Vol.6, Issue 4, pp.1405-1421, 2025
DOI: https://doi.org/10.62754/ais.v6i4.772

https://journals.ap2.pt/index.php/ais/index

Integrating GIS in Classroom Practice: Empirical Evidence on What Drives Teachers to Use Geospatial Technology

Siti Nurindah Sari[1], Nuryanti[2], Irna Anjarsari[3], Mohammad Syifauddin[4], Edi Kurniawan[5], Hanifah Mahat[6]

Abstract

The integration of geospatial technologies such as GIS, remote sensing, and GPS has become increasingly important for advancing spatial thinking skills and geographic literacy in secondary education. However, empirical evidence on the psychological and pedagogical factors that shape teachers' adoption of geospatial technologies—particularly in developing countries—remains limited. This study examines how geospatial awareness and geospatial knowledge shape the actual implementation of geospatial technologies among secondary school geography teachers in Indonesia. Drawing on survey data from 110 teachers across diverse regions and using a Structural Equation Modeling (SEM) approach, the study highlights that teachers' geospatial awareness and knowledge significantly influence the actual implementation of geospatial technologies in classroom-based geography instruction. Nevertheless, the findings indicate that awareness alone is insufficient to translate into classroom action unless accompanied by adequate technical competence. Generational differences further accentuate the digital proficiency gap, with younger teachers demonstrating stronger operational skills. These findings advance theoretical understanding of the awareness–knowledge–practice mechanism and provide practical guidance for geospatial education reform. The study underlines an urgent need for hands-on GIS training, differentiated professional development, and institutional support to strengthen geospatial literacy in Indonesian schools and in other developing-country contexts.

Keywords: *Geographic Information System (GIS); geospatial technology; geospatial knowledge; spatial thinking; teacher awareness.*

Introduction

Geography is a highly important academic discipline (Mansfild, 1994). Geography helps solve environmental problems in the learning process through the questions what, where, when, why, who, and how in order to develop consequences, policies, awareness, and commitment. Therefore, geography learning must be conducted meaningfully through geographical questions that trigger spatial thinking (Schee, et al., 2015). Spatial thinking constitutes a core cognitive ability in geography as a school subject (Mayalagu, Jaafar, & Choy, 2018).

However, geography is often regarded as an unimportant field that merely relies on rote memorization (Bernarz, 2004). Geography instruction frequently does not emphasize the essence and philosophy of geography as a spatial science (Putro, Setyowati, & Hardati, 2019). Consequently, designing geography learning that is engaging and foregrounds spatial thinking must be realized. The demand for a transformative education system, shifting from traditional approaches to active and critical geography learning, has driven the integration of Geographic Information System (GIS) and other geospatial technologies such as remote sensing, virtual globes, interactive maps, and GPS into classroom practice (Kerr, 2016; Metoyer & Bernarz, 2017; Stojsic, et al., 2019).

Learning about GIS enhances students' spatial abilities (Jo & Hong, 2020). GIS is a fundamental tool in geography education for describing objects on the Earth's surface (DeMers, 2016). Geospatial information technologies such as GIS, remote sensing, and GPS are highly important in geography education at both school and university levels (Purwanto, et al., 2020). As tools in learning, geospatial

---

[1]Universitas Ivet, Semarang Indonesia (corresponding author).
[2] Universitas Ivet, Semarang Indonesia.
[3] Universitas Ivet, Semarang Indonesia
[4] Universitas Negeri Semarang, Semarang Indonesia
[5] Universitas Negeri Semarang, Semarang Indonesia
[6] Universiti Pendidikan Sultan Idris Malaysia

technologies offer new perspectives, approaches, and analyses of information in transformative learning using spatial contexts (Vega, 2019). Numerous studies have demonstrated the effectiveness of using GIS in improving spatial thinking skills, such as the studies by Singh, et al. (2016) and Turkuresin (2021), which found that GIS is effective in developing students' skills, promoting more dynamic learning, and enhancing students' achievement. Other studies reporting positive outcomes from the use of GIS and other geospatial technologies include Demirci, Kraburun, & Arslan (2019), Hadi, et al. (2021), Kerski, Demirci, & Milson (2014), Lee & Bernadrz (2009), Mayalagu, et al. (2020), Malek, et al. (2020), Millsaps & Harrington (2017), Pang, Lin, & Lee (2011), and Xiang & Liut (2016).

Nevertheless, although GIS has spread worldwide, its use in teaching and learning activities in schools across many countries remains far from optimal (Artvinli, 2010; Kapluhan, 2014; Kim, et al., 2011; Roulston, 2013). The main obstacles to integrating GIS into teaching include teachers' limited knowledge and skills regarding how to use GIS for instructional purposes (Bernarz & Schee, 2006; Mzuza), the lack of curricula that foreground GIS, teachers' reluctance to put in extra effort and time to learn new technologies (Aladag, 2014), school infrastructure conditions, and the relatively high cost of GIS software (Tastan, 2021). In fact, in the current global context, the primary challenge in geography education is not merely teaching about space, but teaching how to think about space, so that instruction should prioritize learning with GIS rather than learning about GIS (Gonzales, 2013).

In this regard, teachers' capacity and role in integrating GIS and other geospatial technologies into instruction are crucial, as teachers are the spearhead of the learning process. Teachers must also possess adequate geospatial thinking skills in order to implement geography learning based on geospatial technologies. Therefore, this study aims to analyze how geospatial awareness and geospatial knowledge shape the actual implementation of geospatial technologies among secondary school geography teachers in Indonesia.

Literature Review

Spatial Thinking

Spatial thinking integrates a range of cognitive skills. Spatial thinking refers to the knowledge, skills, and habits of mind required to use spatial concepts such as distance, orientation, distribution, and association; to employ representational tools such as maps, graphs, and diagrams; and to apply reasoning processes such as cognitive strategies that facilitate problem solving, decision making, and inquiry (Colins, 2018; Ridha, et al., 2019). Spatial Thinking Ability must be taught in geography (Hadi, et al., 2021) because it is an essential element of the discipline (Heffron & Downs, 2012). Spatial thinking helps students represent, analyze, plan, and connect the physical environment with human activities. It is also highly important for students to improve their understanding of location, distribution, interrelations among geospheric phenomena, and the use of geospatial technologies such as GIS, remote sensing, and GPS (Gersmehl, 2008).

Spatial thinking is a fundamental form of intelligence that is highly needed in modern society and is an essential skill in intellectual development, which should be embedded in an individual's education alongside science, mathematics, and language (Hespanha, Goodchild, & Janelle, 2009). Spatial thinking is not only related to geographic information systems education. It is also indirectly linked to geography and the humanities for addressing various spatial problems (Tsou & Yanou, 2010).

Several previous scholars have constructed frameworks for spatial thinking. Gersmehl (2005) conceptualized spatial thinking based on several dimensions, including understanding of location, conditions, connections, comparison, influence, region, hierarchy, transition, analogy, patterns, association, exceptions, diffusion, and spatial models. Wakabayashi & Ishikawa (2011) state that spatial thinking consists of three elements, namely concepts of space, using tools of representation, and reasoning process. Previously, Jo & Bernarz (2009) also developed a taxonomy named the Taxonomy of Spatial Thinking to identify key aspects of spatial thinking and organize them systematically and consistently. The Taxonomy of Spatial Thinking comprises three main categories: concepts of space, using tools of representation, and reasoning process. Subsequently, Nguyen et al. (2019) constructed the SOLO taxonomy, which consists of a surface level (including unistructural and multistructural) and a deep level (including relational and extended abstract).

Geographic Information Systems in Geography Education

In GIS education, there are two distinct concepts, namely teaching about GIS and teaching with GIS. Teaching about GIS focuses on GIS technology with the goal of training students in the operation of GIS. In contrast, teaching with GIS concerns the use of the potential and benefits of GIS as a learning tool to achieve various educational objectives (Jo, Hong, & Verma, 2016). In this study, the focus is on teaching with GIS and other spatial technologies such as digital maps, remote sensing, and the global positioning system (GPS).

Sistem informasi geografis plays a crucial role in supporting learning. GIS is a highly important Geomedia application and a rapidly developing technology. GIS is a software system that provides broad access to geographical information that includes spatial components and tools to visualize, manipulate, analyze, and display geographic information quickly and flexibly. Therefore, GIS represents an ideal instrument for studying geographical problems. GIS offers numerous opportunities to implement inquiry projects in which students investigate geographic problems in real-world contexts (Favier & Schee, 2013).

GIS is an active learning method that encourages students to be engaged in the learning process while simultaneously bringing technology into the classroom. GIS helps students develop a wide range of skills, including analytical thinking, spatial perception, problem solving, digital literacy, communication, and presentation skills (Audet & Luwig, 2007). Using GIS in instruction helps students define problems, create and explore different representations of data and information, evaluate information, solve problems, and draw appropriate conclusions, thereby fostering higher-order critical thinking skills (Liu & Zhu, 2008). Chun (2010) presents several arguments explaining why GIS is highly important for teaching spatial thinking to students, namely:

a. GIS can facilitate scientific processes in formulating and solving problems, thereby providing examples of discovery- or inquiry-based learning that is student-centered.

b. GIS can be useful for solving problems in a wide range of real-world contexts and can serve as an effective tool to support scientific research and problem solving.

c. GIS has great potential to facilitate learning across different subjects, thereby enhancing interdisciplinary and multidisciplinary learning.

d. GIS can provide a comprehensive, generative, and challenging problem-solving environment, empowering students to address important issues using the same tools employed by professionals to solve their problems.

e. GIS has a special potential to accommodate diverse learners and can be accessed by all students, greatly supporting those who struggle in traditional forms of instruction.

f. GIS can be used effectively in various educational settings, can be integrated into the curriculum and whole-class instruction, and supports multiple modes of use, including individual, collaborative, and network-based learning.

Methods

This quantitative study aimed to analyze the influence of teachers' knowledge and awareness regarding the use of geospatial technologies on their actual classroom practices in integrating such technologies into geography instruction at the senior high school level. The research employed a survey design. To measure knowledge related to the use of geospatial technologies, the study adopted a framework from Purwanto et al. (2020), which comprises conceptual knowledge, implementation, and the use of technology for problem-solving and decision-making (reasoning). Conceptual knowledge concerns the concepts and theories of geospatial technologies. Implementation refers to methods and procedures for using geospatial technologies. Reasoning relates to how geospatial technologies are employed by prioritizing spatial thinking. To measure awareness and actual practice of geospatial technology use, the study used a modified framework based on Ates (2013), Degirmenci (2018), and Yap et al. (2008).

This quantitative study adopted a Survey Method: Explanatory Research design and employed Confirmatory Factor Analysis (CFA) 2nd-order and Structural Equation Modeling (SEM), implemented in two analytical stages using PLS-SEM. The analysis techniques were intended to identify the formation of sub-constructs for the variables of knowledge, awareness, and behavioral implementation of geospatial applications in geography teaching by senior high school teachers through 2nd-order CFA. Subsequently, the study confirmed construct formation at the indicator level (second level) and examined the effect of teachers' awareness on their behavioral implementation of geospatial applications through conceptual knowledge using 1st-order CFA and path analysis with PLS-SEM. The adopted framework consisted of conceptual knowledge, implementation, and the use of technology for problem-solving and decision-making (reasoning). Conceptual knowledge addresses the concepts and theories of geospatial technologies, implementation refers to methods and procedures of geospatial technology use, and reasoning concerns how geospatial technologies are used with an emphasis on spatial thinking.

The research subjects were senior high school geography teachers in Central Java Province, selected randomly. Respondents' profiles were described in terms of age, gender, and years of teaching experience to provide a more detailed characterization of the sample. Data were collected using a questionnaire that met established validity and reliability criteria and was rated on a four-point Likert scale (1–4). The questionnaire was completed directly by respondents via Google Forms. Questionnaire and observational data were entered into Microsoft Excel for tabulation, coding, and grouping according to variables, indicators, and sub-indicators, then saved in CSV format and exported into SmartPLS version 4.1. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with the aim of maximizing the R-square values and minimizing prediction residuals or errors (Sholihin & Ratmono, 2020: 7). The analysis procedure consisted of three stages, as follows.

2nd-Order CFA

In this stage, analyses and evaluations were conducted to establish the constructs of conceptual knowledge, teacher awareness, and implementation of geospatial applications. The 2nd-order CFA stage represents a higher-order CFA analysis in which each variable is examined down to its sub-indicators. The 2nd-order CFA output provides not only the goodness-of-fit of sub-indicators but also the estimated values for each indicator of conceptual knowledge, teacher awareness, and implementation of geospatial applications. Model evaluation comprised analysis of the outer model and the inner model. Outer model evaluation was conducted for each construct or measurement model separately by assessing convergent validity, discriminant validity, and internal consistency reliability (composite reliability and Cronbach's alpha).

Full Model Analysis

At this stage, the full model was analyzed and evaluated, with each variable specified as a 1st-order CFA construct. Model evaluation again comprised analysis of the outer and inner models. The 1st-order outer model evaluation was conducted for each construct or measurement model separately through the assessment of convergent validity, discriminant validity, and internal consistency reliability (composite reliability and Cronbach's alpha). In the inner model evaluation, three aspects were examined: the magnitude and direction (sign) of the path coefficients, the significance of the estimated parameters, and the coefficients of determination (R^2) and effect sizes. Indirect effects were evaluated alongside the inner model assessment.

If, during outer model testing, any construct was found to be invalid or unreliable, the model was revised (respecified) by eliminating the problematic construct. Evaluation of the moderating variable was carried out only at the inner model level by comparing p-values with the 0.05 threshold using the bootstrapping method.

The specification of the construct model in this study is presented in Figure 1, Figure 2, and Table 1 below.

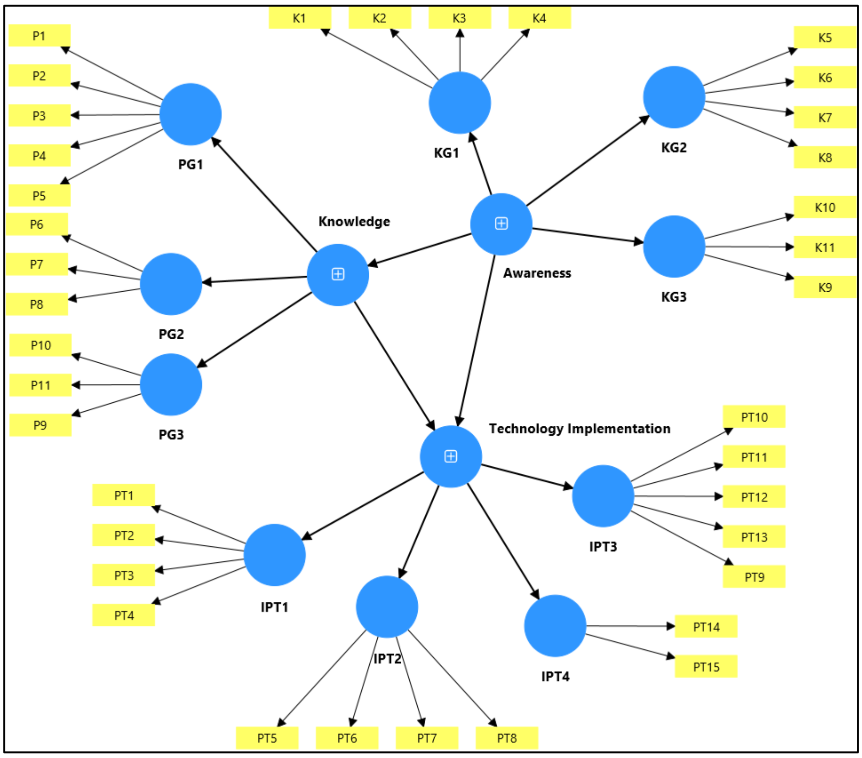

Figure 1. 2nd-Order CFA Model

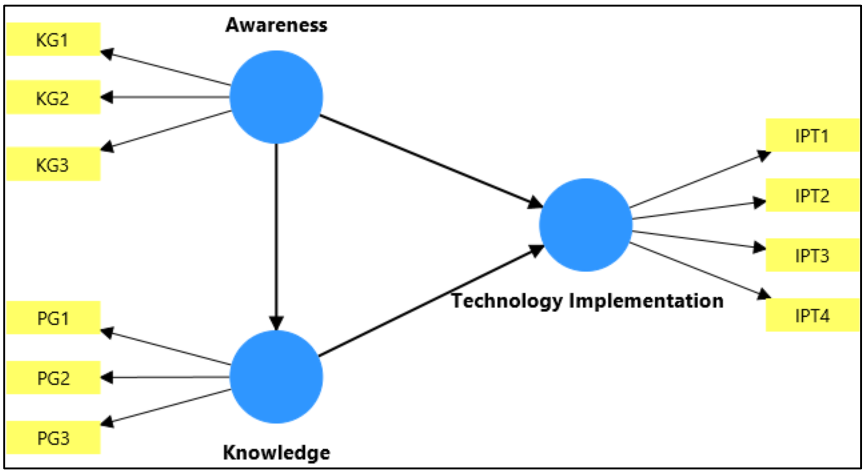

Figure 2. Full SEM Model

Table 1. Model Specification

Latent Variable	Indicator	Sub-Indicator	Code
Awareness	Awareness of Values and Urgency (KG1)	I am aware that geospatial technology is important in geography education.	K1
		I am aware that mastering geospatial technology will improve the quality of geography instruction.	K2
		I am aware that students need learning activities based on geospatial technology.	K3
		I am aware that the use of geospatial technology can enhance students' spatial thinking.	K4

	Awareness of Responsibility (KG3)	I actively participate in training on the use of GIS platforms to improve instructional quality.	K5
		I feel responsible for learning geospatial technology.	K6
		I am aware that the use of geospatial technology demands teachers' creativity.	K7
		I must become a teacher who masters GIS technology in order to realize high-quality instruction.	K8
	Awareness of Challenges and Obstacles (KG4)	I feel the need to continuously update my knowledge of geospatial technology.	K9
		I have a strong interest in mastering geospatial technology.	K10
		I think that the application of spatial technology in teaching is more suitable for young teachers than for senior teachers.	K11
Knowledge	Conceptual Knowledge (PG1)	I know examples of virtual globe applications such as Google Earth.	P1
		I understand the main components of GIS (software, data, people, hardware, methods).	P2
		I understand the basic concepts of remote sensing technology.	P3
		I know the benefits of using geospatial technology in geography education.	P4
		I know examples of vector data in GIS, such as road maps, and raster data.	P5
	Reasoning (PG2)	I can explain examples of using GIS to solve spatial problems.	P6
		I understand the function of high-resolution satellite imagery for land cover analysis.	P7
		I have a clear understanding of the function of each type of spatial data according to its intended use.	P8
	Implementation Knowledge (PG3)	I know how to use GPS to measure coordinates in the field.	P9
		I know various types of innovative GIS software that can be used in teaching.	P10
		I know how to obtain spatial data easily.	P11
Technology Implementation	Frequency of Use (IPT1)	I am aware that mastering geospatial technology will improve the quality of geography instruction.	PT1
		I am aware that students need learning activities based on geospatial technology.	PT2
		I am aware that the use of geospatial technology can enhance students' spatial thinking.	PT3
		I actively participate in training on the use of GIS platforms to improve instructional quality.	PT4
	Type of Technology Used (IPT2)	I feel the need to continuously update my knowledge of geospatial technology.	PT5
		I have a strong interest in mastering geospatial technology.	PT6
		I feel responsible for learning geospatial technology.	PT7
		I must become a teacher who masters GIS technology in order to realize high-quality instruction.	PT8
	Integration in Learning (IPT3)	I am aware that geospatial technology is important in geography education.	PT9
		I am aware that the use of geospatial technology demands teachers' creativity.	PT10
		I ask students to analyze digital maps to understand geography content.	PT11

		I integrate geospatial technology into lesson plans for geography instruction.	PT12
		I utilize spatial data to explain geographic phenomena in the classroom.	PT13
	Purpose of Use (IPT4)	I provide examples of the use of geospatial technology in everyday life when teaching.	PT14
		I use geospatial technology to help students analyze geographic phenomena in depth.	PT15

Results And Discusson

Senior high school geography teachers in Central Java Province who participated in this study numbered 110 respondents, whose general characteristics are summarized in Table 2.

Table 2. Respondent' Characteristics

Characteristics		Age (year)					
		<30		31-40		>40	
		N	N%	N	N%	N	N%
Gender	Males	12	52,17	29	64,44	22	52,38
	Females	11	47,83	16	35,56	20	47,62
Teaching experience	1-2 years	10	43,48	2	4,44	-	-
	2-5 years	11	47,83	4	8,89	-	-
	5-10 years	2	8,70	26	57,78	-	-
	>10 years	-	-	13	28,89	42	100
Total		23	100	45	100	42	100

Based on Table 2, the respondents are grouped into three age ranges: under 30 years, 30–40 years, and over 40 years. The majority of geography teachers in senior high schools across Central Java are female, particularly in the 31–40 age range (64.44% of 45 respondents) and in the over-40 age group (52.38% of 42 respondents). Most respondents in the under-30 and 30–40 age groups have 1–5 years of teaching experience, whereas in the over-40 group all respondents have more than 10 years of teaching experience. The detailed characteristics of the research variables are described using descriptive statistics (Table 3), which present means, standard deviations, and mean-score categories. Following Levine, Stephan, Krehbiel, and Brenson (2008), mean scores on a four-point scale are classified into three categories: low (1–2), medium (2.1–3), and high (3.1–4).

Table 3. Descriptive Statistics of Research Variables

		Usia					
Variable	Indicator/Sub-Indicator	<30		31-40		>40	
		Mean ± St.Dev	Criteria	Mean ± St.Dev	Criteria	Mean ± St.Dev	Criteria
Awarness	Awareness of Values and Urgency	3,7 ± 0,5	high	3,6 ± 0,6	high	3,5 ± 0,6	high
	K1	3,7 ± 0,7	high	3,6 ± 0,5	high	3,6 ± 0,7	high
	K2	3,7 ± 0,4	high	3,7 ± 0,6	high	3,6 ± 0,5	high
	K3	3,6 ± 0,5	high	3,6 ± 0,6	high	3,5 ± 0,5	high
	K4	3,6 ± 0,5	high	3,6 ± 0,5	high	3,5 ± 0,5	high
	Awareness of Responsibility	3,2 ± 0,6	high	3,3 ± 0,5	high	3,2 ± 0,6	high
	K5	2,5 ± 0,7	high	2,7 ± 0,6	medium	2,9 ± 0,7	medium

	K6	3,3 ± 0,6	high	3,3 ± 0,5	high	3,2 ± 0,5	high
	K7	3,6 ± 0,5	high	3,5 ± 0,5	high	3,3 ± 0,5	high
	K8	3,2 ± 0,6	high	3,5 ± 0,5	high	3,3 ± 0,7	high
	Awareness of Challenges and Obstacles	3,5 ± 0,5	high	3,4 ± 0,6	high	3,4 ± 0,6	high
	K9	3,8 ± 0,4	high	3,7 ± 0,5	high	3,6 ± 0,6	high
	K10	3,6 ± 0,6	high	3,5 ± 0,5	high	3,4 ± 0,6	high
	K11	3 ± 0,6	high	3,1 ± 0,7	high	3,1 ± 0,7	high
Knowledge	Conceptual Knowledge	3,4 ± 0,4	high	3,4 ± 0,6	high	3,3 ± 0,6	high
	P1	3,6 ± 0,6	high	3,6 ± 0,5	high	3,4 ± 0,6	high
	P2	3,4 ± 0,5	high	3,5 ± 0,5	high	3,4 ± 0,7	high
	P3	3,3 ± 0,6	high	3,2 ± 0,7	high	3,4 ± 0,5	high
	P4	3,5 ± 0,5	high	3,5 ± 0,5	high	3,3 ± 0,6	high
	P5	3,4 ± 0,6	high	3,3 ± 0,6	high	3,1 ± 0,6	high
	Reasoning	3,1 ± 0,7	high	3,2 ± 0,6	high	3,1 ± 0,5	high
	P6	3,2 ± 0,6	high	3,3 ± 0,5	high	3,3 ± 0,5	high
	P7	3,1 ± 0,7	high	3,2 ± 0,6	high	3,1 ± 0,5	high
	P8	2,9 ± 0,7	high	3,1 ± 0,7	high	2,9 ± 0,6	medium
	Implementation Knowledge	3,1 ± 0,6	high	3 ± 0,6	medium	2,9 ± 0,6	medium
	P9	3,2 ± 0,6	high	3,2 ± 0,6	high	3 ± 0,7	medium
	P10	2,8 ± 0,6	medium	2,9 ± 0,7	medium	2,8 ± 0,6	medium
	P11	3,2 ± 0,7	high	3 ± 0,5	medium	2,9 ± 0,6	medium
Technology Implementation	Frequency of Use	3 ± 0,7	medium	3,1 ± 0,7	high	2,8 ± 0,6	medium
	PT1	2,6 ± 0,8	medium	2,9 ± 0,7	medium	2,7 ± 0,7	medium
	PT2	3,1 ± 0,7	high	3,3 ± 0,7	high	3 ± 0,6	medium
	PT3	2,7 ± 0,7	medium	3 ± 0,6	medium	2,7 ± 0,6	medium
	PT4	3,5 ± 0,7	high	3,3 ± 0,6	high	2,9 ± 0,6	medium
	Type of Technology Used	3,2 ± 0,8	high	2,9 ± 0,8	medium	2,8 ± 0,6	medium
	PT5	3,6 ± 0,5	high	3,3 ± 0,7	high	3,2 ± 0,6	high

	PT6	3 ± 0,9	medium	2,8 ± 0,7	medium	2,7 ± 0,7	medium
	PT7	2,9 ± 0,8	medium	2,5 ± 0,8	medium	2,4 ± 0,6	medium
	PT8	3,1 ± 0,9	high	3,1 ± 0,8	high	2,9 ± 0,5	medium
	Integration in Learning	3,2 ± 0,6	high	3,2 ± 0,6	high	3 ± 0,5	medium
	PT9	3,2 ± 0,7	high	3,4 ± 0,6	high	3,2 ± 0,6	high
	PT10	3,1 ± 0,8	high	2,9 ± 0,7	medium	2,6 ± 0,5	medium
	PT11	3,5 ± 0,5	high	3,4 ± 0,5	high	3,1 ± 0,5	high
	PT12	3,2 ± 0,6	high	3,2 ± 0,7	high	3,1 ± 0,4	high
	PT13	3,2 ± 0,6	high	3,3 ± 0,5	high	3,2 ± 0,4	high
	Purpose of Use	3,3 ± 0,6	high	3,3 ± 0,6	high	3,2 ± 0,5	high
	PT14	3,3 ± 0,6	high	3,3 ± 0,6	high	3,1 ± 0,5	high
	PT15	3,2 ± 0,6	high	3,3 ± 0,6	high	3,2 ± 0,5	high

The results in Table 3 show that sub-indicator K5 falls into the medium category, indicating that teachers in all three age groups are relatively inactive in attending training on GIS platforms, which can negatively affect the quality of instruction. In addition, item K11 shows that teachers aged 30–40 years and over 40 years acknowledge that geospatial technology is more suitable for younger than for senior teachers. The findings also indicate that teachers aged 30–40 years have a better understanding of the functions of different types of spatial data for specific purposes than those under 30 and over 40, whereas teachers under 30 find it easier to obtain spatial data. Moreover, teachers over 40 years of age have weaker understanding of how to use GPS to measure coordinates in the field, suggesting that teachers under 30 and those aged 30–40 are more adaptive to technological developments.

For the Frequency of Use indicator, all three age groups show limited awareness that mastering geospatial technology can improve the quality of geography instruction and enhance students' spatial thinking. Teachers over 40 years old also show limited awareness that geospatial-technology-based geography learning is important for students' needs, and this group is less active in participating in GIS platform training, even though such training can improve teaching quality.

For the Type of Technology Used indicator, all three age groups report high interest in mastering geospatial technology and a sense of responsibility to learn it. The results also reveal that teachers under 30 and those aged 30–40 have higher levels of geospatial technology proficiency that can enhance instructional quality than teachers over 40. Regarding the Integration in Learning indicator, only teachers under 30 recognize that the use of geospatial technology demands teacher creativity, which suggests that this age group is more creative in employing geospatial technologies to achieve high-quality learning.

Subsequently, the analysis was extended to confirm the constructs at the sub-structural (sub-indicator) level, as presented in Figure 3, and the evaluation results are summarized in Table 4.

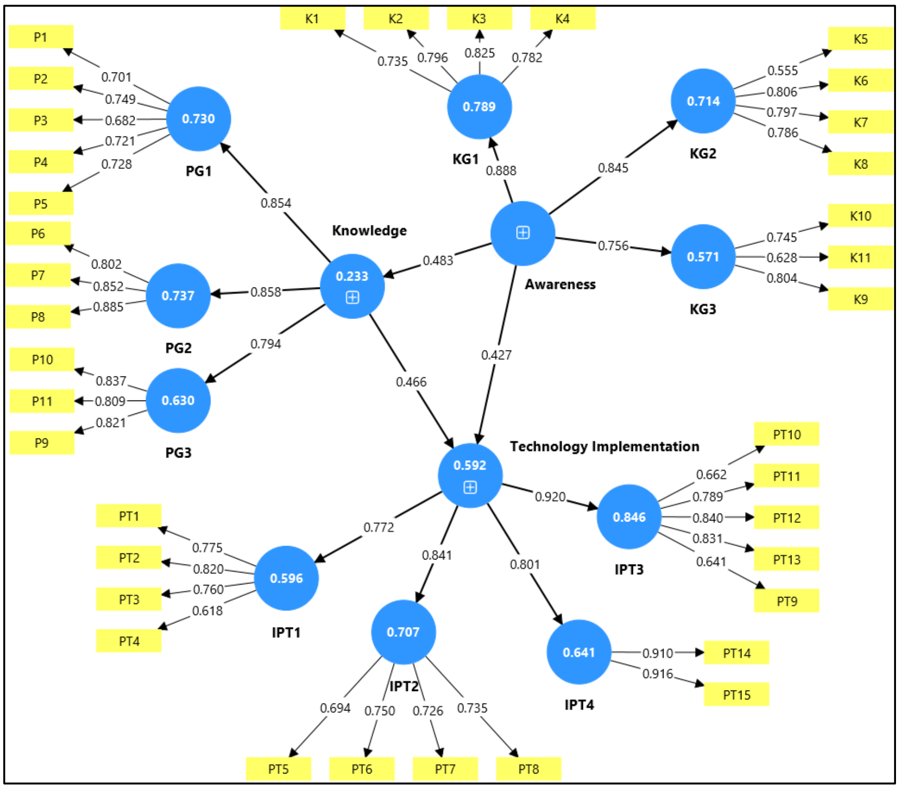

Figure 3. CFA Model at the Sub-indicator Level

Visually, no loading factor values at the sub-indicator level for the awareness, knowledge, and technology implementation variables are negative or below 0.60, so the analysis can proceed to the evaluation of convergent validity and construct reliability at the sub-indicator level, as presented in Table 4.

Table 4. Evaluation of Convergent Validity and Construct Reliability at the Sub-indicator Level

Latent Variable	Indicator	Sub-Indicator	LF	AVE	CA	CR
Awareness	Awareness of Values and Urgency (KG1)	K1	0.735	0.617	0.793	0.865
		K2	0.796			
		K3	0.825			
		K4	0.782			
	Awareness of Responsibility (KG2)	K5	0.555	0.552	0.726	0.829
		K6	0.806			
		K7	0.797			
		K8	0.786			
	Awareness of Challenges and Obstacles (KG3)	K9	0.804	0.532	0.563	0.771
		K10	0.745			
		K11	0.628			
Knowledge	Conceptual Knowledge (PG1)	P1	0.701	0.513	0.763	0.841
		P2	0.749			
		P3	0.682			
		P4	0.721			
		P5	0.728			
	Reasoning (PG2)	P6	0.802	0.717	0.802	0.884
		P7	0.852			
		P8	0.885			

	Implementation Knowledge (PG3)	P9	0.821	0.676	0.761	0.862
		P10	0.837			
		P11	0.809			
Technology Implementation	Frequency of Use (IPT1)	PT1	0.775	0.558	0.730	0.833
		PT2	0.820			
		PT3	0.760			
		PT4	0.618			
	Type of Technology Used (IPT2)	PT5	0.694	0.528	0.703	0.817
		PT6	0.750			
		PT7	0.726			
		PT8	0.735			
	Integration in Learning (IPT3)	PT9	0.641	0.573	0.809	0.869
		PT10	0.662			
		PT11	0.789			
		PT12	0.840			
		PT13	0.831			
	Purpose of Use (IPT4)	PT14	0.910	0.834	0.801	0.910
		PT15	0.916			
Notes: LF = Loading Factor; CA = Cronbach's Alpha; CR = Composite Reliability; AVE = Average Varian Extracted; LF ≥ 0.7 or 0.6≤CA≤0.7 still acceptable; CA >0.7 or 0.6<CA<0.7 still acceptable; CR >0.6 and AVE ≥0.5 acceptable						

Table 4 shows that at the sub-indicator level, all constructs have loading factor and AVE values greater than 0.70 or within the 0.60–0.70 range for each latent variable. The loading factor (LF) for sub-indicator K5 is 0.555, which can still be considered acceptable for retention in the construct model, particularly in social science research (Hair et al., 2021). Most Cronbach's alpha (CA) values for the indicator-level constructs exceed 0.70, except for the Awareness of Challenges and Obstacles (KG3) indicator, which has a CA value below 0.70 (0.563). Overall, however, the constructs are judged to have good reliability because the composite reliability (CR) values are high, exceeding 0.75. Although there is some evidence of limited internal consistency at the item level (as reflected in the lower Cronbach's alpha), the instrument as a whole demonstrates acceptable reliability (as reflected in the higher CR values). Several scholars also note that CA values above 0.50 may still be sufficient for low-stakes reliability requirements.

Discriminant validity at the sub-indicator level was also evaluated to ensure that each sub-indicator within a given construct is conceptually distinct and does not overlap with sub-indicators of other indicator-level constructs, either within the same latent variable or across different latent variables. In this study, discriminant validity assessment yielded HTMT values below 0.90, and the Fornell–Larcker criterion indicated that the square root of AVE for each construct was higher than its correlations with other latent variables. These results confirm that the constructs at the sub-indicator level possess satisfactory discriminant validity.

Since the sub-indicator level meets the requirements for convergent validity, discriminant validity, and reliability, the analysis can be advanced to the full model at the 1st-order CFA level by extracting the true score values for each indicator from its sub-indicators. The resulting full measurement model at the 1st-order CFA level is presented in Figure 4.

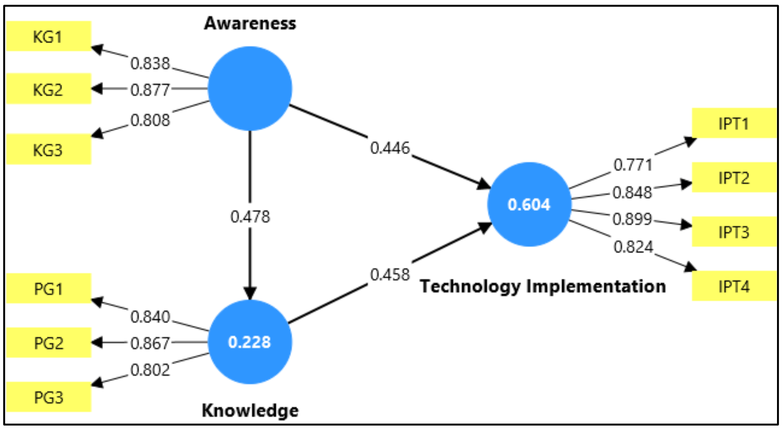

Figure 4. Full SEM Model Analysis at the Indicator Level

Figure 4 shows that none of the indicator loading factors are negative or below 0.70, indicating that the relationships between indicators and their respective latent variables are valid and characterized by high loading values. This supports the adequacy of the measurement model at the indicator level. The details of convergent validity and construct reliability at the indicator level are presented in Table 5.

Table 5. Evaluation of Convergent Validity and Construct Reliability at the Indicator Level

Latent Variable	Indicator	LF	AVE	CA	CR
Awareness	Awareness of Values and Urgency (KG1)	0.838	0.708	0.800	0.879
	Awareness of Responsibility (KG2)	0.877			
	Awareness of Challenges and Obstacles (KG3)	0.808			
Knowledge	Conceptual Knowledge (PG1)	0.840	0.700	0.786	0.875
	Reasoning (PG2)	0.867			
	Implementation Knowledge (PG3)	0.802			
Technology Implementation	Frequency of Use (IPT1)	0.771	0.700	0.856	0.903
	Type of Technology Used (IPT2)	0.848			
	Integration in Learning (IPT3)	0.899			
	Purpose of Use (IPT4)	0.824			
Notes: LF = Loading Factor; CA = Cronbach's Alpha; CR = Composite Reliability; AVE = Average Varian Extracted; LF ≥ 0.6; CA >0.7; CR >0.6 and AVE ≥0.5 acceptable					

The convergent validity analysis indicates that each indicator is valid and robust in reflecting its corresponding latent variables of awareness, knowledge, and technology implementation, as evidenced by loading factors greater than 0.70 and Average Variance Extracted (AVE) values above 0.50. Discriminant validity at the indicator level is also satisfactory, with HTMT values below 0.90 and the square roots of AVE exceeding the inter-latent-variable correlations, demonstrating that the constructs are empirically distinct. Cronbach's alpha and composite reliability values above 0.75 further indicate very good reliability for the indicators reflecting awareness, knowledge, and technology implementation.

Another notable finding in Table 4 is that Responsibility (KG2) emerges as the most important component in shaping teachers' awareness of developing geography instruction using GIS applications.

This is reflected in its highest loading factor (0.877) among the awareness indicators. Nevertheless, the loading factors for Values and Urgency (KG1) and Challenges and Obstacles (KG3), both above 0.80, also show that perceived values, urgency, and challenges associated with implementing GIS applications in senior high school geography lessons are important dimensions of teacher awareness.

Within the knowledge variable, the strongest contributing factors are Conceptual Knowledge (0.840) and Reasoning (0.867). This suggests that teachers' knowledge of GIS applications can be strengthened by deepening their understanding of basic concepts as well as the functions and applications of supporting components. For technology implementation, Type of Technology Used (IPT2) and Integration in Learning (IPT3) are the indicators with the highest loading factors. This implies that teachers should continuously update their knowledge of GIS applications, maintain a strong interest in using them, explore them in depth, and systematically integrate GIS into geography instruction.

The outer model evaluation at both the sub-indicator and indicator levels confirms that the constructs are valid and reliable representations of the research variables. Therefore, the analysis proceeds to the inner model evaluation, which examines the relationships among latent variables in order to test the research hypotheses. The complete inner model evaluation results are presented in Table 5.

Table 5. Hypothesis Testing Results

Path	Coeff	T statistics	P values	f-square	R-square
Awareness -> Technology Implementation	0.446	7.168	0.000	0.387	0.604
Knowledge -> Technology Implementation	0.458	7.461	0.000	0.408	
Awareness -> Knowledge	0.478	6.488	0.000	0.296	0.228
Awareness -> Knowledge -> Technology Implementation	0.219	4.551	0.000		
Note: p-value<0.05 = significant					

The joint effect of Awareness and Knowledge on Technology Implementation is positive and significant, with a medium effect size of 0.604 (60.4%). This result is reinforced by f-square values in the high category (f-square > 0.35) for the paths from Awareness and Knowledge to Technology Implementation. These findings indicate that high levels of teacher awareness, combined with adequate conceptual knowledge, positively influence the implementation of GIS applications in geography teaching.

Recognizing that students require geospatial-technology-based learning to solve geographical problems motivates senior high school teachers to study GIS more deeply, to show interest, and to feel responsible for mastering and applying GIS in their teaching. High teacher awareness of the need for GIS to visualize and facilitate geography learning also drives teachers to continually update their skills in using GIS applications, for example by attending training or engaging in self-directed learning. Accordingly, high teacher awareness exerts a positive influence on teachers' conceptual knowledge of GIS, as reflected in Table 5 by a meaningful positive effect of awareness on knowledge with a medium effect size (f-square = 0.296).

A significant positive indirect relationship is also found between awareness and technology implementation through knowledge. Teachers' conceptual knowledge of GIS serves as a partial mediator of the effect of awareness on implementation. This means that geography teachers who are aware of the importance and urgency of using GIS to address instructional problems, but lack sufficient knowledge, are less able to implement GIS effectively. Indirectly, adequate conceptual understanding of GIS technologies—such as using Google Earth, applying spatial and vector data in GIS, and operating GPS—facilitates teachers' implementation of GIS to enhance instructional quality, for example by enabling students to create digital maps or analyze geographic phenomena in depth.

Discussion

The findings of this study underscore that both geospatial knowledge and geospatial awareness exert significant effects on the implementation of geospatial technologies in senior high school geography classrooms. This result aligns with diffusion of innovation theory and the TPACK integration model, which emphasize that technology adoption is shaped not only by awareness or willingness but also by individuals' cognitive and technical capabilities (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

The evidence indicates that realizing meaningful geography instruction grounded in spatial thinking requires two interconnected emphases: strengthening teachers' awareness and enhancing their cognitive and technical competence in using geospatial technologies. In practice, geography teachers in Indonesia generally display willingness and awareness to integrate geospatial technologies into instruction, yet actual classroom implementation remains constrained by gaps in knowledge.

A key contribution of this study lies in the mediating mechanism identified between awareness, knowledge, and implementation. The results show that awareness alone is insufficient to increase the use of geospatial technologies in geography teaching; its influence becomes meaningful only when mediated by knowledge. In other words, teachers who recognize the urgency of using geospatial technologies in instruction do not automatically implement them; instead, their awareness motivates them to learn, and this enhanced knowledge then translates into concrete practice. This highlights a psychological mechanism in which awareness stimulates a willingness to learn, which eventually leads to actual behavior, a pattern that is consistent with self-determination theory (Ryan & Deci, 2000). The logical implication is the importance of teacher education programs that integrate the cultivation of awareness with the development of substantive knowledge about geospatial technology use.

The study also identifies which factors exert the strongest influence and should therefore be prioritized in intervention efforts. Within the knowledge construct, the most prominent indicators are Reasoning (0.867) and Conceptual Knowledge (0.840). These results suggest that efforts to enhance teachers' knowledge of geospatial technology use should focus on strengthening their mastery of core concepts and the functionalities of key GIS components as a foundational base. In addition, teachers' understanding of the functions of various GIS analyses—particularly those aimed at solving spatial problems and fostering higher-order thinking skills (HOTS) in students—needs to be systematically improved. Within the awareness construct, the strongest indicator is Awareness of Responsibility (0.877), underscoring the need to reinforce teachers' sense of pedagogical responsibility to create engaging, innovative, and spatially informed learning experiences. At the same time, awareness of the importance of geospatial technologies and awareness of challenges and obstacles must also be fostered so that teachers recognize that geospatial-technology-based instruction can be implemented even with relatively simple tools, such as using smartphones to access Google Earth or Google Maps.

For the implementation construct, the indicators with the highest influence are Integration in Learning (0.899) and Type of Technology Used (0.848). These findings indicate that teachers need to continuously upgrade their skills in using diverse and up-to-date spatial technologies and must be able to integrate geospatial technologies into geography instruction in a systematic manner, rather than using them sporadically. Integration should extend to formal lesson planning documents, so that teaching with GIS, rather than merely teaching about GIS, becomes an organizing principle for geography instruction. The results also highlight that the main barriers to implementing geospatial technologies in geography learning are not attitudinal or awareness-based but instead relate to technical competence and access to training. Even when teachers have high awareness, the absence of adequate knowledge and skills prevents the realization of geospatial-technology-based learning, as reflected in the low scores for participation in GIS training and the evident need for continuous professional development. This supports arguments that geospatial technology adoption in developing countries is shaped not only by personal preferences but also by structural constraints.

The study further reveals a clear generational gap in the use of geospatial technologies. Overall, teachers under 30 and those aged 30–40 use geospatial technologies more extensively than teachers over 40, indicating the need for differentiated training programs tailored to age groups and levels of technological experience. Beyond its empirical results, this research enriches the literature on geospatial technology use in developing-country contexts. Much of the existing GIS-in-education literature originates from developed countries such as the United States, European nations, and Australia, whereas the Indonesian context offers a distinct perspective. The findings show that teachers possess high awareness but moderate competence, reflecting a common pattern in developing settings where infrastructure gaps persist. The validated SEM model provides a comprehensive explanatory framework that can be used by future researchers and policymakers to understand psychological, pedagogical, and infrastructural drivers of geospatial technology adoption in schools.

Conclusions And Implications

This study provides empirical evidence that geospatial technology adoption follows a systematic psychological mechanism reinforcing the awareness–knowledge–practice model. The validated SEM model offers a flexible and adaptable structure for measuring geospatial technology adoption across diverse cultural and developmental contexts. The mediating effects observed contribute to the literature on self-efficacy, illustrating that awareness must be supported by competence before it can effectively shape behavior. Generational differences lend support to digital classification theories and highlight the importance of demographic moderators in technology adoption research.

Teacher training should prioritize workshops and hands-on practice rather than purely theoretical seminars, with an emphasis on enhancing spatial reasoning and operational skills. Professional development programs need to be differentiated for younger and older teachers to address disparities in digital proficiency. Schools should provide structural support in the form of software access, technical assistance, and curricular guidelines to normalize the use of GIS in geography classrooms. Policymakers, in turn, should develop a national framework to mainstream GIS education in line with global trends in geospatial literacy. Integrating geospatial literacy into formal curriculum design, teacher association activities, and teacher certification programs is also essential.

This study relies on self-reported survey data, which may be subject to perceptual bias. It does not fully capture classroom dynamics, digital barriers, or variation in technological ownership and sophistication across schools. Moreover, the variables examined do not yet include potential moderators such as institutional support, access to training, and technology availability. Future research should therefore conduct longitudinal studies to track changes in teachers' knowledge and awareness before and after GIS training programs. Subsequent studies are also encouraged to integrate variables related to institutional and infrastructural support to produce more holistic findings. Equally important is expanding the contextual scope, for example by considering variation in school quality, technological advancement, and cross-national differences in technology development and cultural perceptions, in order to deepen understanding of geospatial technology adoption in education.

References

1. Aladag, E. (2014). An evaluation of geographic information systems in social studies lessons: teachers' view. Education Science: Tehory & Practice, 14(4), 1533-1539.
2. Artvinli, E. (2010). The contribution of geographic information systems (GIS) to geography education and secondary school students' attitude related to GIS. Educational Sciences: Theory & Practice, 10(3), 1277-1292.
3. Ates, M. (2013). Geography teachers' perspective towards geography education with Geographic Information Systems (GIS). International Journal of Innovative Research in Science, Engineering and Technnology, 2(10), 5124-5130.
4. Audet, R. & Luwig, G. (2000). GIS in Schols. ESRI Press, Redlands, CA.
5. Bernarz, S. W. (2004). Geographic information systems: A tool to support geography and environmental education, GeoJournal, 60(2), 191-199.
6. Bernarz, S. W. & Schee, J. V. D. (2006). Europe and the United States: The implementation of geographic information systems in secondary education in two contexts. Technology, Pedagogy and Education, 15(2), 191-205.
7. 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.
8. Chun, B. A. (2010). Effect of GIS-integrated lessons on spatial thinking abilities and geographiccal skills. Journal of the Korean Geographical Society, 45(6), 820-844.
9. Collins, L. (2018). The impactof paper versus digital map technology on students' spatial thinking skills acquisition. Journal of Geography, 117(4), 137-152.
10. Degirmenci, Y. (2018). Use of geographic information system (GIS) in geography lessons according to teachers' opinion. World Journal on Educational Technology: Current Issues, 10(3), 186-196.
11. DeMers, M. N. (2016). Geospatial technology in geography education. The Geography Teacher, 13(1), 23-25.
12. Demirci, A., Kraburun, A., & Arslan, S. (2019). Comparing learning geography with ArcGIS online and desktop. J-Reading, Journal of Research and Didactices in Geography, 1, 27-40.
13. Favier, T. T., & Van der Schee, J. A. (2014). The effects of geography lessons with geospatial technologies on
14. the development of high school students' relational thinking. Computers & Education, 76, 225-236.
15. Gersmehl, P. (2005). Teaching Geography. New York: Guilford Press.
16. Gersmehl, P. (2008). Teaching Geography. New York: Guilford Press.

17. Gonzalez, R. D. M. (2013). Innovative learning approaches to secondary school geography in Europe: New challenges in the curriculum. In Innovative learning geography in Europe: new challenges for the 21st century.
18. Hadi, B. S., Mukminan, Siasah M, M., Sariyono, K. E. (2021). The effect of Google Earth-Assisted remote sensing learning on students' spatial thinking ability in solving disaster mitigation problems. IOP Conf. Series: Earth and Environmental Science 884, 1-8.
19. Hair, J.F. et al. (2021) Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R, Practical Assessment, Research and Evaluation.
20. Heffron, S. G. & Downs, R. M. (2012). Geography for life: National Geography Standards (2nd Edition). Washington DC: National Council for Geographic Education.
21. Hespanha, S. R., Goodchild, F., & Janelle, D. G. (2009). Spatial thinking and technologies in the undergraduate social science classroom. Journal of Geography in Higher Education, 33(S1), S17-S27.
22. Jo, I. & Bernarz, S. W. (2009). Evaluating geography textbook questions from a spatial perspective: Using concepts of space, tools of representation, and cognitive process to evaluate spatiality. Journal of Geography, 108, 4-13.
23. Jo, I. & Hong, J. E. (2020). Effect of learning GIS on spatial concept understanding. Journal of Geography, Geography, DOI: 10.1080/00221341.2020.1745870.
24. Jo, I., Hong, J. E., & Verma, K. (2016). Facilitating spatial thinking in world geography using web-based GIS. Journal of Geography in Higher Education, 40(3), 442-459.
25. Kapluhan, E. (2014). The importance and necessity of the use of geographic information system (GIS) in geography teaching. Marmara Geographical Review, 29, 34-59.
26. Kerr, S. (2016). Integrating geospatial technologies into existing teacher education coursework: Theoretical and practical notes from the field. Contemporary Issues in Technology and Teacher Education, 16(3), 328-347.
27. Kerski, J. J., Demirci, A., & Milson, A. J. (2014). The global landscape of GIS in secondary education. Journal of Geography, 112(6), 232-247.
28. Kim, M., Bernarz, R., & Lee, S. (2011). GIS education for teachers in South Korea: Who participates and why ? Journal of the Korean Geographical Society, 46(2), 382-395.
29. Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? Contemporary Issues in Technology and Teacher Education, 9 (1), 60–70.
30. Lee, J. & Bernarz, R. (2009). Effect of GIS learning on spatial thinking. Journal of Geography in Higher Education, 33(2), 183-198.
31. Levine, Stephan, Krehbiel, dan Berenson, Statistics for Managers Using Microsoft Excel , Fifth Edition, Pearson Prentice Hall, 2008.
32. Liu, S. & Zhu, X. (2008). Designing a structural and interactive learning environment based on GIS for secondary geography education. Journal of Geography, 107(1), 12-19.
33. Malek, S. A., Jaafar, M., Aiyub, K., & Mayalagu, G. (2020). Higher-order thinking skills (HOTS) strengthening potential through the GIS story map application in history subjects. International Journal of Science and Technology, 29(1), 801-814.
34. Mansfild, D. (1994). The importance of geography in the school curriculum. National Council for Geographic Education 16A Leonard Hall, Indiana University of Pennsylvania, Indiana, 15705-1087.
35. Mayalagu, G., Jaafar, M., Choy, L. K., & Mahmud, M. I. (2020). The effectiveness of geographic information system (GIS) on spatial thinking skills (STS) among geography students. International Journal of Advanced Science and Technology, 29(9s), 1000-1009.
36. Mayalagu, G., Jaafar, M., Choy, L. K. (2018). Validity of module geographic information system-spatial thinking skills (GIS-STS). International Journal of Engineering & Technology, 7(4.34), 427-430.
37. Metoyer, S. & Bernraz, R. (2017). Spatial thinking assists geographic thinking: Evidence from a study exploring the effects of geospatial technology. Journal of Geography, 116(1), 20-33.
38. Millsaps, L. T. & Harrington, J. A. (2017). A time-sensitive framework for inluding geographic information system (GIS) in professional development activities for classroom teachers. Journal of Geography, 1341, 1-13.
39. Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. Teachers College Record, 108 (6), 1017–1054.
40. Mzuza, M. K. & Westhuizen, C. P. V. D. (2019). Review on the state of GIS application in secondary schools in the southern African region. South African Geographical Journal, DOI: 10.1080/03736245.2019.1579110.
41. Ngoc-AnhNguyen, Muniz-Solari, O., Dang, D. T., & Nguyen, T. P. (2019). Reviewing spatial thinking in geography textbooks questions from the peprspective of spatial thinking. IOP Conf. Series: Earth and Environmental Science, 338, 1-10.
42. Purwanto, Utaya, B., Handoyo, B., & Bachri, S. (2020). Transformation of geospatial technology knowledge in pre-service and experienced geography teachers as pedagogical tools in the technological-pedagogical-content knowledge framework. International Journal of Learning, Teaching and Educational Research, 19(9), 58-76.
43. Ridha, S., Utaya, S., Bachri, S. & Handoyo, B. (2019). Students' geographic skills in Indonesia: Evaluating GIS learning material questions using taxonomy of spatial thinking. Journal of Social Studeis Education Research, 10(4), 266-287.

44. Roulston, S. (2013). GIS in Northern Ireland secondary scholls: mapping where we are now. International Research in Geographical and Environmental Education, 22(1), 41-56.
45. Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68.
46. Saputro, R., Setyowati, D. L., Hardati, P. (2019). The students spatial critical thinking skill by using map and remote sensing imagery on geography lesson. Advances in Social Science, Education and Humanities Research, 443, 250-254.
47. Schee, J. V. D., Trimp, H., Beneker, T., & Favier, T. (2015). Digital geography education in the twenty-first century: Needs and opportunities. In Geospatial Technologies and Geography Education in a Changing World, Advances in geographical and Environmental Sciences, DOI: 10.1007/978-4-431-55519-3_2.
48. Singh, S. S. B., Rathakrishnan, B., Sharif, S., Talin, R., & Eboy, O. V. (2016). The effects of geography information system (GIS) based teaching on underachieving students' mastery goal and achievement. TOJET: The Turkish Online Journal of Educational Technology, 15(4), 119-134.
49. Stojsic, I., Ivkov-Digurski, A., & Marcic, O. (2019). The readiness of geography teachers to use mobile devices in the context of immersive technologies integration into the teaching process. Geographica Pannonica, 32(2), 121-133.
50. Tastan, B. (2021). Teaching and certification in Geographic Information Systems (GIS). International Journal of Social and Educational Sciences, 3(4), 69-86.
51. Tsou, M. & Yanow, K. (2009). Enhancing general education with geographic information science and spatial literacy. Urisa Journal, 22(2), 45-55.
52. Turkuresin, H. E. (2021). The effect of using technology in education on academic achievement of students: The case of geographical information systems. Education Quarterly Reviews, 4(2), 455-468.
53. Vega, A. G. D. L. (2019). Spatial thinking ability acquisition through geospatial technologies for lifelong learning. In Geospatial Technologies in Geography Education, 21-40.
54. Wakabayasih, Y. & Ishikawa, T. (2011). Spatial thinking in geographic information science: a review of past studies and prospects for the future. Procedia Social and Behavioral Sciences 21, 304-313.
55. Xiang, X. & Liut, Y. (2016). Understanding change through spatial thinking using Google Earth in secondary geography. Journal of Computer Assisted Learning, 1-14, DOI: 10.1111/jcal.12166
56. Yap, L. Y., Tan, G. C. I., Zhu, X., & Wettasinghe, M. C. (2008). An assessment of the use of geographical information system (GIS) in teaching geography in Singapore schools. Journal of Geography, 107(2), 52-60.