanation of the research method is as follows:

3.1. Research Design

This study aims to identify e-modules that are suitable for geography education study programs. The TPACK competency of geography pre-service teachers can be achieved through the use of e-module. Surveys were used by the researchers to collect data related to the preferences of geography pre-service teachers. This was an initial Research and Development (R&D) of an e-module based on geospatial technology to improve the geography teachers TPACK competencies. The R&D that was used is a modified version of the Borg and Gall model. The process of conducting a need analysis is collecting information on the specific requirements of a group in education [20]. The analysis phase is the first step to collect initial research information. [21]. This research combined need analysis with the Systematic Literature Review (SLR) approach. Systematic Literature Reviews (SLR) are used to evaluate the state of various research needs analyses in a variety of fields. The approach used is Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 [22].

3.2. Research Participants

186 teacher pre-service candidates participated in this research. The candidates, who also students from the Geography Education, FIS at Universitas Negeri Padang received research instruments from researchers. These teacher pre-service candidates were enrolled in geomorphology courses. These responders are students of the academic year of 2020/2021. The distribution of the students is shown in the following Table 1.

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Gender</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>Male</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>73</td>
</tr>
<tr>
<td>2021</td>
<td>Male</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>75</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>186</td>
</tr>
</tbody>
</table>

3.3. Data Collection Technique

A survey is used in this study to gather participant responses. 186 students responded to an electronic survey and provided the data for this study. Four geography education experts reviewed and approved a set of questionnaires before actually distributing them to respondents with an analysis of their needs. The collected data included curriculum analysis, learning conditions analysis, and needs analysis of pre-service geography teachers. The description of each category is explained in the following Table 2.

<table>
<thead>
<tr>
<th>Category</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis of Curriculum</td>
<td>Curriculum document of Geography Education study program</td>
</tr>
<tr>
<td></td>
<td>Lesson plan for geomorphology courses</td>
</tr>
<tr>
<td>Analysis of Learning Conditions</td>
<td>Learning process</td>
</tr>
<tr>
<td></td>
<td>Laboratory availability</td>
</tr>
<tr>
<td>Analysis of geography pre-service teachers</td>
<td>Teaching medias used in current lectures</td>
</tr>
<tr>
<td></td>
<td>Integration of technology in learning</td>
</tr>
<tr>
<td></td>
<td>The importance of TPACK competency for geography pre-service teachers</td>
</tr>
<tr>
<td></td>
<td>Integration of geospatial technology in learning geomorphology</td>
</tr>
<tr>
<td></td>
<td>Expected various features in e-module</td>
</tr>
</tbody>
</table>

3.4. Data Analysis

The information from the Google Form that the researcher used to collect data was calculated on each item based on the objectives of this research. The researcher used descriptive analysis approaches of significance to determine the research data [23]. Thus, the research objectives can be answered based on the measurements taken in each aspect of the research. The stages of data analysis include 1) collecting the necessary information; 2) summarizing, selecting main points, and focusing on important aspects; 3) present data for simple understanding; 4) conclude the research results.

Article criteria for analyzing e-module needs are determined using the Systematic Literature Review by PRISMA guidelines. The differentiation is described in the following.
Table 3. Criteria of article

<table>
<thead>
<tr>
<th>Inclusion</th>
<th>Exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>The paper is written in English.</td>
<td>Study is not written in English;</td>
</tr>
<tr>
<td>Research Article or Proceedings / Conference Article;</td>
<td>The study is theoretical</td>
</tr>
<tr>
<td>This paper has one of the terms: needs analysis and module in its title</td>
<td>The paper does not include: need analysis and module</td>
</tr>
</tbody>
</table>

The literature research was limited to articles published between 2012 and 2022. The article research was conducted online using the search terms "needs analysis" in the title and "module" in the keywords included in the Scopus indexed article that used Publish or Perish software 8.4. These database sources are widely acknowledged as an important, trustworthy sources of high-quality articles.

The following is an explanation of the research results consisting of curriculum analysis, learning conditions, needs of geography pre-service teachers, and systematic literature review.

4.1. Curriculum Analysis

Curriculum analysis is required as the foundation for building learning tools. The conceptual structure of curriculum analysis in the e-module development process is as follows:

Figure 2. Curriculum analysis conceptual framework

4.1.1. Curriculum Documents of Geography Education Study Program

According to curriculum analysis, TPACK has not been studied as a subject taught in geography curriculums. The development of the curriculum used in the geography education study program requires the revision of the modules used for lectures. The framework and indicators used to construct e-modules are programs educational objectives, program learning outcomes, and course objectives.

4.1.2. Lesson Plan of Geomorphology Course

Geospatial technology is needed to link the content delivery with the course objectives, to support the attainment of the program education objectives. Geomorphology content examines landforms on the earth's surface, requiring visualization with the help of geospatial technology.

4.2. Analysis of Learning Conditions

The analysis of learning conditions consists of the geomorphology learning process and laboratory availability in the geography education study program. The explanation of learning conditions is described as follows:

4.2.1. The Learning Process

Observations made during the learning process revealed that 89% of students were present, indicating their enthusiasm. Lecture progress reports are obtained from the lecturer's notes on the attendance list document and notes on e-learning. Activity during the online and offline learning process does not facilitate enthusiasm. This will have an impact on the learning outcomes and competency achievement of pre-service teachers and students.
E-modules are a solution for reinforcing content independently studied by geography pre-service teachers or students.

4.2.2. Availability of Laboratory

Geography education study program has a laboratory to support geomorphology learning, namely a physical laboratory. In addition, there is a laboratory for geographic information systems and a learning media workshop with the proper media for the development of digital-based learning.

4.3. Needs Analysis of Geography Pre-service Teachers

The needs analysis of geography pre-service teachers was based on several aspects, including current teaching media, technology integration in learning, expected lecture format in learning geomorphology, the importance of TPACK for geography pre-service teachers, geospatial technology integration in geomorphology learning, and expected features in the e-module.

4.3.1. Current Teaching Media

Figure 3 showed that 70.43% of students accessed teaching media from the internet. Reference books and PowerPoint presentations created by lecturers are further examples of teaching media that students frequently accept during lectures. Student modules and worksheets are rarely used in lectures.

4.3.2. Technology Integration in Learning

Figure 4 showed that students perceived the integration or use of technology in learning as both practical (47.31%) and effective (42.47%). Another finding indicated that a small percentage of students (6.45%) believe that integrating technology into learning will be inconvenient for students and will require high costs (3.76%).

4.3.3. Expected lecturing formats in studying geomorphology

Figure 5 showed that students are not interested in social media (18.82%) as a platform to support geomorphology lectures. Geomorphology courses in lecture style are more preferable since they use electronic modules supported with applications (53.76%) and geospatial websites (56.99%). Face-to-face learning had a high score (54.30%), indicating that students still prefer to receive synchronous explanations directly from the lecturer.

4.3.4. The Importance of TPACK for Geography Pre-service Teachers

Figure 6 shows that 68.28% of students agree that pre-service geography teachers must acquire technological pedagogical competency and content knowledge (TPACK).
Because TPACK is aligned with 21st-century education, it improves the quality of geography learning. Meanwhile, students who disagree (26.34%) stated that TPACK is difficult to understand (12.37%).

4.3.5. Geospatial Technology Integration in Geomorphology Learning

According to Figure 7, 76.88% of students feel that geospatial technology should be incorporated into geomorphology courses. The cause for this is because students will study geospatial technology based on geomorphology studies (30.11%) and geospatial technology based on the characteristics of geomorphology courses (28.49%). Students who disagree (15.05%) believe geospatial will be studied in GIS and Remote Sensing courses (6.45%).

4.3.6. Expected Various Features in E-module

Figure 8 demonstrates that augmented reality is the most anticipated feature among students, produced using data, websites, and geospatial software.

4.4. Systematic Literature Review (SLR)

Following is the meta-data extracted from a synthesis of articles published by Scopus between 2012 and 2022 that contain the keywords: need analysis and module.

Table 4. Extraction of synthesis meta-data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Source</th>
<th>Context of Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linguistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[24]</td>
<td>Mobile language learning content animated infographic</td>
<td></td>
</tr>
<tr>
<td>[26]</td>
<td>Social media for writing skills</td>
<td></td>
</tr>
<tr>
<td>Natural Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[27]</td>
<td>Game-based stem module</td>
<td></td>
</tr>
<tr>
<td>[28]</td>
<td>Teaching material based on environmental</td>
<td></td>
</tr>
<tr>
<td>[21]</td>
<td>5E inquiry-based teaching module</td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td>[29]</td>
<td>Chemistry module based on SSCS</td>
</tr>
<tr>
<td>[30]</td>
<td>Module based on REACT</td>
<td></td>
</tr>
<tr>
<td>[31]</td>
<td>LMS-based blended learning</td>
<td></td>
</tr>
<tr>
<td>[32]</td>
<td>E-Module Reaction Rate</td>
<td></td>
</tr>
<tr>
<td>[35]</td>
<td>STEM-PBL</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td>[34]</td>
<td>Problem solving module</td>
</tr>
<tr>
<td>[35]</td>
<td>Scientific M-learning</td>
<td></td>
</tr>
<tr>
<td>[36]</td>
<td>Problem-based physic modules</td>
<td></td>
</tr>
<tr>
<td>[37]</td>
<td>Local wisdom e-module</td>
<td></td>
</tr>
<tr>
<td>[38]</td>
<td>Physic e-module based PjBL--integrated STEM</td>
<td></td>
</tr>
<tr>
<td>[39]</td>
<td>Mobile augmented reality (AR) on global warming</td>
<td></td>
</tr>
<tr>
<td>[40]</td>
<td>A light waves module</td>
<td></td>
</tr>
<tr>
<td>[41]</td>
<td>Physics e-module</td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>[42]</td>
<td>Problem solving based biology module</td>
</tr>
<tr>
<td>[43]</td>
<td>Guide-module based on inquiry</td>
<td></td>
</tr>
<tr>
<td>Mathematics</td>
<td>[44]</td>
<td>iSTEM teaching module</td>
</tr>
<tr>
<td>[45]</td>
<td>STEM-discovery learning module</td>
<td></td>
</tr>
<tr>
<td>[46]</td>
<td>Mathematics module based on PBL</td>
<td></td>
</tr>
<tr>
<td>Technical and Vocational</td>
<td>[47]</td>
<td>Inventive problem-solving module</td>
</tr>
<tr>
<td>[48]</td>
<td>Microcontroller instructional module</td>
<td></td>
</tr>
<tr>
<td>[49]</td>
<td>Module of learning style</td>
<td></td>
</tr>
<tr>
<td>[50]</td>
<td>Module of project-based learning</td>
<td></td>
</tr>
<tr>
<td>Entrepreneurship</td>
<td>[51]</td>
<td>Entrepreneurships pedagogy</td>
</tr>
<tr>
<td>Graphic design</td>
<td>[52]</td>
<td>Module of graphic design learning</td>
</tr>
<tr>
<td>Health Education</td>
<td>[53]</td>
<td>Health education assessment module</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>[54]</td>
<td>E-learning for plagiarism</td>
</tr>
<tr>
<td>[55]</td>
<td>Psychosocial module based on psychoeducation</td>
<td></td>
</tr>
</tbody>
</table>
Based on the data analysis of publications on keywords about 'need analysis' and 'modules', it is possible to determine that Scopus indexed articles published between 2012 and 2022 covered a wide range of topics. However, the data extraction did not show any topics related to social sciences. The context of the research leads to modules that promote High Order Thinking Skills, mobile learning, and STEM (Science, Technology, Engineering and Mathematics). There was no research about the need analysis of TPACK or geospatial technology.

5. Discussion

Need analysis is a critical element in the development process [34]. The demands of the research subjects were ascertained through the use of a needs analysis. A needs analysis can provide an accurate profile of the target audience, directing the content development process [24]. According to several studies on requirements analysis in product development, this step is crucial in establishing the objectives and expectations of students for the learning process. Needs analysis is using "necessities" and "wants" to differentiate between what students must know and what they believe they need to know. The emphasis is on the "lacks" that represent the difference between the required skill in the target situation and the existing proficiency of the learners [26].

According to the curriculum analysis, TPACK knowledge has not been included in the geography education curriculum. This is a result of students who disagree with the importance of TPACK for pre-service teachers. Students have difficulty understanding TPACK competencies. Several improvements have been made to education in order to align it with the rapid development of technology [56]. Pre-service teachers with a strong understanding of technology will have a deeper understanding of pedagogy and subject [57]. TPACK is the knowledge required to facilitate student learning of specific topic through the application of appropriate pedagogy and technology [58], [59]. TPACK is a great tool and approach for evaluating teachers' technological proficiency and ability to use technology for learning [60]. Geography teachers should comprehend the connection between spatial thinking abilities and geospatial technology before using geospatial technologies as a teaching tool [61], [62].

The lesson plan, which is included in the curriculum document, also indicated that technology is not integrated into the learning process.

This demonstrated a new finding that there is a gap between the competencies that geography education students must possess and their actual learning activities. This is reinforced by other studies that found that the use of GIS technology in education was constrained by a lack of teacher resources [63], [64]. The academics established the following required aspects of modern learning systems after studying current global exposure and the forced acceleration caused by the pandemic in 2020 [65]. Information and communication technology use in schools has rapidly increased [66], [67]. In order to acquire TPACK competency among pre-service teachers, it is necessary to integrate geospatial technology as a technology within geography education.

The analysis of learning conditions demonstrates that there are issues with the learning process. Each semester credit consists of in-person learning, structured assignments, and independent work. Observations made during the learning process revealed that 89% of students were present in class, indicating their enthusiasm. Activity does not foster passion during the online and offline learning process. Typically, students are passive, making lecturers the primary source of learning. E-modules can facilitate both synchronous and asynchronous direct learning, scheduled assignments, and independent work outside the campus. A benefit of the idea to create an e-module based on geospatial technology in the geography education study program is the accessibility of a geomorphology laboratory, a learning media workshop, and a geographic information system laboratory. Pre-service geography teachers who understand geospatial technologies have improved cognitive capacities [68]. The best pre-service geography teachers according to current educational standards are those who can combine technical skills with pedagogical and field experience [69], [70].

According to statistical data, the majority of students currently received teaching media materials obtained from the internet, reference books, and lecturers' PowerPoint presentations. E-module is a new development when compared to conventional modules [71], [72]. Module utilization is focused on increasing student activity and motivation [73]. The lack of modules and student worksheets presents a problem and demonstrates the need to design modules equipped with evaluation sheets. Furthermore, students believed that technology must be included into every lecture. According to research, students prefer an e-module that includes GIS applications and websites to support lectures.
Electronic/technology-integrated modules are required for geography pre-service teachers to achieve competence. This is consistent with the study's findings, which showed that students assessed the value of using geospatial technology in geomorphology courses. The results of this study support the assumption that continuous TPACK training will raise the probability of integrating geospatial technology into geography learning [74], [75].

Students expected that the e-module created for geomorphology lectures will include augmented reality, geospatial data, websites, and applications. A multimodal interactive experience called augmented reality replaces components of the real world with artificially generated perceptual data [76]. The growth of learning media is also geared toward technology advancements in the modern era, as the media used to date, such as print modules and printed worksheets, are still categorized as traditional learning media [77]. It is believed that Augmented Reality can improve education by providing interactive and enjoyable social science experiences. Geospatial technology enables the visualization, measurement, and analysis of aspects or events occurring on Earth, such as landscapes, climate, and infrastructure [78], [79]. Several geospatial technologies are facilitating learning and engagement with the environment [80], [81]. It provided evidence in favor of the claim that augmented reality e-module features databases, websites, and geospatial apps that play a significant role in the development of TPACK competencies in geography pre-service teachers.

6. Conclusion

This research contributes to the needs analysis as the initial stage in the development of e-module products. Several countries have published, using needs analysis as a technique to make decisions in product development, based on a systematic review of several Scopus articles on needs analysis modules. Geospatial technology must be incorporated into this study's analysis of curriculum materials and learning environments. The development of e-module products is important to do because prospective geography teachers need learning materials that are integrated with geospatial technology as a consequence of 21st century learning. As pre-service geography teachers, students require e-modules with augmented reality components that were created with geospatial technology. This research is limited to the creation of e-modules for courses in the Geography Education study program. We recommend that future studies should be able to construct conceptual models of e-modules in a variety of disciplines with study based on their scientific capabilities.

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