Chapter 11
Professional Development Focusing on Inquiry-Based Learning Using GIS

Lara M.P. Bryant and Tim Favier

Abstract Geographic inquiry projects with GIS make geography education more relevant and challenging, and provide opportunities to stimulate in-depth knowledge about geography, increase higher-order thinking and develop a wide range of technology skills. Providing professional development that ensures teachers know how to use GIS to support geographic inquiry is necessary. The professional development experiences should take into account the various competencies teachers need to design and conduct geographic inquiry projects using geospatial technologies. The TPACK framework focuses on teacher competencies and is valuable when designing professional development. Considering the TPACK framework, a successful strategy for teacher training is a collaborative inquiry model. When applied to GIS, the collaborative inquiry model is designed to overcome the common barriers to using GIS such as the lack of curriculum, support, and data. The model highlights the successful implementation of geographic inquiry using GIS within a school or district based collaborative team. This chapter explores didactic models for integrating GIS in inquiry projects; frameworks for the competencies that teachers need to design and conduct such projects; and successful strategies for training these competencies.

Keywords GIS • Professional development • Inquiry-based Learning

11.1 Introduction

As technology has become increasingly important in education, geography teachers and teacher trainers have become interested in the possibilities of using Geographic Information Systems (GIS) to enhance students' learning. GIS offers many

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opportunities to support geographic inquiry projects. Inquiry-based geography education with GIS makes learning more relevant and challenging, by connecting practice and theory, and stimulating the development of in-depth geographic knowledge and progression in a wide range of valuable skills such as geographic inquiry, spatial analysis, and critical thinking. However, integrating GIS into curriculum is not easy for teachers, because developing skills in teaching with GIS includes more than just learning to use the software. Teachers should learn to use GIS as a tool for developing students' geographic knowledge and skills by designing and conducting inquiry projects with GIS. In order to develop these skills, teachers need to be supported and provided with adequate professional development. This chapter explores didactic models for integrating GIS in inquiry projects; frameworks for the competencies that teachers need to design and conduct such projects; and a suggested model for training the necessary teacher competencies.

11.2 Supporting Inquiry-Based Geography Education with GIS

Due to media coverage regarding the status of geographic education, the general public often views geography as the memorization of topographical and factual knowledge about places and regions. This focus on discrete facts has been seen internationally in geographic education with inquiry and decision-making less emphasized (Gerber 2001). In the past few decades, more significance has been attached to the development of inquiry skills (Kent 2006). *Inquiry-based learning* (IBL) is a kind of learning which aims to stimulate progression in students' disciplinary subject knowledge and inquiry skills, thinking skills, and self-regulation skills by engaging in activities 'like researchers do' (van Joolingen et al. 2005). Recent reforms in geography education internationally have included movements toward IBL (Marsden 2003). However, the use of the IBL model of learning in geography education was described as early as 1921 by Smith, and mimics the scientific inquiry process. According to this model, inquiry is a cyclical process which consists of the following activities: (1) identifying the problem/hypothesis, (2) collecting data, (3) organizing data, (4) analyzing data or testing the hypothesis, and (5) determining and evaluating a solution (Asmussen and Buggey 1977; Fenton 1968; Moore and Wilcox 1932; Smith 1921). Figure 11.1 presents a model for geographic IBL with GIS, which illustrates the various activities, and the input and output of those activities (Favier 2011).

GIS is an ideal tool for supporting IBL in geography, as it allows teachers to design projects in which students explore spatial problems with digital maps, formulate questions about those problems, collect geodata in the field, visualize and analyze geodata in maps, and use these maps to answer their questions. The literature contains many enthusiastic descriptions of teachers using GIS to support IBL projects about natural disasters, pollution, solid waste, crime, health,

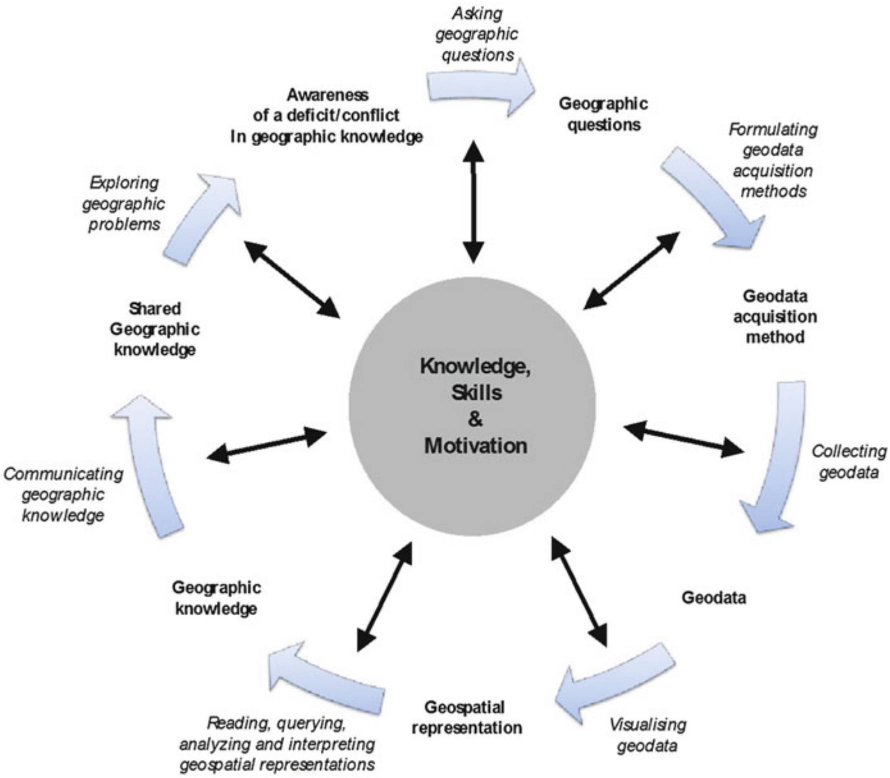

Fig. 11.1 A model for the geography IBL with GIS (Favier 2011)

recreation, market analysis, and political and cultural variability within regions (e.g. Audet and Ludwig 2000; Demirci et al. 2013; Engelhardt 2004; ESRI 2003; Falk and Nöthen 2005; Favier and Van der Schee 2012; Kerski 2003; Milson et al. 2012; Reitz 2005; Schleicher and Schrettenbrunner 2004; Sinton and Bednarz 2007; Unterthurner 2004).

Van Rens (2005) stresses the importance of paying attention to knowledge, skills, and motivation when designing and conducting IBL projects. Engaging in inquiry may stimulate progression in knowledge, skills, and motivation; but knowledge, skills, and motivation are also a precondition for engaging in inquiry. Therefore, GIS-based IBL projects can contribute to a progression in students' geographic knowledge and skills (geographic literacy) and students' motivation to learn about and solve problems in the world around us (the geographic drive). However, students should also have some background geographic knowledge and geographic inquiry skills, including GIS skills, and should be willing to engage in geographic inquiry.

11.3 The Competencies that Teachers Need to Teach with GIS

Since teachers are the "gate keepers of educational innovations" (Wallace 2004), the successful introduction and diffusion of GIS in secondary geography education largely depends on whether geography teachers possess the required competencies. In the literature about geographic IBL projects with GIS, much of the focus has been on the design of the projects and on student achievement, with a lack of attention given to the teachers. During IBL it is the teacher's role to create an environment that supports exploration and discovery. The teacher becomes a facilitator rather than an instructor, and student learning is active rather than passive (Anderson 2002; Luft 2001). This new role may not be easily developed, nor the old familiar role easily discarded by the teachers. Research by Lam et al. (2009) and Favier (2011) has shown that teachers often feel they lack the required competencies regarding teaching with IBL. The question that needs to be answered is what knowledge do teachers need in order to design and conduct good IBL projects with GIS. According to Mishra and Koehler (2006), teachers who want to implement technology in their classes need to have a combination of Technology (T), Pedagogy (P), and (A) Content (C), knowledge (K) (Fig. 11.2). The TPACK can be used to describe the required teacher knowledge base in a systematic way.

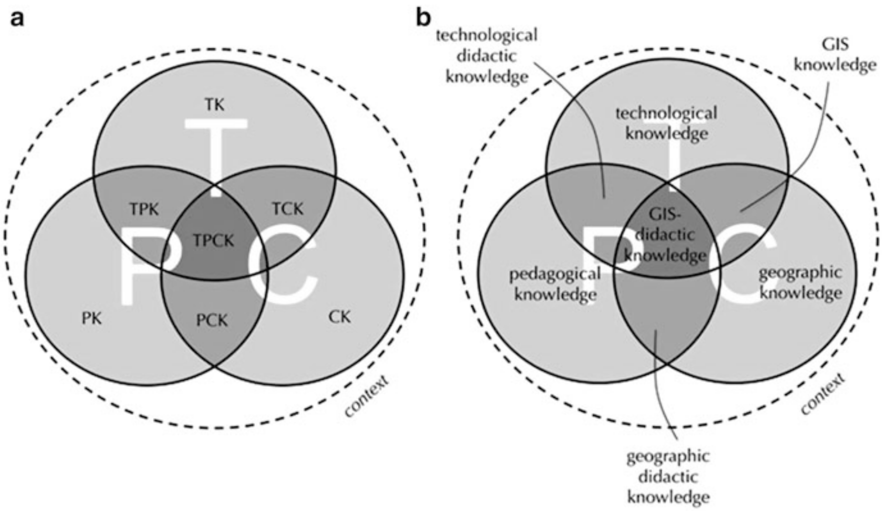

Fig. 11.2 (**a**) The TPACK framework (Mishra and Koehler 2006). (**b**) The teacher-competency framework for designing and conducting geography IBL with GIS (Favier 2011)

11.3.1 The Pedagogical and Content Components

It is clear that teachers need to have general pedagogical knowledge about the processes of teaching and learning for successful classroom management, lesson plan development and implementation, student evaluation, etc. This domain-generic knowledge is called Pedagogical Knowledge (PK) (Mishra and Koehler 2006, p. 1025). PK includes declarative knowledge about cognitive, social and developmental theories. It also includes procedural knowledge about applying these theories in classroom practice, and strategic knowledge about appropriate pedagogical interventions that are useful in specific situations.

Besides PK, teachers clearly also need disciplinary knowledge, or Content Knowledge (CK). Every discipline has core central ideas, concepts, and methods that teachers need to be fluent with in order to teach the subject: geography teachers should be geographically literate themselves. Shulman (1986) argued that combining PK and CK together does not make a teacher. Teachers also need to know how to teach the specific subject knowledge and inquiry methods knowledge of a domain, and therefore introduced the term Pedagogical Content Knowledge (PCK). This knowledge exists at the intersection of PK and CK.

For geography, PCK is *geographic-didactic knowledge*. Following Shulman (1986), Favier (2011) distinguished two sub-components of geographic-didactic knowledge. Knowledge in the first sub-component, '*geographic knowledge for use in educational settings*', includes knowledge about geographic issues and geographic inquiry methods that is transformed so that it becomes accessible for students. Teachers should know *how* to transform their own geographic knowledge to constructs for use in educational settings, and know *which* constructs for use in educational settings are suitable to reach specific learning goals. The second sub-component of geographic-didactic knowledge is '*student geographic inquiry learning processes in relation to tasks and coaching*' (Favier 2011). Knowledge in this sub-component includes: (1) declarative knowledge about how students learn in relation to task-design and coaching in geography classes, (2) procedural knowledge about how to design geographic inquiry tasks and coaching students when these tasks are conducted in classrooms, and (3) strategic knowledge about what kind of geographic inquiry tasks and coaching are suitable to reach specific learning goals.

11.3.2 The Technological Components

Teaching successfully with technology requires that teachers not only have knowledge in the pedagogical and content dimensions of education, but in technology as well (Mishra and Koehler 2006). Mishra and Koehler distinguish four kinds of technology-related knowledge that teachers should have. First, teachers need to have general Technological Knowledge (TK), which is knowledge about how to use standard software tools for text processing, spreadsheets, file management, and the Internet in non-educational settings. If they want to integrate such technologies in the classroom, they need to have Technological Pedagogical Knowledge (TPK): knowledge about how to use general technologies, such as digiboards and electronic learning environments, in the classroom. Geospatial technologies (GSTs), including GIS, are examples of domain-specific technologies, as they are especially suitable for analyzing *geographic* problems. In order to implement GIS in inquiry-based geography education, teachers should know how to use the software themselves to investigate geographic issues. This *GIS knowledge* can be seen as knowledge at the intersection of technology and content, and is therefore called Technological Content Knowledge (TCK). TCK includes declarative knowledge about the characteristics of geodata and the structure of GIS, procedural knowledge about how to apply GIS tools, and strategic knowledge about which sequence of tools should be applied in order to answer a specific geographic question.

However, even more important for successful integration of GIS in teaching is *GIS-didactic knowledge*, which is the overlapping knowledge of Technology, Pedagogy and Content (TPACK). Similar to geographic-didactic knowledge (PCK), TPACK can also be subdivided in two sub-components (Favier 2011). The first sub-component is '*GIS knowledge for use in educational settings*', which refers to suitable methods for data collection, data visualization and data analysis for student inquiry projects. The second sub-component is called '*student GIS-supported inquiry learning processes in relation to tasks and coaching*'. The declarative knowledge in this sub-component refers to knowledge about how students learn when they work on tasks with GIS. It includes declarative knowledge about frequently occurring problems, such as the fact that students rarely switch off irrelevant map layers, which makes it more difficult for them to analyse the representations. It also includes procedural knowledge about how to design good GIS tasks, and how to provide good instruction, support and reflection. In order to create viable and effective projects, teachers need to have sufficient declarative, procedural and strategic knowledge in every component of the TPACK framework (Favier 2011). MaKinster and Trautmann have developed a TPACK framework for GIS specific to the sciences, which include geographic content (2014).

11.4 Challenges Faced During Inquiry-Based Education When Teachers Lack the Required Competencies

Although many teachers believe GIS offers opportunities for inquiry-based geography education, many also agree that designing and conducting quality geographic inquiry projects is difficult (Lam et al. 2009; Favier 2011). Studies suggest the need for deepening teachers' understanding and application of general technologies (TK) (Bryant 2010), as well as their knowledge about how to teach with those technologies (TPK), before they can take steps in teaching with technologies (Kirschner and Davis 2003). With respect to teaching with GIS, research by Favier (2011) and Bryant (2010) suggests that it is not only teachers' limited GIS-knowledge (TCK) that forms an obstruction, but that teachers' geographic didactic knowledge (PCK) is also often insufficient for designing and conducting good geographic inquiry projects with GIS. For example, it was found that teachers had a difficult time connecting required curriculum to relevant local studies (Bryant 2010) and to structure geographic content and make it accessible for students (Favier 2011). It has also been found that teachers mistakenly perceived IBL as a process in which there are resources with answers to be found instead of a process in which answers can be derived though data collection and analysis (Bryant 2010; Crockett 2002; Gayford 2001). Therefore, teachers initially saw GIS as a useful resource, instead of as a tool for IBL and stimulating students' geographic thinking or inquiry skills. This implies that teachers need to have sufficient technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), before they can begin developing their technological-didactic knowledge (TPK), GIS-knowledge (TCK), and geographic-didactic knowledge (PCK), and that they should develop enough knowledge in these components before they can develop their GIS-didactic knowledge (TPCK) via designing, conducting, and evaluating simple inquiry projects with GIS.

11.5 A Recommended Model for Improving Teachers' Competencies

It is important to address teacher competencies in order to overcome the challenges teachers encounter when they implement IBL using GIS based projects. With many educational in-service programs focusing on classroom techniques, teachers have no example of how to implement the theoretical ideas behind geography IBL into practice (Lampert and Ball 1999; Thompson and Zeuli 1999). Teacher trainers should have the knowledge and abilities to model for teachers the appropriate processes in which teachers should engage their students (O'Hara and Pritchard 2008), including modeling inquiry-based lessons (Luft 2001). Therefore, the trainers should be facilitators themselves, not instructors. The best way to model the inquiry process to teachers is to immerse them in the process of inquiry themselves (Supovitz and Turner 2000) and let them structure the geographic issues themselves, and explore how to translate the content to constructs for use in educational settings. Trainings should focus on those elements of GIS that can ensure achievement in educational objectives such as in-depth geographic knowledge, inquiry skills, critical thinking skills, and geographic thinking skills, and should aim to stimulate progression in knowledge in all components of the TPACK framework.

11.5.1 The Collaborative Inquiry Model

The Collaborative Inquiry Model (CIM) (Bryant 2010) provides guidelines for training teachers' competencies in designing and conducting IBL projects with GIS. The model is based on the following principles: (1) follow the philosophy of social constructivism and allow the participants to work collaboratively, (2) create a network of teachers, peers and professionals in the field for ongoing support, (3) provide immediate connection with existing curriculum and content, (4) use local relevant examples that provide a framework upon which to construct global knowledge, and (5) stimulate critical reflection. When these five principles are included in the conceptual framework of professional development, it increases the effective implementation of GIS in the classroom.

In a phenomenological research project, teachers designed, tested and evaluated IBL projects with GIS together by following the principles of CIM (Bryant 2010). The research focused on teachers who participated in a four day summer institute, Geographic Inquiry using GIS which also included two follow-up sessions during the school year. In order to foster the development of a collaborative professional community, the institute targeted teachers from a single urban school district in Texas, United States. Eleven middle and high school teachers and a district instructional technologist participated in the study. During the institute, teachers explored the use of online interactive mapping systems, ArcExplorer, and ArcGIS 9.2. Institute activities included the use of *Mapping our World Using GIS* (Palmer et al. 2008), data collection in the field, and partnerships with local agencies to inform the development of the inquiry-based lessons.

Before beginning, teachers were given time to determine standards and objectives they already teach that would be suited to use with GIS, and plan accordingly (McClurg and Buss 2007). Then they proceeded to work through each step of the inquiry process, and explored how the various components could apply to their specific curriculum. They were reflective throughout the process and were critical about their inclusion of GIS into the curriculum, learning the difference between using the program solely for technology's sake and using it as a tool for teaching geographic subject knowledge and inquiry skills.

11.5.2 Impacts of the Collaborative Inquiry Model on Teachers

By guiding teachers through the geographic inquiry process using the CIM, there was increased meaningful use of GIS during their development of inquiry-based projects (Bryant 2010.) First, teachers reflected upon who should ask the questions during the inquiry process. Some teachers arrived at the same conclusions as Smith (2005) that independent exploration and questioning of geographic data makes using the program more motivating to the student, as it encourages students to be "inquisitive" and "open-minded". So paying attention to the 'geographic drive' is fruitful. Others chose to guide or model the questioning process to the students. Both of these methods are very different in regard to developing the skills necessary for students to learn how to ask their own geographic questions and are dependent on the development stage of the learners themselves. Together teachers discovered the variations in teaching that would lead to the desired objective of students eventually being able to formulate questions themselves.

Second, teachers examined the importance of data acquisition in developing IBL projects using GSTs. Acquiring data can be as simple as turning on a layer in an online database, or more advanced by downloading the layer for use in the desktop software, joining tables to shapefiles, or collecting the data in the field. The inquiry process depends not only on the ability to collect and gather geospatial data, but the accessibility of that data as well developing strategies of data collection. In order to be useful, the data need to be connected to existing curricula, and broad enough to allow students to pursue lines of inquiry (Liu and Zhu 2008). Providing a regional data set for teachers during trainings has been a successful strategy (McClurg and Buss 2007). Community-based projects involving student-collected data in citizen science projects have also been very successful. Depending on the objectives of the lesson, teachers will weigh the value of data collection differently (Bryant 2010). Teachers who focused on the development of research skills wanted students to collect their own data, while teachers who wanted primarily to strengthen questioning strategies and analysis placed less emphasis on data collection.

Teachers also improved their GIS skills regarding organizing and analyzing data. This improvement was evident in their changed expectations from having students perform general activities creating maps to requiring that students conduct analytical tasks such as ranking countries, classifying data to make thematic maps or embedding evidence such as photos, tables or charts. Most of the teachers still expected the students to conduct visual pattern analysis. This fact suggests that either the skill level of the teachers did not improve to the level needed to include using GIS as part of the analysis process, or that the visual analysis and development of student spatial skills was the intent of the developed curriculum. Finally, the most noteworthy change in teacher expectations after the CIM experience was the fact that the teachers expected the students to use the program to find data that would support the conclusions, predictions, or answers the students derived instead of simply expecting the students find an answer (Bryant 2010). This is fundamental to IBL for students and the reason why collaborative inquiry models for teacher education are promising.

11.6 Recommendations for Teacher Professional Development

Teacher education should not only focus on training the technical knowledge (general technological knowledge, GIS knowledge and GIS didactic knowledge), but also on the geographic didactic knowledge. Teachers need knowledge in all components of the GIS TPACK framework. Working collaboratively, to develop knowledge within the TPACK framework is important for teacher success. Therefore, schools should take advantage of existing teaming and collaboration already in place in many school structures to improve successful implementation of GIS in the classroom (Bryant 2010). Finally, teachers benefit from the time to process their own student needs, examine how GIS can support mandated priorities and reflect upon their teaching practices in order to design curriculum accordingly.

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