International Journal of Learning, Teaching and Educational Research
Vol. 19, No. 9, pp. 58-76, September 2020
https://doi.org/10.26803/ijlter.19.9.4

Transformation of Geospatial Technology Knowledge in Pre-service and Experienced Geography Teachers as Pedagogical Tools in the Technological-Pedagogical-Content Knowledge Framework

Purwanto, Sugeng Utaya, Budi Handoyo and Syamsul Bachri
Universitas Negeri Malang, Malang, Indonesia
https://orcid.org/0000-0001-5434-4528
https://orcid.org/0000-0003-3239-5273
https://orcid.org/0000-0001-7352-2932
https://orcid.org/0000-0003-4576-5616

Abstract. This study aims to uncover GST's gaps and patterns (Geospatial Technology) knowledge transformation among Pre-service and experienced geography teachers using GST as an educational tool based on the Technological, Pedagogical, and Content Knowledge (TPACK) framework. GST integration into material content is implemented as a basis for thinking and acting to solve problems and decision-making, especially geographic content. This study is doing a cross-sectional survey with 600 respondents of the population. They were divided into five groups, such as Pre-service teachers, in the beginning, middle, final semester, and then beginner and experienced teachers, and each group consisting of 120 respondents. The measured GST component includes conceptual knowledge, implementation, and reasoning acquired by tests. The obtained test values were analyzed by the SPSS software for statistic descriptive and plotting gap knowledge value in the scatterplot-graph. Then, deviation values were obtained; the transformation model was mapped and interpreted in the Cartesian diagram. The results showed a GST knowledge gap between Pre-service and experienced geography teachers. The low implementation ability of experienced teachers means that GST is not optimal as a pedagogical tool in geography learning with the TPACK framework. Therefore, the TPACK framework needs to be practiced in continuous geography learning and changing the paradigm *learning from GST* Be *learning with GST* to strengthen the curriculum.

Keywords: Transformation; Geospatial technology; Gap knowledge; Technological-pedagogical-content knowledge; Geography study

1. Introduction

Geospatial Technologies (GST), including Geographic Information Systems (GIS), Remote Sensing, and Global Positions System (GPS) is now a universal tool for solving problems geographically and in several scientific disciplines (Liu et al., 2019). Since its introduction, GST has been proven to create geography learning more effectively (García de la Vega, 2019; Verma & Estaville, 2018). The effectiveness affects people's awareness of its use as an educational tool (Clarke, 2013; Kim, 2011; Kouziokas, 2015). GST's use as a pedagogical tool in geography learning is increasingly open along with internet technology development. These developments have encouraged the GST industry's growth globally and ultimately provided unlimited geographic learning opportunities (Moorman & Crichton, 2018). Distance and time are no longer an obstacle since they present various accurate geospatial information from various places in the world. This openness offers the opportunity to broaden the new knowledge and skills of the 21st century through the ability to think critically, creatively, communicatively, collaboratively, and in technological competence with GST (Belgiu et al., 2015). Therefore, Pre-service teachers and geography teachers need to have the capacity to use technology as an orientation to obtain new knowledge.

Geospatial information technology knowledge in geography learning in colleges and schools is an important component in learning geography. GST has been widely implemented in learning practices as a new strength in learning that uses a technology base to acquire knowledge. GST, as a pedagogical tool, offers a new way to view, study, and analysis information in transformative learning in spatial contexts (García de la Vega, 2019). The practice of using GST as a pedagogical tool as a basis for reasoning and thinking in learning spatial thinking (Jo & Hong, 2018; S. Metoyer & Bednarz, 2017; S. K. Metoyer et al., 2015) geospatial thinking (Baker et al., 2015; Clarke, 2013; García de la Vega, 2019), and geographical thought (Brendel, 2017; Muñiz Solari et al., 2015).

GST's potential as a pedagogical tool in geography learning is identified (Muñiz Solari et al., 2015). A survey of 47 geography teachers by Kerr (2016) showed 70% are interested in using GST, and even the rest have been practiced. Through a series of surveys in community service activities and GST training workshops, geography teachers in Indonesia are also interested in using GST. In particular, experienced teachers who have low implementation skills have never used GST. The condition shows that GST implementation as a pedagogical tool has a strong appeal and is proven effective (Curtis, 2019; Hong & Stonier, 2015; MaKinster et al., 2014; Oda et al., 2020).

However, the effectiveness of GST as a pedagogical tool in its implementation still reaps problems. The application's complexity is a common obstacle faced by many people (Kerski et al., 2013). The same thing was revealed by The National Assessment of Educational Progress (NAEP), where the complexity of GST applications is a major obstacle for pre-service and geography teachers in America (Boehm et al., 2018; Langran, 2016). Other studies by Mzuza & Van Der Westhuizen (2019) are obstacles faced by geography teachers in Africa in using GST because it is increasingly complex. The complexity of GST as a pedagogical tool is due to the pre-service teachers and geography teachers having little GST knowledge. This matter means that pre-service teachers and geography teachers lack strong GST knowledge, specifically on implementing. Lack of experience, knowledge, technical expertise, and teachers' reluctance to change the way they teach, underfunding, and inadequate resources. These constraints triggered the non-continuation of the geography teacher's professional development program in the implementation of GST as a pedagogical tool (Collins & Mitchell, 2019; Curtis, 2019; Hammond et al., 2018).

According to Muñiz Solari et al. (2015) and Mathews & Wikle (2019), the importance of engaging prospective teachers and geography teachers directly to use GST. Besides, teachers should have a framework of knowledge about Technology (T), Pedagogy (P), and Content (C) called TPACK (Mishra, 2019). The framework has a strong influence on practices in teacher education and professional development on a broad scale. GST integration as a pedagogical tool within the TPACK framework affects the correlation between technology, pedagogy, and content knowledge (Elas et al., 2019).

Some studies have suggested that GST has a positive impact on learning in the field of geography studies. However, the practice of GST is still a challenge in some countries, especially Indonesia. However, prospective teachers and geography teachers have been provided with GST knowledge during lectures and training. A low level of GST knowledge is still an optimal constraint of GST as a pedagogical tool and the complexity of the application. According to Taimalu & Luik (2019), GST knowledge and other technologies are related to three main concepts: conceptual, implementation, and reasoning. These three components are important to master, especially prospective teachers and geography teachers, to use GST as a pedagogical tool. The reasoning component is considered the heart of technology (Taimalu & Luik, 2019).

There has not been much research that reveals the in-depth incongruity of GST knowledge. Therefore, this research aims to uncover the process of transforming GST knowledge from prospective teachers to geography teachers. GST knowledge is obtained through survey activities by conducting tests divided into three components: conceptual, implementation, and reasoning. The trend of transformation and the GST knowledge gap is the findings in this study.

Research Hypothesis:

1. The transformation of pre-service teachers to experienced teachers is directly proportional to the GST knowledge level increase.
2. There is a GST knowledge gap between pre-service teachers and experienced teachers.

1.1 Geospatial Technology (GST)

Geospatial technology (GST) consists of geographic information systems (GIS), remote sensing (RS), Global Position Systems (GPS), and digital globes com-prize (Baker et al., 2015). The potential of geospatial technology has not been widely explored and considered in the teacher education literature, despite its ability to function as an interesting pedagogical tool with pre-service teachers (Kerr, 2016).

GIS as a geospatial technology inherently, GIS has the potential to facilitate problem-based learning and inquiry-based learning (Favier & Van Der Schee, 2012; Howarth & Sinton, 2011). Likewise (Hong & Stonier, 2015) has integrated

TPACK in GIS training to assist pre-service teachers in using GIS as a tool in learning with the consequences of using sustainably.

According to (Kholoshyn et al., 2019), there are three fundamental reasons for using remote sensing GST as a pedagogical tool, namely 1) remote sensing can present the Earth's surface by reality to increase student motivation in learning geography, 2) in small scales it allows students constructing regional relationship patterns, 3) high temporal resolution capability allows monitoring of environmental changes. Remote sensing and GIS provide valuable spatial frameworks for scientific inquiry and are very effective in integrating earth system science (Bihrer et al., 2019). Through the power of spatial, temporal, and spectral resolution, sensing data is much more dynamic, so that it can be categorized as a type of modern representation because it measures not only cognitive competence but also students' ability to think sustainably (Kholoshyn et al., 2019; Saputro et al., 2020). The integration of Geographic Information Systems (GIS), Satellite Remote Sensing (RS), and the Global Position System can be very effective tools for many subjects in the field of Geography Studies (Cheung et al., 2011).

1.2 GST Knowledge Transformations

Transformation is the creation and change of a completely new form, function, or structure. Transformation means creating something new that has never existed before and cannot be predicted from the past. According to Ross (2020), transformation is a change of shape, nature, and function. Meanwhile, Paralič et al. (2013) assume that transformation is practically converting understood knowledge into personal knowledge. In the context of GST knowledge, transformation is defined as a change in GST knowledge conceptual, implementations, and reasoning. Based on this concept, a series of knowledge transformation processes includes several stages: knowledge acquisition and storage, sharing of knowledge, and synthesis of knowledge. Changes in time have an important influence on the transformation process, which forms a new pattern of knowledge (Paralič et al., 2013), which positively affects learning geography in the classroom because it can build students' thinking abilities (Bodzin, 2011).

The imbalance in the development of GST with the knowledge of the teacher causes inequality. This study's function and purpose are to reveal the GST knowledge gap from transforming stages into teachers. Here is the difference between this study and the previous one in uncovering GST issues as a pedagogical tool from previous studies. The discovery of the knowledge gap is then used as an orientation in improving the geography learning component. TPACK as a framework for integrating technology as a pedagogical tool depends very much on GST knowledge from teacher candidates and geography teachers. Non-fulfillment of GST knowledge The value of inequality obtained is used to assess teacher readiness using GST as a pedagogical tool.

1.3. GST as a Pedagogical Tool in the TPACK framework

The pedagogical and content technology framework (TPACK) presents ways of thinking about effective technology integration, specifically knowledge related to integrating technology effectively into the learning environment (Brinkley-Etzkorn, 2018; Mishra, 2019; Pamuk, 2012; Sickel, 2019). Wongsopawiro et al.

(2017) explained that pedagogical content knowledge (PCK) produced the idea that teachers must know content and pedagogy in teacher professional development programs. TPACK has strongly influenced research and practice in teacher education and professional development on a broad scale (Mishra, 2019). The integration of technology into the PCK concept makes TPACK unique to teachers.

The TPACK framework consists of 3 main components, namely Technology Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK) (Mishra, 2019; Rahayu, 2017). Technology integration as a pedagogical tool in the TPACK framework can be interpreted from two relationship contexts: TK-CK, which generates Technology Content Knowledge (TCK), and TK-PK that results in a Technological form of Pedagogical Knowledge (TPK) relationship. TCK is knowledge about how to integrate technology with related content. The success of teachers in integrating material with technology depends on how far the teacher can use technology. There is no understanding of how the technology works with the material's content to be integrated; it is difficult to realize effective learning.

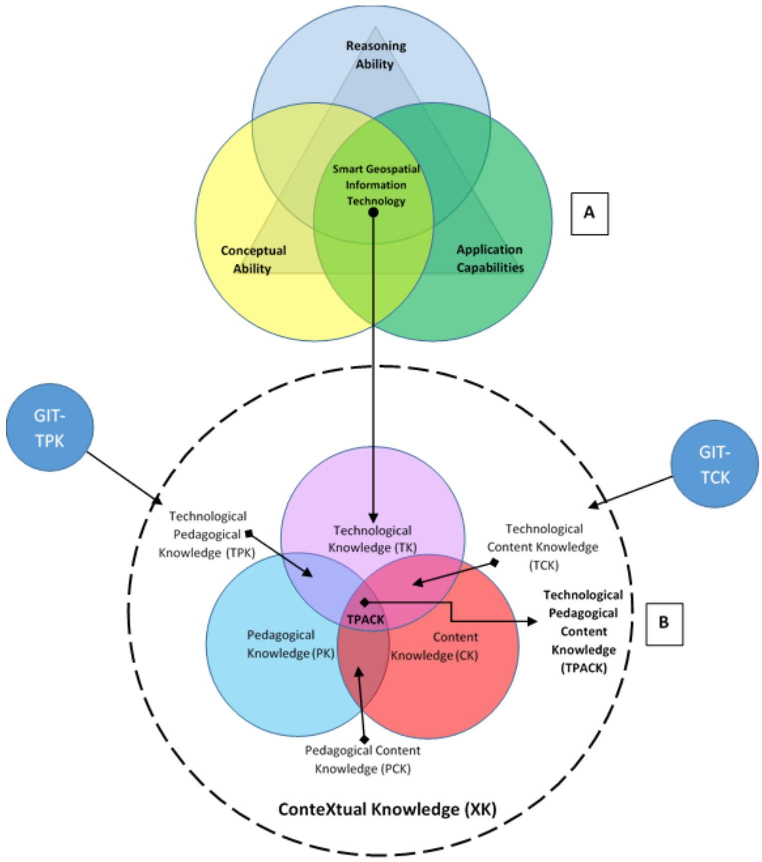

Figure 1. Representation of Geospatial Technology (GST) Knowledge within the TPACK framework (Mishra, 2019)

Likewise, Technological Pedagogical Knowledge (TPK) is an integration of technological knowledge with pedagogical knowledge. In this context, a teacher does not know enough about technology, but conceptually, the teacher's implementation and reasoning can use the technology (Coogle et al., 2019) in teaching practice.

The use of GST as an analytical tool in the TPACK framework depends very much on implementation ability. Without being supported by this ability, candidates and geography teachers have difficulty establishing the GST logic. According to the National Research Council (NRC) and the National Academy of Engineering (NAE), there are three main components of using technology as an orientation in thinking, namely knowledge, abilities, and critical thinking in decision making (Pleasants et al., 2019). From this concept, it can be interpreted that to utilize GST as a pedagogical tool, candidates and geography teachers should have conceptual knowledge, implementation, and use of these technologies to solve problems and make decisions.

2. Methods

2.1 Research Design

This research is a cross-sectional observational study conducted to assess the level of GST knowledge by pre-service students (generation of 2016 to 2019) and geography teachers. The survey was conducted from 2017 to 2020. This research is quantitative by collecting data on GST knowledge scores. The score in question results from a GST knowledge test created and uploaded online via the web (https://geoedu224. wordpress.com/) with uses the google forms platform as a data collection tool. Because online surveys are an alternative to traditional surveys (face-to-face surveys, posts, or telephones) that can cost and time and reach a larger and diverse sample (Braun et al., 2020; Regmi et al., 2017). GST knowledge questions and answers are visually represented, so it is necessary to consider the file size that can affect the download process due to internet speed (Regmi et al., 2017). Score data is obtained from the pre-service Teacher's GST knowledge pedagogical test at the end of each odd semester with a different class of students. Meanwhile, in geography teachers, this pedagogical competency test is carried out during the Teacher Professional Education program [PPG] (Ningsih et al., 2016). The score data were then analyzed to reveal the GST knowledge gap between pre-service teachers and geography teachers.

Table 1. Characteristics of Geospatial Information Technology Knowledge

No	Geospatial Information Technology Knowledge		
	GST Conceptual Ability	**GST Implementation Ability**	**GST Reasoning Ability**
1.	GIS Concepts, Theory, and Methods	GIS: Geometric Correction, layer creation, digitize, data editing, buffer analysis, overlays, interpolation, 3D, and Network Analysis.	Doing reading of maps, images, graphs, tables, summarizing, and decision making.

No	Geospatial Information Technology Knowledge		
	GST Conceptual Ability	GST Implementation Ability	GST Reasoning Ability
2.	RS Concepts, Theory, and Methods	Remote sensing: Digital Interpretation, Land use, NDVI, and Temperature.	Interpretation of temperature, land changes, and density of vegetation, water, and decision-making capabilities
3.	GPS Concepts, Theory, and Methods	Global Positions System (GPS) including Plotting location, reading coordinates, altitude, and accuracy check using a compass.	Way to read, using GPS to plot locations, and decision-making.

Source: (Gu et al., 2019; Knieova et al., 2016; Pleasants et al., 2019)

2.2 Research Strategy
Respondents to GST knowledge testing used stratified random sampling, in the sense of taking samples from grouped populations, including pre-service teacher first semester, mid-semester, final semester, beginner teacher, and experienced teacher, especially for geography study. The population per group is 120 out of 600 for the whole. We determine the population because of students' total quota in geography education per-generation and [PPG] teachers as many as 120. This method's advantage is to narrow the differences in individual types through classification by determining the number of representative samples (Shi, 2015). The number of samples specified in this study is n = 92 per-group. Determination of the number of samples can be spelled out with the following formulas (Survey Monkey, 2014):

$$\boldsymbol{sample\ size} = \frac{\frac{z^2 \times \boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\boldsymbol{e}^2}}{\mathbf{1} + \frac{z^2 \times \boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\boldsymbol{e}^2 \boldsymbol{N}}}$$

where, $\boldsymbol{N}$ = population size, $\boldsymbol{e}$ = margin of error (percentage in decimal form), z = z-score. Z-score is a standard deviation number with a given proportion of the average.

Web-based research instruments have calculated the value of internal consistency or reliability by Cronbach Alpha at 0.774, with 27 items asked questions. The acceptable alpha value of instrument reliability is ≥ 0.7 or more (Taber, 2018; Tavakol & Dennick, 2011).

2.3 Data Collection and Analysis

The data collection analyzed in this study is a question of GST knowledge divided into three components, including conceptual understanding (11 items), implementation capabilities (9 items), and reasoning (7 items) to understand and solve problems in a geographical phenomenon. Researchers created an original question. Before taking the test, respondents are advised to fill in academic information first as identity (student or teacher number [PPG], (student only), and class codes). The maximum score of each component is 100.

Table 2. GST knowledge gap design using the IPA method

Stage of Being a Geography Teacher	Conceptual Ability	Implementation Ability	Reasoning Ability	Importance Value between Knowledge Components (x̄)	Gap Knowledge Value between Components
Pre-service teacher for the first semester					
Pre-service teacher mid-term					
Pre-service teacher for the final semester					
Beginner Teacher					
Experienced Teacher					
Importance Value between Knowledge Groups (x̄)					
Gap Knowledge Value between Groups					

In descriptive statistical analysis, we use tools like IBM SPSS version 24. The average value on each component of GST knowledge and per-group of respondents is calculated to find the gap value. The method used is Importance-performance Analysis (IPA) adopted from student perception research on academic services by Saggaf et al. (2017) and Zulfahri et al. (2019). The test score is the actual performance per-group of education level, while the passing grade value = 76 is the average value that has been set (Kemendikbud, 2020). Gap values can be entered into positive or negative categories by comparing the average value of actual performance and the value of interests that have been reduced by the passing grade value. The GST knowledge component's average gap value is the x-axis, while the per-group is the y-axis. Deviation value, transformation model, mapped in cartesian diagram through SPSS software. Matrix of four quadrants plotted on the cartesian diagram (figure 2).

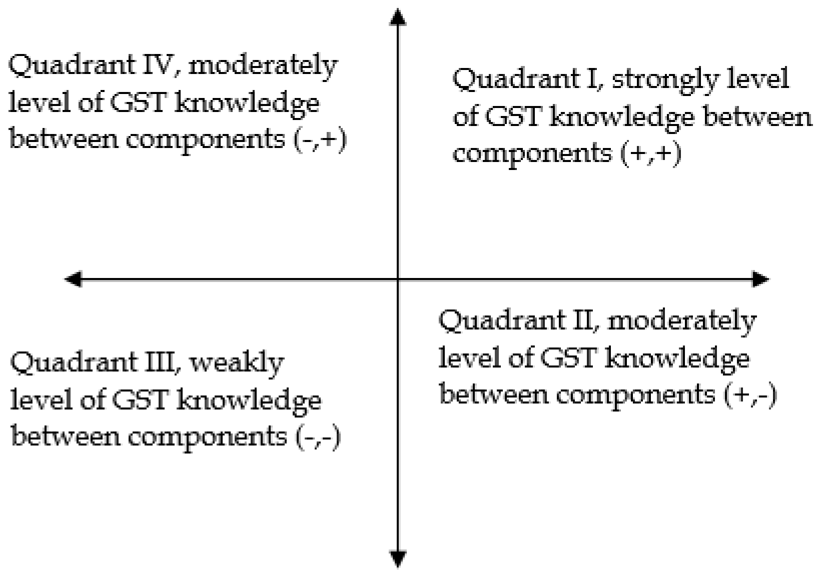

Figure 2. Representation of Gap Analysis with Cartesian diagram.

3. Result

3.1 Geospatial Technology Knowledge Pre-service and Geography Teacher

The results of tests on GST knowledge from pre-service teachers to teachers are described in Figure 2 Following.

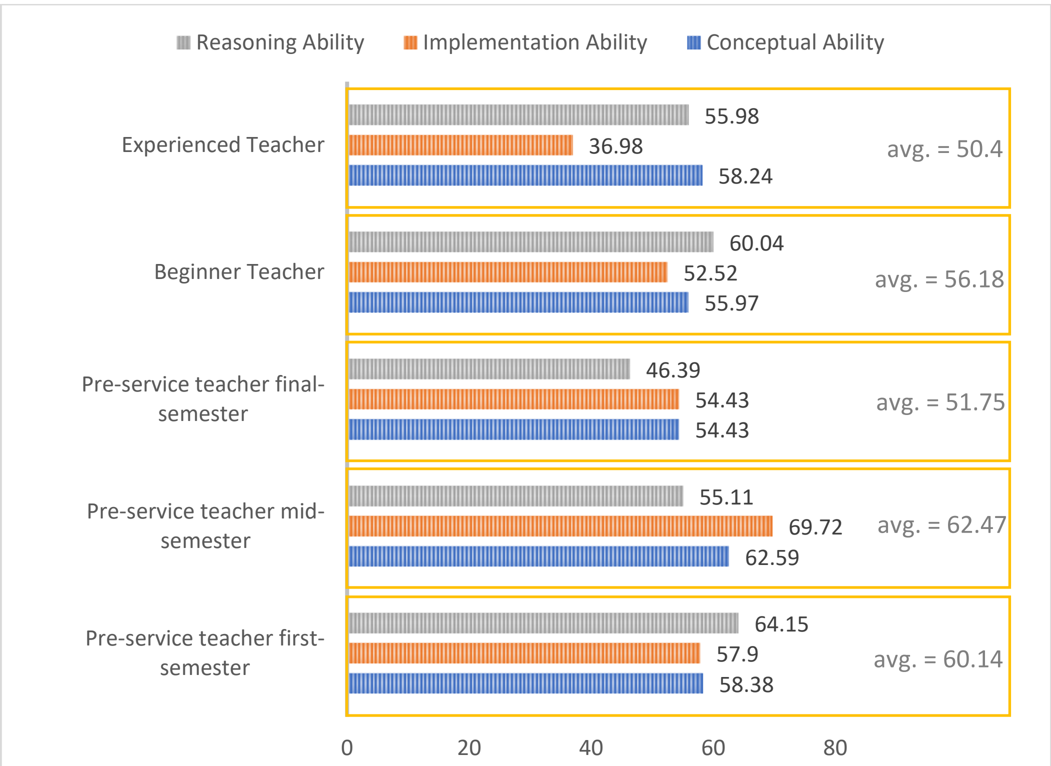

Figure 3. GST Knowledge scores for teacher candidate and geography teacher

The test results showed that the highest GST knowledge was achieved when pre-service teachers were still students in the middle semester, with an average knowledge component of 62.47. The second-highest average knowledge when pre-service teachers sit as students in the first semester. The lowest knowledge is achieved when pre-service teachers are students in the experienced teacher, and the second-lowest is a student in the final semester. Based on the results of the analysis, it can be seen that the trend of GST knowledge has declined when becoming an experienced teacher. Based on these facts, it can be seen that the length of time the acquisition of knowledge with the waiting time to become a teacher has a long influence on the GST knowledge of geography teachers. Therefore, the first hypothesis we have proposed is rejected, in the sense that the transformation of pre-service teachers to experienced teachers is not directly proportional to the increase in the level of GST knowledge.

3.2 GST Knowledge of Pre-service Teachers and Geography Teachers As Pedagogical Tools In The TPACK Framework

To determine the readiness of pre-service teachers and geography teachers in using GST as a pedagogical tool, an in-depth analysis of GST knowledge is carried out. The analysis showed a GST knowledge gap between pre-service teachers and geography teachers, which has been proven in the second hypothesis. The results of the gap analysis of GST knowledge from pre-service teachers are presented as in Table 3.

Table 3. Results of GST Knowledge analysis at the stages of becoming a geography teacher

Stages of Being a Geography Teacher	Con*	Imp*	Rea*	Importance Value	Gap Con*	Gap Imp*	Gap Rea*
P*	58.38	57.9	64.15	15.86	-1.76	-2.24	4.01
P**	62.59	69.72	55.11	13.53	0.12	7.25	-7.36
P***	54.43	54.43	46.39	24.25	2.68	2.68	-5.36
Beg*	55.97	52.52	60.04	19.82	-0.21	-3.66	3.86
Exp*	58.24	36.98	55.98	25.6	7.84	-13.42	5.58
Importance Value	18.08	21.69	19.67				
Gap P*	0.46	3.59	7.82		-1.76 ; 0.46	2.24 ; 3.59	4.01 ; 7.82
Gap P**	4.67	15.41	-1.22		0.12 ; 4.67	7.25 ; 15.41	-7.36 ; -1.22
Gap P***	-3.49	0.12	-9.94		2.68 ; -3.49	2.68 ; 0.12	-5.36 ; -9.94
Gap Beg*	-1.95	-1.79	3.71		-0.21 ; -1.95	-3.66 ; -1.79	3.86 ; 3.71
Gap Exp*	0.32	-17.33	-0.35		7.84 ; 0.32	-13.42 ; -17.33	5.58 ; -0.35

Note: P* (Pre-service Teacher First-semester); P** (Pre-service Teacher Mid-semester); P*** (Pre-service Teacher Final-semester); Beg* (Beginner Teacher); Exp* (Experienced Teacher); Con* (Conceptual Ability); Imp* (Implementation Ability); Rea* (Reasoning Ability).

Besides, it shows two characteristics of the GST knowledge gap, namely strong and weak. A positive value indicates a substantial gap, while a negative value indicates a weak gap on both axes. Based on the two characteristics' comparison results, the Pre-service Teacher in the first and final semester is the most powerful stage of GST knowledge acquisition. This matter is showed in the dominance of the positive gap value. However, in terms of the gap range, the Pre-service Teacher in the mid-term semester has the highest by 7.25;15.41 on the implementation ability. When analyzed from the gap value composition, the pre-service teacher has a relatively balanced transformation pattern between knowledge components in the final semester. Conversely, the negative gap with the highest range was achieved by experienced teachers with a value of -13.42;-17.33 in the implementation content.

Based on the type of knowledge, the conceptual ability is the most powerful knowledge mastered by Pre-service and experienced geography teachers. This matter is showed in the dominance of the positive gap with the highest value of 7.84;0.32. This fact further strengthens their GST knowledge capacity.
The mapping results of the GST knowledge transformation pattern based on becoming a teacher are presented in the Cartesian diagram, as shown in the following figure 4.

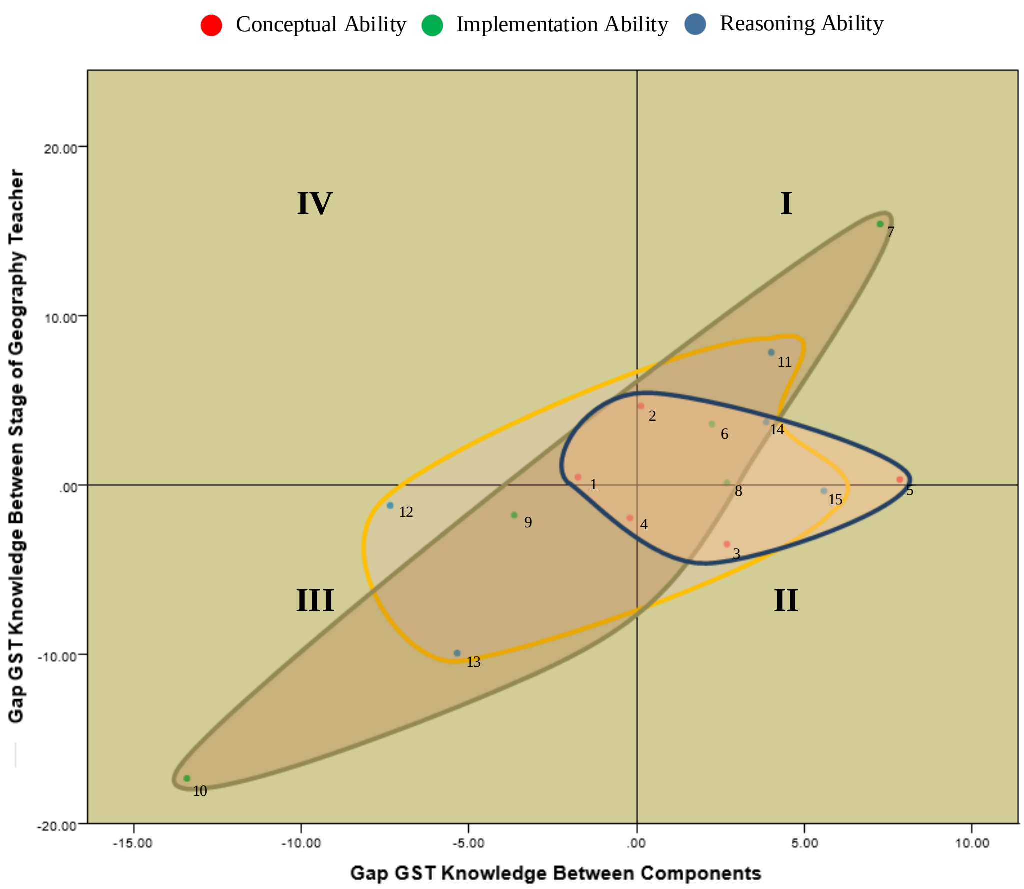

Figure 4. The pattern of GST knowledge transformation on Pre-service and Geography Teachers

Based on the three components of GST knowledge, each has a different model and dynamic. Furthermore, based on the Cartesian diagram, the mastery of conceptual knowledge is spread in all quadrants. This matter means that geography teachers (7.84;0.32) have a strong mastery level with a positive gap value. The lowest gap was found in the Pre-service Teacher for the first semester with a comparative value of -1.76;0.46.

GST knowledge of implementation ability has dynamic patterns and transformations. This ability is divided into two quadrants, including I and III. This matter shows that the implementation of knowledge is strong and weak. GST knowledge with strong implementation skills occurs among students in the middle semester, and it is weak experienced teachers (table 4). Based on this pattern, it is seen that the implementation ability trend tends to decrease from Pre-service to experienced geography teachers (figure 3).

Table 4. Cartesian diagram legend (figure 4)

	Gap Con*	Gap Imp*	Gap Rea*
	Label(Quadrant)		
Gap P*	1(IV)	6(I)	11(I)
Gap P**	2(I)	7(I)	12(III)
Gap P***	3(II)	8(I)	13(III)
Gap Beg*	4(III)	9(III)	14(I)
Gap Exp*	5(II)	10(III)	15(III)

Note: P* (Pre-service Teacher First-semester); P** (Pre-service Teacher Mid-semester); P*** (Pre-service Teacher Final-semester); Beg* (Beginner Teacher); Exp* (Experienced Teacher); Con* (Conceptual Ability); Imp* (Implementation Ability); Rea* (Reasoning Ability).

GST knowledge of reasoning ability is divided into two quadrants, including I and III. Quadrant I reflects strong reasoning ability, and III is weak. This condition shows that the reasoning capacity at each stage has a different capacity. This gap is not as large as the implementation ability and even tends to be accommodating since it covers the design and conceptual ability.

The GST knowledge transformation pattern in Pre-service and experienced geography teachers has not occurred continuously based on the results. The high implementation ability gap showed that this is still a major obstacle for both teachers (beginner and experienced) when using technology as a pedagogical tool. This matter is certainly a challenge for universities and geography teachers in Indonesia, especially in utilizing GST as a pedagogical tool.

The high knowledge gap in implementation ability shows that it is still an obstacle for Pre-service and experienced geography teachers in using GST. This matter is in line with research findings (Boehm et al., 2018; Hong & Stonier, 2015; Kerski et al., 2013; Langran, 2016). Its application complexity is still a major obstacle to Pre-service and experienced geography teachers. The absence of a curriculum structure that examines the use of GST as an educational tool means that the knowledge of the Pre-service teachers does not develop sustainably. This matter means that the GST learned is still limited to meeting the needs of the subject.

The challenge for geography teachers at schools includes implementing a tight study schedule and the high burden and assignment and administrative matters. The implementation of GST requires a planning process with sufficient time. The tight schedule is the main obstacle for GST when implemented in the classroom by the teacher.

4. Discussion

The implementation of GST skills that were not optimal in the TPACK framework is due to the course's unsustainability, which specifically teaches students' skills regarding GST use. Furthermore, Pre-service teachers need to understand this technology on a cognitive level and use it theoretically as a basis for reflection. This knowledge is still fundamental and should be trained in different implementations as a pedagogical tool. This activity certainly has positive effects and experience for Pre-service geography teachers. To create a learning experience with sustainable GST, Baker, et al. (2015) recommended four components as a pedagogic tool such as (1) examining the relationship between GST and geospatial thinking; (2) learning GST; (3) curriculum and student learning through GST; and (4) professional development of educators with GST. Based on the statement, Pre-service and experienced geography teachers have the knowledge, experience, and ability to use GST in an integrated way. Also, Rubino-Hare et al. (2016) emphasize that the use of GST as a pedagogical tool takes 1 to 2 years in continuous learning. Therefore, Pre-service and experienced geography teachers focus on learning about GST and how to teach it (Donert et al., 2016; Zwartjes & de Lázaro y Torres, 2019).

As Curtis (2019) stated, geography teachers should know the relationship between geospatial thinking skills and GST before using it as an educational tool. Geospatial thinking that uses location as a basis for thinking has important meaning for the Pre-service and experienced geography teachers in generalizing the relationship between spatial components and decision making. Based on the Verma & Estaville (2018), students that learn geospatial technology have better-thinking abilities. Geospatial thinking with the basis of reasoning processes, spatial conceptualization, and representation tools, is a set of cognitive skills with some knowledge form and operators used to change one's way of thinking and to act towards the phenomenon in the Earth's surface through problem-solving (García de la Vega, 2019).

Second, in the context of the learning experience, it can be reported that this ability is an important element in the implementation of GST as an educational tool. GST applications' complexity is a major challenge for Pre-service and experienced geography teachers (Boehm et al., 2018; Kerski et al., 2013; Langran, 2016). This matter can be overcome when GST is consistently used as a pedagogical tool (Clarke, 2013; Kim, 2011; Kouziokas, 2015).

Third, the learning experience with GST has not been supported in the curriculum. Previous results showed that the Educational Personnel Education Institution [LPTK] curriculum has a GST course weight of 7-14% of the total courses presented. This matter is still limited to basic GST courses, such as remote sensing, Geographic Information Systems, thematic cartography, and photogrammetry integrated with Global positions system (GPS). No GST course development covers its ability to be implemented, and it certainly becomes an obstacle for Pre-service and experienced geography teachers since they lack authentic experience. Fourth, as uniqueness in geography learning, it should make a distinction between geography and other fields of study integrated with spatial approaches. This ability needs to be strongly mastered by experienced or professional teachers. However, it is inversely proportional. This matter is because of weak implementation skills in using GST for changes orientation in geography learning. Students' impact is strong with conceptual understanding because the teacher has a reinforced mastery concept, and it ultimately causes geography to lose its uniqueness in learning.

Pre-service teachers' lack of experience in using GST as a pedagogical tool harms geography learning. The wide gap in the ability to implement the concept shows three different strengths. Due to the transformation process, the three GST knowledge is not well integrated into Pre-service or experienced geography teachers. This weakness makes GST ineffective towards learning geography. According to, direct involvement in implementing GST as a pedagogical tool provides meaningful learning experiences. Furthermore, Kang & Keinonen (2017) and Masters (2013) reported that direct learning experiences could remember 90% of the material being studied. Therefore, it has an impact on memory.

The lack of GST knowledge on the implementation ability is the main obstacle for Pre-service and experienced geography teachers in using GST as a pedagogic tool with the TPACK framework. This matter can cause a non-optimal correlation between technology, pedagogy, and content knowledge. The integration of technology in the learning context needs mastery ability in its implementation. As a pedagogical tool, Pre-service and experienced geography teachers need to understand how GST works in an integrated way to solve problems, ways of thinking, and decision-making process.

Second, it needs to be technically supported by the ability to integrate technology with content knowledge. Understanding this material is important in terms of the thinking logic taught to students and GST methods' accuracy. A lack of content knowledge means that students do not develop their thinking logic due to limited knowledge (Pamuk, 2012). Furthermore, Rubino-Hare et al. (2016), developing thinking skills, need to be supported with strong knowledge, which occurs when Pre-service and experienced geography teachers can ultimately connect one concept to produce new knowledge.
For the GST to function as an educational tool, the teachers need to have a good knowledge understanding of the GST in terms of implementation, design, and reasoning. Besides, Langran (2016), it has been argued that its solid knowledge is important since it stimulates the thinking capacity of users. Strong GST knowledge can be achieved by placing it as a pedagogical tool in geography learning.

5. Acknowledgment

This research is supported by the Faculty of Social Sciences, State University of Malang, Indonesia, through the dissertation grant from the Ministry of Education and Culture of the Republic of Indonesia, contract number: 053/SP2H/LT/DRPM/2020. Thank you to the students, teachers, and all those who have contributed to writing this article.

6. Conclusions

In this study, GST knowledge for prospective teachers to experienced geography teachers was obtained from the test results. There are three components of GST presented, including conceptual, implementation, and reasoning. To uncover the GST knowledge gap between education levels, the importance-performance analysis (IPA) method is used based on the average test result score of each level of education and each component of GST as the actual value. Meanwhile, the passing-grade value is set at 76 as a requirement of professional teachers. The GST knowledge gap value is plotted into a cartesian diagram divided into four quadrants. Results show that GST knowledge for pre-service teachers and experienced teachers is not strongly categorized because there is a negative gap value. The implementation ability of experienced geography teachers should be widely practiced to strengthen pre-service reasoning further weakened in the semester's final stages. The inconsistency of GST knowledge from pre-service teachers to experienced geography teachers is due to the inconsistency of understanding GST knowledge.

7. Recommendations

The findings of the problems revealed in this study need evaluation. Our recommendations for solutions address the unconscionable understanding of GST knowledge. First, the TPACK framework needs to be integrated into geography learning practices. This matter is to achieve the goal of gaining a strong and consistent mastery of GST knowledge. Second, it is necessary to change the paradigm of geography *learning from GST* to *learning with GST* through strengthening the curriculum.

8. Limitations

This study's limitation is that surveys are not conducted continuously, focusing on one generation ranging from prospective teachers to experienced teachers. This research is still limited to the invisible implications of GST knowledge that could increase geospatial technology as a learning tool such as google earth, map, or Web-GIS applications in the future. Of course, research needs to be done in the future to see the implications of GST mastery on the use of world ball applications.

9. References

Baker, T. R., Battersby, S., Bednarz, S. W., Bodzin, A. M., Kolvoord, B., Moore, S., Sinton, D., & Uttal, D. (2015). A Research Agenda for Geospatial Technologies and Learning. *Journal of Geography*, *114*(3), 118–130. https://doi.org/10.1080/00221341.2014.950684

Belgiu, M., Strobl, J., & Wallentin, G. (2015). Open Geospatial Education. *ISPRS International Journal of Geo-Information*, *4*(2), 697–710. https://doi.org/10.3390/ijgi4020697

Bihrer, A., Bruhn, S., & Fritz, F. (2019). Inquiry-Based Learning in History. In *Inquiry-Based Learning – Undergraduate Research* (pp. 291–299). Springer International Publishing. https://doi.org/10.1007/978-3-030-14223-0_27

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. https://doi.org/10.1002/tea.20409

Boehm, R. G., Solem, M., & Zadrozny, J. (2018). The Rise of Powerful Geography. *The Social Studies*, *109*(2), 125–135. https://doi.org/10.1080/00377996.2018.1460570

Braun, V., Clarke, V., Boulton, E., Davey, L., & McEvoy, C. (2020). The online survey as a qualitative research tool. *International Journal of Social Research Methodology*, 1–14. https://doi.org/10.1080/13645579.2020.1805550

Brendel, N. (2017). Using Weblogs to Determine the Levels of Student Reflection in Global Education. In C. Brooks, G. Butt, & M. Fargher (Eds.), *The Power of Geographical Thinking* (pp. 119–135). Springer International Publishing. https://doi.org/10.1007/978-3-319-49986-4_9

Brinkley-Etzkorn, K. E. (2018). Learning to teach online: Measuring the influence of faculty development training on teaching effectiveness through a TPACK lens. *Internet and Higher Education*, *38*, 28–35. https://doi.org/10.1016/j.iheduc.2018.04.004

Cheung, Y., Pang, M., Lin, H., & Lee, C. K. J. (2011). Enable Spatial Thinking Using GIS and Satellite Remote Sensing – A Teacher-Friendly Approach. *Procedia - Social and Behavioral Sciences*, *21*, 130–138. https://doi.org/10.1016/j.sbspro.2011.07.014

Clarke, K. C. (2013). *Future U.S. Workforce for Geospatial Intelligence*. National Academies Press. https://doi.org/10.17226/18265

Collins, L., & Mitchell, J. T. (2019). Teacher training in GIS: what is needed for long-term success? *International Research in Geographical and Environmental Education*, *28*(2), 118–135. https://doi.org/10.1080/10382046.2018.1497119

Coogle, C. G., Storie, S., Ottley, J. R., Rahn, N. L., & Kurowski-Burt, A. (2019). Technology-Enhanced Performance-Based Feedback to Support Teacher Practice and Child Outcomes. *Topics in Early Childhood Special Education*, *0*(0), 1–14. https://doi.org/10.1177/0271121419838624

Curtis, M. D. (2019). Professional Technologies in Schools: The Role of Pedagogical Knowledge in Teaching With Geospatial Technologies. *Journal of Geography*, *118*(3), 130–142. https://doi.org/10.1080/00221341.2018.1544267

Donert, K., Desmidt, F., de Lázaro y Torres, M. L., de Miguel González, R., Linder-Fally, M., Parkinson, A., Prodan, D., Wołoszyńska-Wiśniewska, E., & Zwartjes, L. (2016). *GI-Learner: a project to develop geospatial thinking learning lines in secondary schools*. 1–13.

Elas, N. I. B., Majid, F. B. A., & Narasuman, S. A. (2019). Development of Technological Pedagogical Content Knowledge (TPACK) For English Teachers: The Validity and Reliability. *International Journal of Emerging Technologies in Learning (IJET)*, *14*(20), 18. https://doi.org/10.3991/ijet.v14i20.11456

Favier, T. T., & Van Der Schee, J. A. (2012). Exploring the characteristics of an optimal design for inquiry-based geography education with Geographic Information Systems. *Computers and Education*, *58*(1), 666–677. https://doi.org/10.1016/j.compedu.2011.09.007

García de la Vega, A. (2019). Spatial Thinking Ability Acquisition Through Geospatial Technologies for Lifelong Learning. In *Geospatial Technologies in Geography Education* (pp. 21–40). Springer, Cham. https://doi.org/10.1007/978-3-030-17783-6_2

Gu, J., Xu, M., & Hong, J. (2019). Development and Validation of a Technological Literacy

Survey. *International Journal of Science and Mathematics Education*, *17*(S1), 109–124. https://doi.org/10.1007/s10763-019-09971-6

Hammond, T. C., Bodzin, A., Anastasio, D., Holland, B., Popejoy, K., Sahagian, D., Rutzmoser, S., Carrigan, J., & Farina, W. (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. https://doi.org/10.1080/15230406.2017.1419440

Hong, J. E., & Stonier, F. (2015). GIS In-Service Teacher Training Based on TPACK. *Journal of Geography*, *114*(3), 108–117. https://doi.org/10.1080/00221341.2014.947381

Howarth, J. T., & Sinton, D. (2011). Sequencing spatial concepts in problem-based GIS instruction. *Procedia - Social and Behavioral Sciences*, *21*, 253–259. https://doi.org/10.1016/j.sbspro.2011.07.042

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). https://dc.uwm.edu/ijger/vol5/iss3/1

Kang, J., & Keinonen, T. (2017). The effect of inquiry-based learning experiences on adolescents' science-related career aspiration in the Finnish context. *International Journal of Science Education*, *39*(12), 1669–1689. https://doi.org/10.1080/09500693.2017.1350790

Kemendikbud. (2020). *Syarat & Mekanisme – PPG Prajabatan 2020*. https://sdm.ppg.kemdikbud.go.id/prasyarat/

Kerr, S. (2016). Integrating Geospatial Technologies Into Existing Teacher Education... *Contemporary Issues in Technology and Teacher Education*, *16*(3), 328–347.

Kerski, J. J., Demirci, A., & Milson, A. J. (2013). The Global Landscape of GIS in Secondary Education. *Journal of Geography*, *112*(6), 232–247. https://doi.org/10.1080/00221341.2013.801506

Kholoshyn, I., Varfolomyeyeva, I., Hanchuk, O., Bondarenko, O., & Pikilnyak, A. (2019). Pedagogical techniques of Earth remote sensing data application into modern school practice. *CEUR Workshop Proceedings*, *2433*(2018), 391–402. http://arxiv.org/abs/1909.04381

Kim, M. (2011). *Effects of a GIS course on three components of spatial literacy*. Texas A&M University.

Knieova, V., Janovec, J., Kroufek, R., & Chytrý, V. (2016). AFFECTIVE DIMENSION OF TECHNOLOGICAL LITERACY. *ICERI2016 Conference*, 590–596. https://doi.org/10.21125/iceri.2016.1146

Kouziokas, G. N. (2015). Development of an Information System as a GIS-Based Learning Environment for Geoscience and Geography Education. *The International Journal of Technologies in Learning*, *22*(4), 67–82. https://doi.org/10.18848/2327-0144/CGP/v22i04/49081

Langran, E. (2016). Special Issue: Geospatial Technologies in Teacher Education. *Contemporary Issues in Technology and Teacher Education*, *16*(3), 373–379.

Liu, R., Greene, R., Li, X., Wang, T., Lu, M., & Xu, Y. (2019). Comparing Geoinformation and Geography Students' Spatial Thinking Skills with a Human-Geography Pedagogical Approach in a Chinese Context. *Sustainability*, *11*(20), 5573. https://doi.org/10.3390/su11205573

MaKinster, J., Trautmann, N., & Barnett, M. (2014). Introduction. In *Teaching Science and Investigating Environmental Issues with Geospatial Technology* (pp. 1–9). Springer Netherlands. https://doi.org/10.1007/978-90-481-3931-6_1

Masters, K. (2013). Edgar Dale's Pyramid of Learning in medical education: A literature review. *Medical teacher*, *35*(11), e1584–e1593.

https://doi.org/10.3109/0142159X.2013.800636

Mathews, A. J., & Wikle, T. A. (2019). GIS&T pedagogies and instructional challenges in higher education: A survey of educators. *Transactions in GIS*, *23*(5), 892–907. https://doi.org/10.1111/tgis.12534

Metoyer, S., & Bednarz, R. (2017). Spatial Thinking Assists Geographic Thinking: Evidence from a Study Exploring the Effects of Geospatial Technology. *Journal of Geography*, *116*(1), 20–33. https://doi.org/10.1080/00221341.2016.1175495

Metoyer, S. K., Bednarz, S. W., & Bednarz, R. S. (2015). Spatial thinking in education: Concepts, development, and assessment. In *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned* (pp. 21–33). Springer Japan. https://doi.org/10.1007/978-4-431-55519-3_3

Mishra, P. (2019). Considering Contextual Knowledge: The TPACK Diagram Gets an Upgrade. *Journal of Digital Learning in Teacher Education*, *35*(2), 76–78. https://doi.org/10.1080/21532974.2019.1588611

Moorman, L., & Crichton, S. (2018). Learner Requirements and Geospatial Literacy Challenges for Making Meaning with Google Earth. *International Journal of Geospatial and Environmental Research*, *5*(3). https://dc.uwm.edu/ijger/vol5/iss3/5

Muñiz Solari, O., Demirci, A., & van der Schee, J. (2015). Geospatial Technology in Geography Education. In O. Muñiz Solari, A. Demirci, & J. Schee (Eds.), *Geospatial Technologies and Geography Education in a Changing World* (pp. 1–7). Springer, Tokyo. https://doi.org/10.1007/978-4-431-55519-3_1

Mzuza, M. K., & Van Der Westhuizen, C. P. (2019). Review on the state of GIS application in secondary schools in the southern African region. *South African Geographical Journal*, *101*(2), 175–191. https://doi.org/10.1080/03736245.2019.1579110

Ningsih, M., Fatchan, A., & Susilo, S. (2016). PROGRAM PPG UNTUK MEMBANGUN KOMPETENSI GURU GEOGRAFI (STUDI KASUS DI UNIVERSITAS NEGERI MALANG). *Jurnal Pendidikan - Teori, Penelitian, Dan Pengembangan*, *1*(10), 2031–2039. https://doi.org/10.17977/jp.v1i10.7582

Oda, K., Herman, T., & Hasan, A. (2020). Properties and impacts of TPACK-based GIS professional development for in-service teachers. *International Research in Geographical and Environmental Education*, *29*(1), 40–54. https://doi.org/10.1080/10382046.2019.1657675

Pamuk, S. (2012). Understanding pre-service teachers' technology use through TPACK framework. *Journal of Computer Assisted Learning*, *28*(5), 425–439. https://doi.org/10.1111/j.1365-2729.2011.00447.x

Paralič, J., Babič, F., & Paralič, M. (2013). Process-driven approaches to knowledge transformation. *Acta Polytechnica Hungarica*, *10*(5), 125–143. https://doi.org/10.12700/APH.10.05.2013.5.8

Pleasants, J., Clough, M. P., Olson, J. K., & Miller, G. (2019). Fundamental Issues Regarding the Nature of Technology: Implications for STEM Education. *Science and Education*, *28*(3–5), 561–597. https://doi.org/10.1007/s11191-019-00056-y

Rahayu, S. (2017). Technological Pedagogical Content Knowledge (TPACK): Integrasi ICT dalam Pembelajaran IPA Abad 21. *Prosiding Seminar Nasional Pendidikan IPA IX*, *October 2017*, 1–14.

Regmi, P. R., Waithaka, E., Paudyal, A., Simkhada, P., & Van Teijlingen, E. (2017). Guide to the design and application of online questionnaire surveys. *Nepal Journal of Epidemiology*, *6*(4), 640–644. https://doi.org/10.3126/nje.v6i4.17258

Ross, S. L. (2020). A Concept Analysis of the Form that Trans-forms as a Result of Transformation. *International Journal of Psychological Studies*, *12*(2), 52. https://doi.org/10.5539/ijps.v12n2p52

Rubino-Hare, L. A., Whitworth, B. A., Bloom, N. E., Claesgens, J. M., Fredrickson, K. M., Henderson-Dahms, C., & Sample, J. C. (2016). Persistent Teaching Practices after Geospatial Technology Professional. *Contemporary Issues in Technology and Teacher Education*, *16*(3), 208–285.

Saggaf, M. S., Salam, R., Darwis, M., & Jamaluddin, M. (2017). Examining Academic Service using Importance Performance Analysis (IPA). *Proceedings of the 2nd International Conference on Education, Science, and Technology (ICEST 2017)*. https://doi.org/10.2991/icest-17.2017.47

Saputro, R., Liesnoor, D., Setyowati, & Hardati, P. (2020). The Students Spatial Critical Thinking Skill by Using Map and Remote Sensing Imagery on Geography Lesson. *Proceedings of the International Conference on Science and Education and Technology (ISET 2019)*, 250–254. https://doi.org/10.2991/assehr.k.200620.049

Shi, F. (2015). Study on a Stratified Sampling Investigation Method for Resident Travel and the Sampling Rate. *Discrete Dynamics in Nature and Society*, *2015*, 1–7. https://doi.org/10.1155/2015/496179

Sickel, J. L. (2019). The Great Media Debate and TPACK: A Multidisciplinary Examination of the Role of Technology in Teaching and Learning. *Journal of Research on Technology in Education*, *51*(2), 152–165. https://doi.org/10.1080/15391523.2018.1564895

Survey Monkey. (2014). *Sample Size Calculator*. https://www.surveymonkey.com/mp/sample-size-calculator/

Taber, K. S. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Taimalu, M., & Luik, P. (2019). The impact of beliefs and knowledge on the integration of technology among teacher educators: A path analysis. *Teaching and Teacher Education*, *79*, 101–110. https://doi.org/10.1016/j.tate.2018.12.012

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Verma, K., & Estaville, L. (2018). Role of Geography Courses in Improving Geospatial Thinking of Undergraduates in the United States Role of Geography Courses in Improving Geospatial Thinking of. *International Journal of Geospatial and Environmental Research*, *5*(3). https://dc.uwm.edu/ijger/vol5/ iss3/2

Wongsopawiro, D. S., Zwart, R. C., & van Driel, J. H. (2017). Identifying pathways of teachers' PCK development. *Teachers and Teaching*, *23*(2), 191–210. https://doi.org/10.1080/13540602.2016.1204286

Zulfahri, A. F., Edi Widodo, C., & Gernowo, R. (2019). Implementing Importance-Performance Analysis (IPA) for Measuring Students Satisfaction Levels. *2019 International Seminar on Research of Information Technology and Intelligent Systems (ISRITI)*, 363–367. https://doi.org/10.1109/ISRITI48646.2019.9034615

Zwartjes, L., & de Lázaro y Torres, M. L. (2019). Geospatial Thinking Learning Lines in Secondary Education: The GI Learner Project. In *Geospatial Technologies in Geography Education* (pp. 41–61). https://doi.org/10.1007/978-3-030-17783-6_3