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Geography Teachers' Technological, Pedagogical, and Content Knowledge and Practical Challenges in Integrating Geospatial Technology in Secondary Schools in Bale Zone, Ethiopia

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Abstract

In Ethiopia, there is limited research indicating the level of geography teachers' knowledge and skills and classroom use in relation to geospatial technology in secondary schools. For this reason, this study assessed (1) teachers' technological, pedagogical, and content knowledge levels regarding geospatial technology; (2) practical challenges to geospatial technology integration; and (3) opportunities for using geospatial tools in selected public secondary schools in Bale Zone, Ethiopia. Using a mixed-methods approach, data were collected through questionnaires, interviews, and observations from 51 teachers and 10 department heads, selected purposively. Frequencies, percentages, means, and standard deviations were used for data analysis. Results revealed that teachers face significant gaps in technological knowledge, technological content knowledge, technological pedagogical knowledge, and technological, pedagogical, and content knowledge. According to 80% of respondents, the deficiency is mainly because of the lack of geospatial tools in schools, limited familiarity with technology, insufficient training, and a lack of strategies for effective technology integration. However, opportunities like a few desktop computers and information and communication technology centers exist. Findings from interviews and observations corroborated the quantitative results. The study recommends that Ethiopia's education system consider providing geospatial resources, ongoing professional development, and support for integrating technology into teaching.

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INTRODUCTION

Today, people around the world are looking at technology as a guarantee of life. People are taking it as a symbol of progress, innovation, and social flourishing. Technological advancements have played an important role in this evolution, with digital tools and resources revolutionizing teaching and learning processes in secondary schools. According to Haleem et al. (2022), technology enhances digital engagement and promotes collaboration and access to information, all of which are fundamental in today's interconnected world. The major technological discoveries have changed how we access geospatial data and digital resources and how we advance education in various subjects. In this context, technology facilitates teaching by developing experience and skills, and strengthens critical abilities, understanding, and analytical skills, and helps to develop geographical understanding and skills. Because of these advancements, the use of spatial technology in classrooms, especially at the

secondary level, has facilitated the instructional process to apply new approaches and develop an understanding of geography concepts. This is an indication that education is moving from being described only in theory to using technology to solve problems in practice, and these competencies are aligned with learning outcomes in subjects like geography, which now increasingly leverage geospatial technology to deepen understanding of concepts like location, distribution, patterns, human-environment interactions, and sustainable regional development; and developing critical thinking and practical skills that students need in the future.

To truly understand and implement these technological improvements, teachers must have a strong knowledge of technology and how to match pedagogy and knowledge with content—the TPACK framework (Mishra & Koehler, 2006). Mishra and Koehler (2006) assert that the TPACK system comprises three fundamental components. The components include pedagogical knowledge (PK), content knowledge (CK), and technological knowledge (TK). Furthermore, four hybrid components were established at their intersections: pedagogical content knowledge (PCK), technical pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPCK). Within this paradigm, content refers to the subject matter to be taught and learned, whereas TK encompasses the use of both basic and advanced technologies, including internet-based digital learning tools and digital video. The processes and methodologies employed to facilitate teaching and learning are encompassed in PK. PCK refers to pedagogical content knowledge pertinent to specific teaching materials, while TPK examines the alterations in teaching methodologies resulting from the integration of particular technologies. TCK refers to the comprehension of the interrelationship between technology and content, particularly how technological application might alter subject matter. TPACK represents a synthesized knowledge framework for integrating educational technology, situated at the convergence of content, technological, and pedagogical knowledge domains. TPACK is defined as the amalgamation of technology within the framework of educational settings. The framework delineates the interconnection between technology, pedagogical approaches, and content, facilitating the development of diverse competencies in educators: technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). Recognizing the interrelationship of these components aids educators in selecting appropriate resources and pedagogical strategies to enhance learning efficacy. Some recent advances in geospatial tools such as the Global Positioning System (GPS), remote sensing (RS), and Geographic Information Systems (GIS) have not only enriched geography education but also provided opportunities to understand regional dynamics, environmental change, and spatial patterns (Kolvoord et al., 2019). Importantly, online technologies such as Google Earth and GIS software have played a great role in making students more active and participative in educational delivery. Haleem et al. (2022) asserted that the swift advancement of modern technologies is enriching the teaching and learning of geography and environmental science in a more profound and interactive manner, thereby augmenting TPACK.

Research on technology integration indicates that geospatial tools enhance higher-order thinking, problem-solving abilities, in-depth analysis, visual literacy, and conceptual comprehension (Fleischmann & Van der Westhuizen, 2016). The use of GIS tools strengthens understanding of maps, data, and diagrams at various levels, and geospatial technology tools are effective in the delivery of geography based on the teacher's knowledge of the subject, appropriate teaching methods, and technical skills. Also, while Opoku (2019) mentions that successful geography education today is ensured by integrating geospatial technology with pedagogy strategies, Bednarz (2019) and the Commission on Geographical Education of the International Geographical Union

(CGEIGU, 2016) argue that geospatial tools like GIS and RS make instruction active, collaborative, and creative. Geospatial tools not only facilitate the dissemination of information but also make our understanding of the environment valuable.

Statement of the Problem

Worldwide, many geography teachers have limited students' compassionate participation and in-depth knowledge by relying only on outdated digital resources, textbooks, and lectures (Ridha & Kamil, 2021). This situation has contributed to the widening of the digital knowledge gap, mainly due to the fact that many teachers around the world lack sufficient technological knowledge and skills. Apart from a lack of technological knowledge, policy issues, inadequate infrastructure, and resource deficiencies challenge the adoption of geospatial technology in regions like sub-Saharan Africa (Mwaluko et al., 2023). On the other hand, the official inclusion of GIS in national curricula, textbooks, and educational manuals, encouraging national policies, the accessibility of computer resources, and the increasing focus on technology foster a positive shift in attitudes, despite some individuals experiencing challenges and frustration (Perugini & Bodzin, 2020).

In Ethiopia, although there has been a good focus on modernizing education in terms of government policies, plans, and strategies in recent years (FDRE, 2015, 2018), it is not really visible on the ground for various reasons. In this regard, the role of educational technology in strengthening learning outcomes did not reach the expected level. Amanuel (2019) highlighted the infancy of technology integration in Ethiopia, and there is a wide gap between educational delivery and technology use, which has not reached the levels seen in developed nations.

Studies (Alemu, 2017; Amanuel, 2019) found that problems such as lack of teacher preparation, fear of technology, limited resource availability and access, inadequate training, and lack of awareness on the benefits of technology use are major challenges for technology integration. This shows that although many teachers have a positive attitude towards using technology in teaching and learning, they choose not to use technology because they consider themselves unskilled and incompetent. According to Hunduma and Mekuria (2023), the integration of technology has been postponed owing to insufficient infrastructure, insufficient funds, lack of technical and administrative support, lack of time, teachers' knowledge, abilities, and use of technology, where ICT policy and school leaders' attitudes also had a major impact on technology not being integrated in different subjects and teaching approaches. To address these problems, researchers have proposed solutions to introduce technology into the curricula of all subjects and incorporate teaching strategies. The authors have also recommended integrating technology thoroughly across curricula of all subjects and its use in specific subjects and instructional methods, and these are assessed by professionals.

Above all, empirical evidence is limited on the use of geospatial technology in teaching geography at the secondary level. Also, various evidence from field observations and experiences in schools shows that many teachers do not use modern technology in teaching geography. Specifically, many teachers, when teaching, cling to traditional teaching methods, focusing on information and rote memorization rather than conceptual understanding. This prevents geography content, such as map reading, cartography, projections, and climate change, from being learned effectively. In some places, the situation rendered the subject worthless, leading students to develop a negative attitude towards it, which also distorts their perception of geography as a science.

Notwithstanding these challenges, the Federal Democratic Republic of Ethiopia's Ministry of Education (FDRE MoE, 2018, 2021) has established frameworks to include technology throughout all educational tiers. The new geography curricula and instructional materials explicitly include provisions for using geospatial technology to enhance learning outcomes and ensure students develop relevant skills. In fact, the latest geography curriculum openly urges educators to include geospatial tools in their instructional

methodologies. Given the issues shown, there is a clear need to examine teachers' level of knowledge and their actual use of geospatial technology. Significantly, digital technology has been receiving considerable global attention as it is a potentially powerful system for preparing competent learners. This study sought to fill the gaps in the literature by examining the specifics of geospatial technology and its applications, as well as its integration into secondary school geography, and it also sought to answer the call for scholars' recommendations for empirical research on technology integration into subject area curricula to promote its application in subject contents and pedagogical implementations. This study employs the TPACK framework to assess geography teachers' proficiency in integrating geospatial technology. The main goal is to assess teachers' TPACK knowledge, identify the challenges they face, and explore opportunities for integrating geospatial tools into geography lessons in selected public secondary schools in Bale Zone, Ethiopia.

Research Questions

1. What is the level of TPACK among geography teachers in integrating geospatial technology into geography teaching?
2. What challenges do geography teachers encounter in integrating geospatial technology into geography teaching?
3. What opportunities exist for integrating geospatial technology into geography teaching?

MATERIALS AND METHODS

Description of the study area

The study was conducted in the Bale Zone, Oromia Regional State, Ethiopia. The Bale Zone is situated between latitudes 05°11'03"N – 08°09'27"N and longitudes 38°12'04"E – 42°12'47"E. It is bordered to the east by the East Bale zone, to the north by the Arsi zone, to the west by the Arsi zone, and to the south by the Guji zone. It is a zone within the Oromia Regional State, encompassing a total size of 29,958 km². The administrative center of the Zone, Robe, is situated around 430 km from Addis Ababa, the capital of Ethiopia.

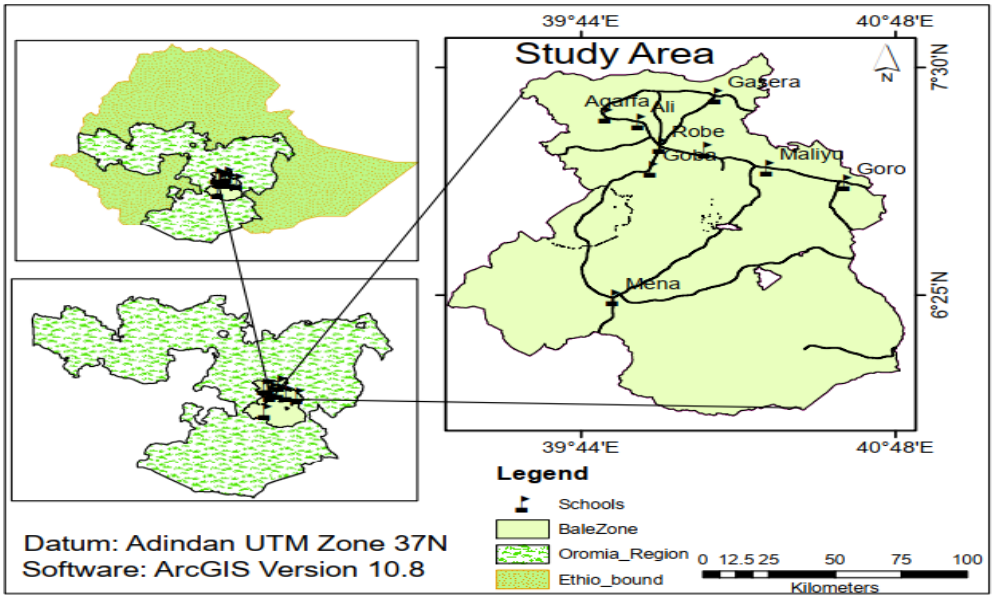

Figure 1. *Location map of the study area*

Figure 1 indicates the geographical distribution of secondary schools in Bale Zone, where the study was conducted, and data were gathered. The Bale Zone exhibits diverse topography, including lowlands, gorges, high plateaus, and peaks, shaped by tectonic activity and erosion. This variation

results in distinct microclimates, soil types, and vegetation zones, supporting abundant natural resources. Its agro-climatic zones are Dega (highland), Woina Dega (midland), and Kola (lowland), differentiated based on altitude and temperature. Rainfall varies from 400 mm in the lowlands to 1200 mm in the highlands. In 2022, the population living in rural areas was about 85.36%. The main economic activity is agriculture, mainly mixed farming with Summer and Spring as the major cropping seasons. The education infrastructure includes 120 first-cycle and 436 second-cycle primary schools, 40 secondary schools, 40 TVET centers, and 5 colleges, with varying enrollment numbers across the districts (Oromia Planning and Development Commission-OPDC, 2023).

Research Methodology

The study employed a convergent parallel design, as outlined by Creswell and Clark (2011), utilizing mixed methods to investigate the incorporation of geospatial technologies in geography instruction. The methods used were both quantitative and qualitative. Thus, the study employed surveys, interviews, and classroom observations to gather comprehensive data and to understand deeply the teachers' TPACK and the challenges they encountered in the integration of geospatial technology in geography teaching.

Sampling procedure and sample size

Ten purposively selected, relatively resource-sufficient public secondary schools were selected from Bale Zone and Robe city administration based on the availability of resources, ICT facilities, and work experience. Their number is manageable in the schools, and an in-depth analysis was desired; all the teachers and department heads of the various schools where the study was conducted participated in the study (61 individuals, 51 teachers, and 10 department heads). Of the teachers, 41 returned surveys, and 10 were interviewed as key informants. Classroom observations were conducted for three teachers for about 40 minutes each, and some were recorded to capture the use of geospatial technology in teaching. Considering the assumption that educators possess ICT resources, these instructors were randomly chosen, and the observation concentrated on their presence in the classroom with technological devices, their proficiency and expertise in geospatial technology, and their incorporation of technology with various pedagogical approaches.

Data collection

Data collection was conducted using context-adapted questionnaires, derived from proven instruments including the TPACK survey by Schmidt et al. (2009) and tools developed by Muñiz Solari et al. (2015). The surveys had closed-ended questions to measure the availability of resources, knowledge, and challenges of teachers. Additional qualitative data were obtained via semi-structured interviews with the department chair and geography instructors (average duration of 20 minutes) and through classroom observations to assess practical uses in the classroom.

Data analysis

Data analysis employed quantitative methods for Likert-scale data using SPSS 27 for descriptive statistics, and qualitative techniques, such as coding and thematic interpretation, for open-ended questions and interviews to contextualize findings. This multi-source approach enhanced validity and provided a holistic view of teachers' engagement with geospatial technology.

Validity and Reliability

The survey instrument was tested and validated by specialists prior to data collection. The Cronbach's alpha value was 0.81, indicating a good level of internal consistency. The pilot further enhanced clarity and content validity while ensuring the maintenance of ethical standards and participant rights throughout the investigation.

Ethical considerations

Ethical standards were upheld by informing participants of the study's goal, ensuring anonymity and confidentiality, securing consent for data usage, and respecting participants' rights throughout the research process.

RESULTS AND DISCUSSIONS

Results

Respondents' profile

This study involved 41 survey respondents, where most participants, 31 (75.6%), were from secondary schools in the Bale zone, while 10 (24.4%) were from Robe administrative town's secondary schools. The demographics revealed a significant gender imbalance among survey respondents: 40 (97.6%) males and only 1 (2.4%) female. Age-wise, over half (53.7%) were between 30 and 39.9 years old, 19.5% were aged 20–29.9 years, another 19.5% were 40–49.9 years, and 7.3% were 50–59.9 years. All participants studied geography, with 68.3% holding master's degrees (M.A. or M. Ed.) and 31.7% holding bachelor's degrees, indicating high academic qualifications. Teaching experience varied: 14.6% had 10-14.9 years, 22% had 15-19.9 years, 39% had 20-24.9 years, 17.1% had 25-29.9 years, and 7.3% had 30 or more years. This diverse experience likely enriched the study, as most respondents had substantial familiarity with geography. Teachers taught grades 9 to 12, with 14 teaching grades 9 and 10, 18 teaching grades 11 and 12, 4 teaching grades 10 and 11, 3 teaching grade 9, and 2 covering grades 10–12, providing a broad perspective on geography education across secondary levels.

Geography Teachers' TPACK level of integrating geospatial technology

Teaching geography with geospatial technology benefits teachers and students but requires teachers to have TPACK. Therefore, this study assessed geography teachers' knowledge within the TPACK framework.

Table 1

Geography teachers' TPACK level of integrating geospatial technology into geography teaching

Item	Mean	Std. Deviation
Technological Knowledge (TK)		
I know different geospatial technologies	2.27	0.92
The use of technology specific to teaching geography is important	3.90	0.89
The skills that I am learning while using the GIS help to improve my teaching performance	3.37	0.89
The skills that I am learning while using GPS help to improve my teaching performance	3.46	0.84
Using the Google Earth app can help improve my teaching of geography	3.85	1.06
I know ways of solving technical problems using geospatial technology	2.41	1.00
I can learn technology easily using GIS software/app	2.27	0.92
I can learn technology easily using the RS software/app	2.17	0.89
I frequently use GPS technology	2.07	0.91
I have the technical skills I need to use geospatial technology	2.24	0.97
Content Knowledge (CK)		
I know a lot about Geography	4.27	0.74
I know different strategies for developing my knowledge of Geography	4.41	0.63
I can think analytically about the subject matter	3.85	0.85
Pedagogical Knowledge (PK)		

Table 1 continues

I know how to assess students' progress and achievement	4.41	0.67
I can adapt my teaching based on what students currently need	3.88	0.75
I can adapt my teaching style for different learners	4.27	0.59
I can use different teaching methods and approaches	4.32	0.76
Pedagogical Content Knowledge (PCK)		
I can select teaching methods to guide student learning in Geography	3.80	0.64
I can select teaching resources that guide student learning	3.78	0.79
I know how to assess student learning in Geography	4.15	0.76
Technological Content Knowledge (TCK)		
I know how to use GIS and its software for teaching Geography	2.85	0.82
I know how to use a GPS device for understanding and teaching Geography	2.80	0.84
I know how to apply various satellite images for teaching Geography	2.05	0.89
I know how to use Google Earth for teaching Geography	3.00	0.74
I know how to use Google Maps for teaching Geography	2.78	0.73
Technological Pedagogical Knowledge (TPK)		
Using geospatial technology is important when teaching geography	3.59	0.87
I can choose geospatial technology and teaching strategies in teaching Geography	3.29	0.87
I can adapt the use of geospatial technology to different teaching activities	2.20	0.87
I can use GIS (ArcGIS software) to engage students in their learning	2.15	0.88
I can use GPS as a teaching tool for different teaching activities	2.34	1.02
I can use the Google Earth app as a teaching tool for teaching Geography	2.88	1.12
Technological, Pedagogical, and Content Knowledge (TPCK)		
I can plan by combining teaching strategies, geospatial technology use, and content in my Geography teaching	2.02	0.91
I can teach lessons that combine Geography content, geospatial technologies, and teaching strategies	3.27	0.81
I can respond to problems that arise when combining Geography content, geospatial technologies, and teaching methods	3.15	0.69
I can help my colleagues to successfully combine their teaching strategies, geospatial technology use, and content in Geography	3.22	0.69

Source: Field Data (2024)

Table 1 displays the mean scores and standard deviations for items categorized under different dimensions of teachers' knowledge pertinent to teaching geography with geospatial technologies, organized according to the TPACK framework. The 38 TPACK Likert-scale items were examined to ascertain the averages and standard deviations for each of the seven TPACK domains: TK, PK, CK, PCK, TPK, TCK, and TPACK. Each section of the table reflects a different domain of teacher knowledge. Higher means (closer to 5) reflect stronger self-perceived proficiency or agreement with the statement, and lower means (closer to 1) indicate lower confidence or less frequent use.

As Table 1 indicates, the level of geography teachers' knowledge on technology in general, as well as geospatial-TPACK components, is heterogeneous. Under TK, a mean of 3.90 (SD=0.89) and 3.85 (SD=1.06), respectively, showed that geography teachers highly rated items related to using geography-specific technology and Google Earth. Similarly, teachers recognize the importance of technology in geography education, scoring a mean of 3.90 (SD=0.89), and believe that skills in GIS and GPS can enhance their teaching, with respective means of 3.37 (SD=0.89) and 3.46 (SD=0.84). In contrast, as indicated by the respective means 2.07, 2.17, and 2.24, and standard deviations of 0.91, 0.89, 0.97, teachers' frequent use of GPS, teaching with RS and GIS software, and confidence in troubleshooting geospatial technology issues received lower scores.

Related to CK, the finding shows that geography teachers possess high content knowledge. The respondents strongly agree they possess sufficient geography knowledge (mean= 4.27, SD=0.74), effective strategies for developing it (mean= 4.41, SD=0.63), and confidence in analytical thinking about geography (mean= 3.85, SD=0.85). In addition, as the results demonstrate, geography teachers have high knowledge and good self-confidence in teaching geography. Particularly, teachers are confident in assessing student progress (mean=4.41, SD=0.67), using diverse teaching methods (mean=4.32, SD=0.67), and adapting instruction (3.88, SD=0.75). Besides, teachers feel capable of planning geography activities, assessing learning opportunities, and selecting appropriate teaching methods and resources, with means of 4.15, 4.10, and 3.80, indicating high PK.

The findings indicate that in TCK, teachers are somewhat familiar with Google Earth (mean 3.00, SD=0.74). Teachers' knowledge on how to use GIS, GPS, and Google Maps for teaching is moderate, scoring 2.85, 2.80, 2.78, and 0.82, 0.84, 0.73, respectively, but knowledge on how to apply satellite images is the lowest (mean 2.05, SD=0.89). For TPK, teachers recognize the importance of geospatial technology (mean 3.59, SD=0.87). Still, confidence in integrating GIS, GPS, Google Earth, and Maps into teaching remains low, with a mean between 2.15 (SD=0.88) and 2.88 (SD=1.10), often near or below 2.50.

In the TPACK domain, educators exhibit confidence in lessons integrating geographic content, geospatial technology, and pedagogical practices (mean = 3.27, SD = 0.81). But confidence drops significantly when planning to combine strategies, technology, and content (mean: 2.02, SD = 0.91). Teachers are moderately confident in helping colleagues integrate teaching strategies and geospatial technology into content, as well as in combining geospatial technology with teaching methods, with respective means of 3.22 (SD=0.69) and 3.15 (SD=0.69). Overall, synthesizing technology, pedagogy, and content into cohesive lessons is challenging, making this their weakest area.

Key informant teachers also provided insights into their knowledge and use of geospatial technology. The informants showed varying familiarity across technological, pedagogical, and content knowledge. In contrast, seven informants favored student-centered approaches like fieldwork, projects, and cooperative learning, one preferred lectures and gapped lectures. All claimed to teach geography content (CK) effectively, especially basic topics, but six noted complex topics like map reading, cartography, population projection, and resource analysis were difficult to teach.

Six informants reported limited use of technology in their teaching, with only one or two integrating it (TCK) regularly. Only two key informants mentioned that teachers used applications like Google Earth and Google Maps on smartphones for classroom demonstrations (TCK), such as showing location measurements and historical sites. One teacher, in particular, emphasized that students need to interact with GIS, GPS, and other applications to fully benefit from practical learning. The other two informants stated that a few teachers use laptops with ArcGIS software (TPCK), but only occasionally. Despite this, seven informants raised that teachers lack access to technology, whereas eight explained that

teachers do not know how to incorporate it effectively, mainly due to limited knowledge, training, and familiarity. For instance, two informants particularly explained, "Secondary school teachers do not consider integrating geospatial technology with geography content and teaching-learning methods (TPCK) to teach students. This is because teachers do not know how to integrate technology with teaching content and strategy." Moreover, eight informants confirmed that about 70% of school teachers are only at the stage of having information about geospatial technology, but are not yet able to practically apply it in classrooms. The remaining 30% are at the awareness stage, using some tools but not fully integrating them. In addition, eight informants did not think teachers have received specific training on pedagogical strategies for using geospatial technology, often relying on trial-and-error to incorporate these tools into lessons.

Geography department heads reflected similar sentiments. Four informants indicated some level of technology use in activities like field visits and assignments, while three believed it's mainly the teachers' responsibility to adopt strategies for using technology (TPK). The remaining three were unaware of advanced strategies beyond basic technology use. Overall, all department heads agreed that the department is at an initial stage, familiar with some geospatial tools and performing simple activities, marking the beginning of a gradual integration process.

Additionally, the information raised from two informants was summarized and presented as follows:

Geography teachers have no shortage of teaching geography content and using different methods to teach content. Occasionally, they use technological tools, but there is currently a huge gap in teaching the content using technological tools in conjunction with different strategies. This is because approximately 80% of geography teachers in schools do not use these technological tools to teach and therefore have difficulty in combining different strategies to teach content using modern technologies.

Classroom observation was also used in three secondary schools, BaGasa (BGs), BaObor (BOb), and RoWagut (RWg), to assess teachers' knowledge of geospatial technology implementation. Results show varying levels of educators' knowledge and application of technology in geography lessons across the schools. At BGs, the grade 11 teacher mainly used traditional, teacher-centered methods and some student-centered techniques (PK), without incorporating geospatial tools (TPK). At Bob, the grade 11 teacher used student-centered methods and briefly demonstrated a smartphone app for spatial data (TPK), but students struggled to use it effectively. RWg's teacher, despite having sufficient content knowledge (CK) and engaging delivery (PK), did not use technological tools during lessons (TPK), even though the school has good infrastructure.

Practical challenges of integrating geospatial technology

Table 2 shows that integrating geospatial technology into geography teaching faces key challenges mainly related to teachers' capacity. Mean scores of 4.66, 4.34, and 4.29, and respective standard deviations of 0.58, 0.76, and 0.75 indicate issues like a lack of training, a shortage of awareness of geospatial technology in pedagogy, and insufficient knowledge of technological tools. Conversely, teachers' lack of interest and readiness, and the motivation of educators to apply geospatial technology were not major challenges, as indicated by respective means of 2.00 (SD=0.89) and 2.73 (SD=0.78). Student-related challenges also emerged, with a mean score of 4.22 (SD=0.82), reflecting students' inadequate training in using these tools.

Table 2

Practical challenges of integrating geospatial technology into geography teaching

Item	Mean	Std. Deviation
Challenges related to teachers		
Lack of knowledge of geospatial technology	4.29	0.75
Lack of interest in learning and using geospatial technology	2.00	0.89
Lack of skill to use various geospatial technology techniques	4.20	0.81
Readiness and motivation of teachers	2.73	0.78
Lack of training	4.66	0.58
Lack of awareness about the use of geospatial technology in pedagogy	4.34	0.76
Challenges related to students		
Lack of knowledge of technology/software	3.71	1.01
Lack of skill to use various geospatial technology techniques	3.78	1.19
Readiness and motivation of students	2.34	0.86
Lack of interest in students	2.07	0.82
Low proficiency level	2.56	0.74
Lack of training	4.22	0.82
Challenges related to the system and administration		
School policy	2.51	0.93
Lack of incorporation of geospatial technology into the curriculum	3.68	1.01
Lack of literature and manuals	3.95	1.02
Lack of management awareness about the use of geospatial technology in pedagogy	3.44	0.81
Lack of administrative support	2.22	0.94
Challenges related to resources		
Cost of hardware and software	3.00	0.67
Lack of budget in implementing geospatial technologies	3.20	1.19
Lack of computers or Laptop	4.12	0.98
Lack of a smartphone that can browse	2.02	0.82
Lack of internet accessibility	3.93	1.10
Lack of necessary software/data	2.95	0.63
Problem of power supply	3.61	1.20
Lack of time	2.12	0.90

Source: Field Data (2024)

The students' lack of skills and knowledge of using geospatial technology were scored high, with means of 3.78 (SD=1.19) and 3.71 (SD=1.01), respectively. Nevertheless, lack of interest, lack of readiness and motivation, and low proficiency level of students were perceived as low, with mean scores of 2.07 (SD=0.82), 2.34 (SD=0.86), and 2.56 (SD=0.74), respectively. Regarding system and

administration challenges, lack of literature and manuals, the absence of geospatial content in curricula, and low awareness among school management were the major challenges, with means of 3.95, 3.65, 3.44, and standard deviations of 1.02, 1.01, and 0.81, respectively.

Resource limitations, like a lack of computers or laptops (mean 4.12, SD=0.98), limited internet access, power supply, budget shortages, and high hardware/software costs (means of 3.93, 3.61, 3.20, and 3.00, with respective standard deviations of 1.10, 1.20, 1.19, and 0.67), further hinder implementation. However, in general, the most common challenges cited were teachers' lack of training (mean=4.66, SD=0.58), shortage of awareness about the use of geospatial technology in pedagogy (mean=4.34, SD=0.76), and lack of knowledge of geospatial technology (mean=4.29, SD=0.75), while less frequent issues involved teachers' lack of interest to learn and use geospatial technology (mean=2.00, SD=0.89), lack of smartphones for browsing (mean=2.02, SD=0.82), and students' shortage of interest (mean=2.07, SD=0.82).

Key informant teachers confirmed these challenges, with eight reporting a widespread lack of knowledge of geospatial technology among teachers. Six informants raised limitations of geospatial resources, and the other six highlighted limited training and awareness as barriers to using GIS and GPS tools in teaching. However, one teacher, despite limited training, practiced with a personal laptop and shared that "Although I am not adequately trained, I practiced repeatedly and managed many activities, so integrating geospatial technology into geography teaching is feasible." Notably, none of the respondents identified content knowledge as a problem.

Geography department heads also reflected these concerns, noting that most teachers only knew tool names without understanding their benefits, leading to minimal classroom use. Seven emphasized resource shortages, such as the lack of GPS, GIS, and RS software, and inadequate infrastructure. Two mentioned internet access issues, and three pointed out the absence of dedicated geography labs, all hindering effective integration, underscoring the need for better resources, training, and curriculum support to fully utilize geospatial technology in teaching. School budgets for technology integration remain another challenge; four informants stated that without sufficient budget, technology integration cannot rely solely on departmental support, and management must plan budgets to ensure the availability and accessibility of resources. Two key informants noted that departments are not authorized to plan or budget independently but stressed that a proper financial system and efficient use of existing resources are essential, as additional budgets alone won't improve teaching with geospatial technology.

During the time of observation, resource checks revealed basic facilities like ICT centers, some desktop computers, a few digital cameras, and internet access in all schools, though access varies. Advanced tools such as ArcGIS, LCD projectors, laptops, and smartphone apps are only available at JWg School. BGs's school has an Internet center, and smartphone applications like OpenStreetMap and Location Finder are used by the geography teacher. Bob has minimal resources, with only a desktop computer besides common facilities. Overall, infrastructure is limited, and the application of geospatial technology in geography instruction (TPACK) also remains limited. Teachers' familiarity with these tools varies, and positive attitudes towards ICT are mainly seen at RWg.

Opportunities for integrating geospatial technology

The key informant teachers had diverse perspectives regarding the potential for integrating GIS technology into geography instruction and learning. The majority of teacher informants (80%) regarded it as a beneficial opportunity, particularly the integration of GIS technology in education and the establishment of ICT laboratories in schools. Importantly, one informant pointed out the benefits of having ICT professionals to support a geography teacher trained in GIS. Another informant

mentioned the internet access as an additional advantage to improve educational practices. Similarly, geography department heads had different views of current technological opportunities. One said that the integration of technology in the curriculum is promising, especially with video recordings, social media, and computer use. The informant defined it as:

There are good prospects at the moment for the use of technology in the education curriculum and system. This is highly likely to be done with video recordings, different social media, hard copy devices, and computers in many places. Therefore, teachers and students can benefit greatly if they create and use different strategies.

Four department head informants recognized the availability of some computers, ICT-skilled teachers, computer centers, and online resources as significant opportunities. A smaller portion, two informants, saw potential in incorporating GIS tools and software, with some mentioning the presence of teachers trained in GIS and the importance of internet access as key factors for advancing geography education.

Discussions

Teachers' technological, pedagogical, and content knowledge (TPACK)

This study demonstrates that the integration of technology influences educators' opinions of their pedagogical proficiency. Teachers typically regard themselves as adept in Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK), although they express diminished confidence in the integration of geospatial technology with geography content and pedagogy, particularly in relation to Technological Knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). This indicates that while the utilization of technology is essential for teaching some geography material, educators possess inadequate technological understanding and are ineffective in employing technology for geography instruction. Likewise, the research conducted by Antwi et al. (2018) indicated that while it is difficult to train specific geography subjects without technological tools like Google Earth, GPS, and GIS, numerous educators are not well-versed in instructional technology, and thus, primarily employ conventional techniques such as lectures, discussions, fieldwork, projects, and questioning in many regions. In South Carolina, even in an advanced region, Osborne et al. (2020) found that while over 85% of geography instructors feel prepared to integrate technology into their instruction, hardcopy maps and Google Earth remain the predominant geospatial tools utilized.

The current study's results specifically indicate that teachers possess strong general teaching knowledge, including assessment and differentiated instruction, and are effective at connecting content with pedagogy (PCK). They have solid content knowledge (CK), particularly in developing strategies and creating analytical thinking. Although in a modern geography classroom, technology tools are key resources for effectively teaching geospatial content, this study shows that despite recognizing the importance of technology and a few tools like Google Earth, teachers lack practical experience with GIS, GPS, and RS (TK). Limited technical skills and the difficulty of integrating technology pose significant barriers. This aligns with findings that pedagogical aspects of technology integration, such as applying technical skills and effectively utilizing technologies in classrooms, often receive little attention in teaching institutions. In the teaching process, technology helps to bridge the cognitive gap between theoretical GIS concepts and real-world applications by creating visually rich learning environments thus, geospatial technology applications, according to Firomumwe and Gamira (2021), enable teachers to design interactive and practical GIS lessons using real-world data that makes suitable for secondary school environments, where learners and teachers may be new to GIS technologies; but many less-developed countries face a significant gap in GIS knowledge and implementation. E.g., it was noted that secondary-level teachers are not integrating modern

technologies into their teaching due to a lack of necessary knowledge and skills. In Ethiopia, Amanuel (2019) observed that technology integration in education is still in its infancy, far from the levels seen in developed countries, with a significant gap in pedagogical practices.

Curtis (2019) presented that TPACK supports teachers in selecting appropriate tools that promote learning, and is a key consideration when teaching data-intensive GIS topics. In the present study, the mean scores of geography teachers for the items pertaining to the TPACK construct were predominantly the lowest, despite this item being deemed crucial by the researchers, as Mishra and Koehler (2006) characterized TPACK knowledge as fundamental to effective teaching in the 21st century. The result shows that while teachers are familiar with Google Earth, their ability to apply technology directly to content remains limited. Teachers struggle to synthesize technology, pedagogy, and content into cohesive lessons. The idea can be supported by Kamil et al.'s (2020) study, which found that teachers rarely use geospatial technologies systematically for teaching geography knowledge, skills, or key thinking, focusing instead on a conventional map elaboration system. Overall, in the study area, teachers have a strong foundational knowledge but lack the skills and understanding necessary for integrating geospatial technology, leading to high gaps in TK, TCK, TPK, and TPACK.

Also, many key informant teachers and department head responses emphasize their knowledge as being 'sometimes,' indicating a basic familiarity with the technology, but not comprehensive or consistent expertise. This suggests that a teacher possessing only content and pedagogical skills, without technological expertise, will find it challenging to use technology in instruction. This study also reveals that geography instructors require professional development training to effectively incorporate technology into lessons and meet contemporary educational objectives. Consistent with this finding, Uerz et al. (2018) discovered that educators are required to cultivate four domains of knowledge for effectively teaching with technology, thereby fostering similar competencies in students; consequently, geography teachers must enhance their proficiency in pedagogical practices and technological applications. Santos and Castro (2021) determined that users must possess a sufficient understanding of technology to implement it effectively, indicating that geography teachers require the knowledge and skills to utilize various geospatial technologies to enhance teaching and learning processes, thereby necessitating adequate training. Our findings align with the FDRE (2021) curriculum for geography education in Ethiopian secondary schools, which emphasizes the necessity for teachers to possess advanced technological expertise and the ability to integrate it effectively with content and pedagogy.

Challenges of integrating Geospatial technology into geography teaching

The study shows several challenges to integrating geospatial technology into geography education, where the major ones include the unavailability of geospatial tools and resources, a lack of training and knowledge among teachers, and insufficient knowledge for effective technology integration into pedagogy.

Limited resources

The study reveals that availability and access to geospatial resources such as GIS software, GPS devices, computers, and internet differ across the secondary schools. Many schools do not have regular access to desktop computers and laptops, so some teachers use their own personal devices. This has resulted in a wide gap in the capacity to utilize geospatial technology effectively in teaching. Most schools also have no reliable internet access, which limits teachers' ability to develop their TPACK and to design lessons that involve digital tools. Regarding this, Osborne et al. (2020) found that many schools continue to rely on paper-based teaching methods due to limited access to technology, and this negatively impacts the adoption and improvement of technology use in geography classrooms. The findings also showed that that 85% of geography educators express

preparedness to integrate technology into their instruction; nevertheless, 95% encounter difficulties owing to insufficient exposure within geography classes. Brandao's (2020) study indicates that the substantial expenses associated with acquiring and sustaining technological infrastructure and software licenses compelled educators to depend on conventional methods, hence hindering the enhancement and potential integration of technology in educational institutions.

In Ethiopia, barriers such as management attitudes, inadequate facilities, shortages of skilled ICT staff, and unreliable power supplies hinder the application of technology in schools (Moges, 2014). For instance, only 28% of secondary schools had internet access in 2017, with only 6% offering high-capacity content, delaying technology integration.

Teachers' lack of training and knowledge

The insufficient training of teachers and their inadequate understanding of GIS technology were recognized as key obstacles in this study, hindering effective integration. Previous studies also confirm that many developing countries have a technology knowledge gap. Mkhize (2023) in South Africa found that gaps in teacher training are barriers to the effective application of GIS. Also, Turugare and Rudhumbu (2020) stressed the need for proper training, stating that without proper training, teachers face challenges in using technology tools that greatly hinder successful technology integration, and even lead to frustration and undermine effective teaching of geography.

Lack of Knowledge to Use Technology Effectively

The study found that many geography teachers do not use geospatial technology in their teaching. This indicates a huge deficiency in teaching geography content with these tools, leading to a very low level of TPACK. Teachers' lack of proper training makes it difficult for them to acquire and update their skills to use technology, which directly impacts instruction. In Ethiopia, Alemu (2017) stated that some teachers with positive attitudes to technology do not use it due to their low self-efficacy and belief that they do not possess the skills. Another study (Kamil et al., 2020) also shows that many teachers depend on traditional methods such as textbooks and PowerPoint, with little use of geospatial analysis and map reading skills. In brief, the above limitations and challenges imply that teachers are less equipped to use technologies effectively without adequate training, resources, and supportive management, thus limiting the potential benefits of geospatial technology in improving learning outcomes. Therefore, overcoming these challenges is significant for encouraging technology adoption and improving technology knowledge and its application in education.

Opportunities for integrating geospatial technology

In this study, while the majority of teacher informants (80%) viewed the introduction of geospatial technology into the curriculum, ICT-skilled teachers, and the establishment of ICT laboratories in schools as valuable opportunities, a smaller portion, two informants, particularly added potential in incorporating GIS tools and software into the curriculum. The official inclusion of GIS in national curricula, textbooks, and educational manuals, the accessibility of computer resources, and the increasing focus on technology adoption are good opportunities. Related to this, Perugini and Bodzin (2020) claimed that inclusion of geospatial technology creates a change for the improvement of attitudes, although some find it difficult and frustrating. Also, the findings of this study align with the revised geography curricula and instructional materials (FDRE, 2021), which explicitly include provisions for using geospatial technology to enhance learning outcomes.

CONCLUSIONS

This study assessed the TPACK of geography teachers, the challenges, and opportunities to integrate geospatial technology into geography teaching in selected public secondary schools in Bale Zone. The results show that teachers are not deficient in content knowledge (CK) and pedagogy

knowledge (PK) in teaching geography. However, teachers' knowledge of geospatial technology (TK), integrating technology into teaching-learning methods (TPK), and using technology to teach content (TCK) was lacking. Above all, the study found that there is a significant issue with teaching geography content through technology and adapting it to various approaches (TPACK). On the other hand, it has been identified that there are many challenges to teaching geography using technology.

The main barriers include the unavailability of geospatial tools, limited knowledge of geospatial technology, a lack of teacher training, and a lack of knowledge of strategies for effective technology integration into pedagogy, although a few opportunities, such as desktop computers, ICT centers, and occasionally technology-skilled teachers, are available in a few schools. These difficulties cause teachers and students to lack the necessary expertise, self-assurance, and knowledge, which seriously impede the attainment of the intended geographic education outcomes.

Recommendations

This finding indicates that the use of geospatial technology in secondary schools' teaching of geography is low for different reasons. To address this, the study recommends that the Ethiopian education system:

Ensure the availability of geospatial technology and related resources in secondary schools and make them available for teaching.

Build teacher competencies through pre-service and on-the-job training on geospatial technology and its application in pedagogy. Ultimately, such measures will contribute to the improvement of the standard of geography teaching and consequently of education in Ethiopia.

CRediT authorship contribution statement

Kedir Gebi: Conceptualization, Methodology, Formal analysis, Writing - original draft

Kidanemariam Paulos: Supervision, Administration

Solomon Tadesse: Writing - review and editing

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

Ethical Approval

All methods involving human subjects adhered to the ethical standards established by the Addis Ababa University Research Ethics Committee and complied with pertinent national rules. All participants gave verbal informed consent following a comprehensive explanation of the study's objectives and methodologies, in compliance with ethical protocols.

Data Availability

The data utilized in this investigation can be obtained upon request.

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