Positioning Geospatial: Classroom Benefits and Theoretical Implementation

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Abstract

Teachers of geography have an intuitive sense that geospatial technologies are useful additions to their classrooms but the academic literature supporting this intuition is not substantial. This article summarises the documented benefits of geospatial technologies for geography teachers and students. Implementation of geospatial technologies in schools is examined for its usefulness in relation to the TPACK (technological, pedagogical and content knowledge) model. Geospatial technologies are found to promote spatial thinking, help students understand geographical content, enhance geographic inquiry, and increase student engagement when they are used with students. The research available suggests that these geospatial tools are useful for teachers and students and should be more widely used by teachers of geography.

Introduction

There is no such job as a *geographer*. There are, however, lots of jobs that take advantage of the skills that are taught in geography classrooms. These jobs can be as obvious as hydrologists, urban planners or volcanologists or as divergent as real estate agents, marketing officers or landscape architects. These skills require technologies that analyse and manipulate data spatially, and geospatial technologies (GSTs) are the tools that these professionals typically use to help them with their work.

Geography teachers know this and see value in sharing with their students the tools that professionals in their field are using (Curtis, 2020). Since the early 1990s, educators have seen the value of GSTs for their students and these tools have been implemented in classrooms across the world (Baker et al., 2015; Kerski, 2003; National Research Council [NRC], 2006). However, this implementation has been “haphazard, uncoordinated, and therefore disorganized” (NRC, 2006, p. 289) with research in the field of geospatial education reflecting this disorganisation (Baker et al., 2015).

Geography teachers are at the forefront of data use in classrooms and GSTs allow teachers to introduce, use and manipulate data in interesting ways that they and their students may not otherwise experience. GSTs are a unique combination of a map and associated data table and can bring about powerful insights into problems or issues being studied by students when collecting, manipulating and using geospatial data. They are also attractive to students because of their medium: computers. They can be a powerful motivating factor for many students. GST outputs are also visually appealing with data insights being provided by colourful two- and three-dimensional maps. For many students, this is far more attractive than looking at a notebook or the board!

Despite anecdotal accounts though, the collective body of evidence for the benefits of GSTs in the classroom is not substantial. Being a relatively new field of study, there is not yet the breadth of research available, nor is that research mature.

This article sets out to summarise the current literature that relates to the impacts of GSTs in school classrooms. It also outlines a model for integration of these tools that can serve as a useful guide for teachers who want to use GSTs in their teaching.

I begin by examining the literature that focuses on GST classroom applications and describe what GSTs are, why they are important in education, and their contribution to geography education. I then outline the dominant model of technology integration in education, the TPACK (technological, pedagogical and content knowledge) model, and identify how it may be used to integrate GSTs into a school’s work program.

Review of literature

What are GSTs and how do they impact geography education?

The geospatial industry represents a relatively new technological field that is involved with all aspects of measuring and representing information about our planet. GSTs are the tools that help us measure and represent this information about our world. GSTs, an umbrella term, most commonly refers to three distinct fields: remote sensing, geopositioning (such as global positioning systems, or GPS), and geographic information systems (GIS) (Baker & White, 2003; Hong & Melville, 2018; Kerski, 2003; Metoyer, 2014).

Remotely-sensed data are data collected about the earth without being in contact with the earth. Our progress in this field has continued since the camera was first developed in the nineteenth century. Our preferred methods for remotely capturing images and information about the world have moved from pigeons with cameras attached, and people literally hanging out of hot air balloons in the late nineteenth century, to satellites, airplanes and Uncrewed Aerial Vehicles, or drones today. These devices can be fitted with an array of sensors that collect data from across the electromagnetic spectrum, including aerial images but also the likes of infrared and ultraviolet imagery.

The positioning industry, underpinned by the Global Navigational Satellite Systems (GNSS) network, and associated hardware and software technology, has been growing since humans left our planet to explore the solar system. The GNSS network is a network of satellites that circles the earth recording and transmitting their position. Receivers on the ground, such as a handheld GPS unit or a modern smartphone, pick up signals from a number of these satellites to record the users' position or track their location over time. The industry was almost exclusive to the US military until the year 2000 when civilian access was granted to channels with useful levels of accuracy for the general public. The global network has since multiplied, with other countries adding their satellite networks to the GNSS, with many varied, useful, engaging, and valuable applications of this technology influencing our daily lives.

The technology known today as GIS was initially developed in the 1960s in Canada as a natural resource management tool. GIS is a software framework which captures and analyses geographic and spatial data. GIS software allows the user collect, manipulate, represent, query and analyse geographic and spatial data usually using a 2D or 3D map and associated geodatabases. These databases form the basis of the information presented on the map. GIS has been used in geography classrooms for more than thirty years (Kerski, 2003). These technologies are collectively known as GSTs.

The adoption of technologies is usually slow in education (Curtis, 2020; Shriner et al., 2010; Wilson & Wright, 2010) and this is especially true with the uptake of geospatial technologies (Curtis, 2020). It has taken the education sector considerable time to get any sustained, useful benefit from using GSTs, mainly due to the complexity of the hardware and software required to gather and represent information spatially. Prior to the 1990s, GST use in schools came from the outputs of such remotely-sensed data as satellite images or aerial photographs. Teachers rarely used geospatial software tools in hands-on ways, and certainly not GNSS as this only became available to the public at the turn of the 21st Century. Outside the lone hobbyist or teacher with industry connections, usually through family or friends, there was little in the way of GST in schools (Kerski et al., 2013; Kidman & Palmer, 2006) until earlier this century.

As software became more accessible, smaller in size and more user-friendly, geography educators began to see the value of using these tools in their teaching. Now these tools are well known in geography and science education communities and are highly desirable in geography classrooms (Bednarz & Kemp, 2011). Software has also advanced to allow users to engage with GSTs through browser-based applications, rather than high-end software packages, to conduct higher-order tasks with the tools and available data (Kerski & Baker, 2019).

Although desirable, GSTs have fallen short of their potential to transform teaching and learning, specifically in the fields of social studies, geography, history and the sciences (Tan & Chen, 2015). But beyond a gut feeling, what do we know of the actual effectiveness of these tools? It is worth exploring the academic contributions made in the relatively new field of research on GST use in the classroom.

Impacts of GSTs in education

Geospatial tools are intuitively recognisable to geography teachers as being beneficial in the classroom, even to those teachers without hands-on experience with the tools. At first glance, they appear to replicate such traditional geographical tools as an atlas, but with greater accessibility, functionality and usability.

There is a growing body of research supporting the benefits of GSTs in education and evidence that they have the power to be transformative tools for geography teachers in their classrooms. Most of the research that supports use of geospatial tools in education makes the same general claims about the tools. These are summarised below.

Geospatial tools:

- enable and enhance visualisation and promote spatial thinking

- help students understand geographical content
- enhance the process of inquiry
- increase student motivation to learn.

Enabling and enhancing visualisation and promoting spatial thinking

The backbone of GSTs is visualisation. Tables are useful for storing information, but being able to visualise that information spatially, and to see the geographic patterns, is what makes GIS unique to other digital technologies used in geography classrooms.

Spatial thinking, a distinct form of thinking, is defined by Bednarz (2019, p.3) as "the use of spatial concepts, spatial representations, and processes of reasoning to conceptualise and solve problems." GIS promotes spatial thinking involving concepts of space and spatiality, visualisation of information and (spatial) reasoning (Kidman & Palmer, 2006). GSTs help students visualise spatial relationships and geographic patterns in their data which allows them to better understand and analyse data that they represent (Baker et al., 2015; Demirci, 2015; Favier & van der Schee, 2010; Kim & Bednarz, 2013; Merç & Ersoy, 2019). In a study by Westgard (2010), students using Google Earth outperformed their peers who did not use Google Earth in pattern recognition and understanding spatial relationships. García de la Vega (2019) highlights the link between geospatial technologies, visualisation and analysis of geographic patterns in data, while Baker et al. (2015, p. 121) note that GSTs facilitate "visualisation of spatial relationships, analysis, and filtering or querying of geospatial data" in students and that these are "all activities that can be of use in making sense of spatial data and patterns."

In studies that have examined career or academic choices and how they relate to spatial thinking, participants with higher spatial thinking abilities have greater competency in spatially dependent subjects and are more attracted to geospatial courses and careers. Spatial thinking is also shown to positively impact on performance in STEM courses and persistence in STEM careers, and this observation would be transferable to the geospatial sciences (Metoyer et al., 2015).

Helping students understand geographical content

Students' understanding of geographical content, such as location information, is enhanced by geospatial technologies. Shin et. al. (2016) used qualitative analysis to demonstrate a positive relationship between GST use and students' learning and cognitive strategies.

Goldstein and Alibrandi (2013) found that using geospatial technologies in the classroom had a positive effect on high school student achievement in science and social studies. Kulo and Bodzin (2013) found significant increases in content knowledge for all participants in their study while Metoyer (2014) found that instruction with GSTs gave students significant positive gains in content knowledge retention.

Uttal et al. (2013) conducted a meta-analysis and determined that geospatial tools help to develop accurate understandings about complex earth and environmental science concepts in secondary learners and a spatially enriched curriculum helps to increase performance and participation in fields that rely on these concepts. Hammond et. al. (2018) found that geospatial technologies helped to deepen students' understanding of important discipline-based content and complex earth and environmental science concepts in secondary learners. Metoyer and Bednarz (2017) found that using GSTs was a more effective method for teaching geographical content that is spatially dependent, than traditional paper maps.

In an Australian study that examined the influence of classroom GST pedagogies on higher- and lower-order thinking skill development in Year 9 students, Kinniburgh (2018) found that the pedagogical approach used, either direct instruction or guided learning, had no impact on development of these skills. He did find that scaffolding interventions, that were targeted and well-constructed, did help *middle ability students* to develop their higher-order thinking skills.

Enhancing the process of inquiry

GSTs are useful additions to a geographic inquiry for their data collection, representation and analysis in that they allow students to explore, analyse and question geographic data, which are all useful attributes for a good geographic inquiry.

GSTs can also play an integral role within a geographic inquiry as they are student centred (Kerski, 2003). They can enhance geographic inquiry by allowing students to formulate geographic questions, access geographic data, visualise geographic data in various forms such as maps, charts, images and tables, and to query and analyse the data to identify patterns, relationships and to draw conclusions (Hammond et al., 2018).

Rather than passively receiving information, constructivist approaches and methods with GSTs allow users to become active explorers of their own imagination and to learn via their own experiences (Demirci, 2015). GSTs promote higher-order thinking skills (Liu et al., 2010) and relate the subject of geography back to real-world issues that students (Hong & Melville, 2018) can identify with. Kinniburgh, (2012) provides an example of such an inquiry, that is supported by GST, to help students examine sea level rise in and around Sydney in line with predicted climate change.

Increase student motivation to learn

Using technology in the classroom can have an immediate effect on students' learning motivation and learning engagement, with one study finding considerable positive impacts on student motivation even after a short intervention of only three hours (Nugent et al., 2010). Using GSTs in typical secondary school classrooms can considerably increase students' motivation and desire to learn and make learning more engaging for reluctant learners (Bednarz & Kemp, 2011; Demirci, 2015; Hammond et al., 2018; Kerski, 2003).

Current pedagogical thinking in geospatial education

Constructivism dominates the learning of information technology tools and likely informs most teachers who use GSTs in their classrooms. Variations of Project-Based Learning (PBL) or Inquiry-based learning have been the main vehicle for implementation of GSTs in educational settings since geospatial education came about in the 1990s (Kerski, 2008; Kerski et al., 2013). These frameworks embed GSTs in an inquiry approach to teaching and learning which is firmly part of the constructivist tradition.

The primary approaches to the teaching and learning of GSTs over the last thirty years have involved either the traditional lecture-based pedagogies and more recent experiential learning pedagogies (Balram, 2019) combined with PBL or inquiry models, or a combination of elements. More recently, the TPACK model has dominated as a lens through which to evaluate effective use of technological tools in the classroom.

Theoretical perspective on implementation

What is TPACK and how is it applied in geospatial education?

TPACK overview

Mishra and Koehler (2006)'s TPACK model is a knowledge framework for technology integration in education. It helps guide the integration of technological, pedagogical and content knowledge in educational contexts that involve the integration of technology. The TPACK framework builds on Shulman's (1986, 1987) Pedagogical Content Knowledge (PCK) framework to include the technological knowledge domain and it emphasises the combination of all three knowledge domains as important to the success of implementation of technology in the classroom (Koehler et al., 2013).

In the context of GSTs, technological knowledge encompasses knowledge about the use of geospatial tools; what they are, how to use them, what different tools do, outputs from the systems, data requirements and details around how the technology works. Pedagogical knowledge relates to knowledge and understanding of how to teach using GSTs, including the processes and practices of teaching and learning. These are the practical skills used to help more effectively transfer knowledge to a person. Content knowledge relates to teachers' knowledge about the geographical subject matter or issue being studied, such as earthquakes, land cover, volcanoes, and water quality. Shulman (1986, 1987) noted that this content knowledge includes knowledge of concepts, theories, ideas, organisational frameworks, knowledge of evidence and proof, as well as established practices and approaches to developing that knowledge (Koehler et al., 2013). Successful integration of technology, using the TPACK framework, comes when all three forms of knowledge are mastered and combined effectively in the classroom with digital tools. The framework is represented in Figure 1.

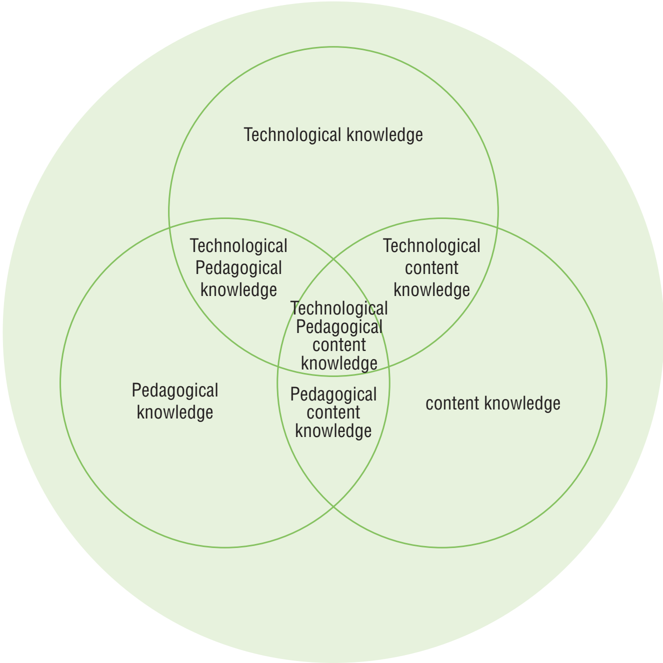

Figure 1: *TPACK conceptual model, with arrangement of knowledge domains (adapted from Koehler, Mishra and Cain, 2013).*

Recent research in the application of the TPACK model has focused on the specific contexts that influence teachers' ability to integrate different technologies (Chandra, 2015). Contextual elements might include the educator's access to technology, the experience of the student cohort, or the institutional rules or processes that might impact on technology integration in education. Context is represented in Figure 1 as an outer circle that encompasses all other parts of the model.

Out of the three knowledge domains in the TPACK model, teachers typically underperform in the technological knowledge domain. It is for this reason that this domain is the focus of this study. When the pedagogical and content knowledge domains are considered, it will be in the context of their overlap with technological knowledge (see Figure 1).

How is TPACK applied in geospatial education?

There is limited research into the TPACK model and its application in geography or its application with GSTs including GIS. Table 1 shows the results of recent searches across two prominent educational databases for terms related to TPACK and its integration of GST. The search variables used include: 'TPACK & geography', 'TPACK & geospatial' and 'TPACK & GIS'. These results, while all valuable, show that there is limited available research in this area.

Some of this broad research into the application of TPACK with geospatial education confirms that the TPACK model is an effective tool to help integrate GSTs into the curriculum. Although the body of research is relatively small, emerging trends are evident across different contexts to suggest that further research should be undertaken into the value of using TPACK to guide the implementation of GSTs into the curriculum and classrooms.

Doering et al. (2014), in their study of 44 primary and secondary geography teachers, observed mean increases across all TPACK knowledge domains, and statistically significant increases in all technological domains (TK, TCK, TPK and TPACK) following a week-long professional

Table 1: *Database search results for TPACK and geo-related terms, August 2022.*

Search variable	ERIC	APA PsycInfo
TPACK & geospatial	3	0
TPACK & geography	10	1
TPACK & GIS	5	0

development intervention. In another week-long program for 11 experienced teachers, TPACK helped teachers learn how to effectively integrate GIS into their teaching practice (Hong & Stonier, 2015). TPACK was confirmed in a further study as a valuable tool that influences teachers' decisions about integrating GSTs into instruction (Curtis, 2019, p. 139) and that without a concerted effort to develop teachers' TPACK in relation to the use of GST, the rate of adoption of GSTs by teachers will remain slow (Curtis, 2019). Oda et al. (2020) reported that, after undergoing professional development in GIS based on the TPACK framework, teachers valued GIS as a technical tool in the geography classroom and as a tool that can support PCK development. Findings also show that pre-service teachers benefit from the inclusion of TPACK in their humanities teacher training (Miguel-Revilla et al., 2020).

There is very little research relating to how the TPACK model is specifically applied to the integration of GSTs in education. However, it is possible to begin to understand how TPACK might be implemented in classrooms using GSTs. Oda (2020) and Doering et al. (2014) both identify three distinct approaches to applying the TPACK framework in educational contexts that mirror the epistemological perspective of the entity, institution or person that is implementing the technology. The first is that the TPACK framework is a direct adaptation of Shulman's (1986) PCK model where technology is at the centre of the integration task (Doeringer et al., 2014). One perspective is that implementation of TPACK mirrors the learning perspective of the institution/entity where TPACK is being applied. The second perspective emphasises that TPACK is an integration of all components and domains of the model. This more holistic approach (Doeringer et al., 2014) highlights the interaction between all parts of the TPACK model with no emphasis on any one or more knowledge domains. The final perspective is a sequential one where the technological knowledge comes after mastery of the PCK domains. The different perspectives influence how TPACK is implemented, with all three providing different approaches that have different impacts on teachers and students (Oda et al., 2020).

There is also limited research that directly examines how teachers acquire knowledge in the different TPACK domains. There is research that looks at interventions that build this knowledge, however this research is primarily focused on short-term interventions of no longer than a one day-long professional development session. All these interventions found a significant improvement across all knowledge domains of participating teachers (Curtis, 2019; Doeringer et al., 2014; Hammond et al., 2018; Oda et al., 2020). Pedagogical knowledge showed the least improvement while technological knowledge showed the most. As teachers start with high levels of experience in the pedagogical knowledge domain, improvement here was predictably lower than the other knowledge domains. Differences were also found in how teachers applied the different domains as they gained teaching experience. Teachers shift their domain knowledge focus as they build PCK through classroom experience. More experienced teachers spend more time on technological knowledge, including TCK and TPK, to build these skills that they can adapt across different technologies (Oda et al., 2020).

The importance of developing TPACK in pre-service teachers has been addressed in recent research. Curtis (2019) states that pre-service education must embrace a more comprehensive approach to preparing educators to teach with GSTs because educators currently piece their knowledge together and engage in trial and error to discover methods for teaching with GSTs. Doering et al. (2014, p. 223) note, in relation to geography educators, a "lack of exposure to existing curricular and pedagogical models that teachers can use to guide meaningful integration of technology into the curriculum." Hammond et al. (2018, p. 316) propose that "augmenting the geospatial PCK of in-service teachers is critical if early-career teachers are to effectively implement . . . investigations using . . . geospatial technologies," a method of delivery that has been identified as important to the integration of GSTs in schools. Other studies note the value in re-evaluating how the digital competence of social studies teachers is addressed in teacher training (Miguel-Revilla et al., 2020, p. 8) or the lack of preparation of pre-service geography educators to teach with and about GSTs in schools (Walshe, 2017, p. 618).

Conclusion

This account has shown that GSTs offer a range of benefits to students and teachers and their increasing use in P–12 schools and classrooms is justified. There is a growing body of evidence that GSTs promote spatial thinking, help students understand geographical content, enhance geographic inquiry, and increase student engagement when they are used with students. However, there is still much to understand about GSTs in schools, including the connection between spatial thinking and GSTs, how students use GSTs, how teachers teach with them, how they can be used for assessment, how they form part of an inquiry, what aspects of spatial thinking they promote, why and how they are (or not) designed for student use, and how they can best be implemented in geography and other classrooms.

While TPACK benefits have been broadly established, there is little research examining how TPACK is applied in geographical or geospatial contexts. There are limited studies with timeframes longer than one week of training and there are clear opportunities to examine long-term GST use in schools and how they are implemented. There is also insufficient research to make any considered claims about how teachers acquire their technological and pedagogical knowledge to teach GSTs which may inform future methods of GST integration in the classroom. The TPACK model appears to be a suitable and useful model to help with the integration of GSTs by schools, although more research is required to confirm this usefulness and in what context it should be used.

As the *go to* tool for professional geographers, GSTs are a natural fit for geography classrooms. The limited research available, at present, suggests that these tools are useful for teachers and students and should be more widely used by teachers of geography.

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