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Evaluating the Implementation and Effectiveness of Inquiry-based Learning to Teaching Paper-based GIS in Secondary Schools

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ABSTRACT

This study evaluated the implementation and effectiveness of inquiry-based learning in teaching paper-based geographic information systems (PBGIS) in South African secondary schools. PBGIS refers to teaching GIS through maps without using digital applications such as Quantum GIS and ArcGIS. The Department of Basic Education (DBE) has not provided geography teachers with clear guidelines for teaching PBGIS. Although DBE has provided geography teachers with sufficient PBGIS content, PBGIS pedagogical approaches are still fragmented. National Senior Certificate diagnostic reports indicate poor performance of learners on questions related to GIS in the examinations. The Technological Pedagogical Content Knowledge is the conceptual framework used to understand the implementation and effectiveness of Inquiry-based Learning (IBL) in teaching PBGIS in secondary schools. This interpretive paradigm study underpinned the qualitative research design. The findings show that geography teachers implement IBL to engage learners in PBGIS research projects and mapwork activities that use scenarios to solve problems. Teachers believe using IBL is effective because it assists learners in becoming critical thinkers and developing skills to question their curiosity to construct knowledge through research projects. The study recommends that geography teachers use IBL to teach PBGIS in ways that stimulate learners' critical thinking and help them learn to collaborate with others during the inquiry process. The study's contribution may assist the DBE, teachers, learners, lecturers, and students with insights towards understanding the implementation and effectiveness of IBL in teaching PBGIS in secondary schools.

Keywords: *Inquiry-based Learning (IBL), Paper-based GIS (PBGIS), Secondary Schools, TPACK.*

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INTRODUCTION

The South African National Curriculum Statement (NCS) listed GIS as a skill to be acquired in the curriculum in 2003, although its inclusion was only phased in by 2006.[1] In 2006, the Department of Basic Education (DBE) only introduced GIS as part of the grade 10 geography syllabus for the first time, and it

[1] Elfrieda Fleischmann and Christo van der Westhuizen, "The Educational Research Landscape on GIS Integration and Challenges–Globally and in South Africa," *The Journal of Geography Education in Africa* 3 (2020): 63–80.

extended to grades 11 and 12 in 2007 and 2008, respectively. However, research conducted during 2008 and in the last decade about implementing PBGIS in secondary schools revealed that many geography teachers lack the pedagogical content knowledge for teaching GIS in secondary schools.[2] Similar concerns were noted by Akinyemi, who opines that many teachers lack theoretical grounding and practical experience in using GIS.[3] Zondi and Tarisayi point out that the lack of theoretical grounding and practical experience is because many teachers in South Africa lack professional development in teaching GIS, which was supposed to have taken place upon the introduction of GIS in the secondary school geography curriculum.[4]

Lack of funding and infrastructure has also been cited as hindrances to proper GIS implementation in secondary schools.[5] Many schools in South Africa do not have computers and GIS software. As a result, they cannot offer computerised GIS lessons to geography learners.[6] Computer-based GIS (CBGIS) is a system that allows geographically referenced information to be captured, stored, edited, displayed, analysed, and printed.[7] The failure to utilise CBGIS in developing countries such as South Africa led to the development and distribution of a PBGIS manual to teach GIS in resource-poor schools.[8] This research aims to evaluate the implementation and effectiveness of the IBL approach to teaching PBGIS in South African secondary schools.

LITERATURE REVIEW

Various studies have been written about using IBL to teach GIS in secondary schools. Oda et al.'s article reported on professional development in which twenty-four middle- or high-school teachers from Greater Los Angeles learnt about integrating GIS in science or social science classes.[9] The article shows that GIS is an ideal tool for supporting IBL in geography. GIS allows teachers to design research projects in which learners explore spatial problems with digital maps, formulate questions about those problems, collect geodata in the field, visualise and analyse geodata in maps, and use these maps to answer their questions.[10] However, DeMers point out that integrating GIS into the curriculum is not easy for teachers because developing skills in teaching with GIS includes more than just learning to use the software.[11] Oda et al. recommend that teachers learn to use GIS to develop learners' geographic knowledge and skills by designing and conducting inquiry projects with GIS.[12] In order to develop these skills, teachers need to be supported and provided with adequate professional development.

In a study conducted in Malaysia, Bikar et al. mention that the study showed that IBL in teaching GIS is an innovative teaching method that geography teachers can utilise to stimulate and enhance

[2] Mary Fargher, "Using Geographic Information (GI)," in *Debates in Geography Education*, ed. Jones Mark and David Lambert (Abingdon: Routledge, 2017), 197–210.
[3] Felicia O Akinyemi, "An Assessment of GIS Use for Teaching in Rwandan Secondary Schools," *The Geography Teacher* 12, no. 1 (2015): 27–40.
[4] Kudzayi S Tarisayi and Thabile A Zondi, "A Learner Perspective on the Implementation of Geographic Information Systems in Selected Schools in KwaZulu-Natal Province," *TD: The Journal for Transdisciplinary Research in Southern Africa* 16, no. 1 (2020): 1–6.
[5] Thulasizwe Fredrick Mkhize, "Teachers' Perceptions of Paper-Based GIS Implementation in The Rural Learning Ecology," *Journal of Curriculum Studies Research* 5, no. 2 (2023): 118–35.
[6] Fleischmann and van der Westhuizen, "The Educational Research Landscape on GIS Integration and Challenges–Globally and in South Africa."
[7] Gregory Breetzke, Sanet Eksteen, and Erika Pretorius, "Based GIS: A Practical Answer to the Implementation of GIS Education into Resource-Poor Schools in South Africa," *Journal of Geography* 110, no. 4 (2011): 148–57.
[8] Breetzke, Eksteen, and Pretorius, "Based GIS: A Practical Answer to the Implementation of GIS Education into Resource-Poor Schools in South Africa."
[9] Katsuhiko Oda, Thomas Herman, and Angela Hasan, "Properties and Impacts of TPACK-Based GIS Professional Development for in-Service Teachers," *International Research in Geographical and Environmental Education* 29, no. 1 (2020): 40–54.
[10] Lara MP Bryant and Tim Favier, "Professional Development Focusing on Inquiry-Based Learning Using GIS," in *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned*, ed. Muniz Solari, Osvaldo, Ali Demirci, and Joop van der Schee (New York: Springer, 2015), 127–38; Ningning Nicole Kong et al., "Spatial Information Literacy for Digital Humanities: The Case Study of Leveraging Geospatial Information for African American History Education," in *The Digital Humanities* (Routledge, 2020), 243–58.
[11] Michael N DeMers, Joseph J Kerski, and Christopher J Sroka, "The Teachers Teaching Teachers GIS Institute: Assessing the Effectiveness of a GIS Professional Development Institute," *Annals of the American Association of Geographers* 111, no.4(2021):1160–82.
[12] Oda, Herman, and Hasan, "Properties and Impacts of TPACK-Based GIS Professional Development for in-Service Teachers."

learners' intrinsic motivation to self-directed learning.[13] The study also demonstrated that the GIS-integrated method could enhance underachieving learners' motivation to learn geography. The study recommended that the findings could be explored further and inspire teachers to integrate GIS and IBL into their geography teaching. In another study, Mitchell et al. explored the critical connections among technology, pedagogy, and content, particularly in developing technology-enhanced, inquiry-based lessons in which the teachers and their learners used GIS technologies to analyse, visualise, and present data in real-world contexts.[14] The study findings highlighted the importance of well-structured professional development that builds community, integrates diverse content and pedagogical expertise, provides feedback and coaching, and is of sufficient duration to effect change.

A thesis study by Zondi explored using an IBL framework for teaching GIS in a rural learning ecology.[15] The study identified four major impediments to teaching GIS: lack of formal GIS training, traditional teaching approaches, inadequate resources, and a negative teacher attitude towards GIS.[16] It was noted from these findings that there was a training gap. Consequently, the co-researchers and the study's researcher participated in training workshops on GIS content knowledge and pedagogy. An IBL framework was integrated into the training workshops, and as a result of these workshops, the co-researchers started exhibiting a positive attitude towards GIS.

IBL is a pedagogical approach that engages learners actively in knowledge-building by generating answerable questions. Chu et al. note that the IBL approach is related to problem-based learning (PBL), in which learners adopt an inquiry mindset to address epistemic issues with a relatively open-ended set of answers.[17] Firomumwe states that IBP and PBL are instructional methods based on constructivism, challenging the customary methods used in secondary schools.[18] Nageen et al. reveal that active learning is a method where the teacher only acts as a facilitator, and learners are at the centre of the learning process through their high involvement in practical activities and discussion.[19] Hence, using IBL enables geography teachers to actively engage learners in inquiry PBGIS activities to construct knowledge by generating answerable questions.

In a different study, Mkhize argues that in South Africa, PBGIS was introduced as a strategy to resolve the hindrances in schools without computers to implement GIS.[20] However, Fleischmann and van der Westhuizen state that geography teachers face the challenges of teaching GIS in the classroom.[21] Therefore, this study evaluates the implementation and effectiveness of IBL in teaching PBGIS in secondary schools. The above studies have contributed to using IBL in teaching GIS in schools. However, none of them have focused on evaluating the implementation and effectiveness of IBL in teaching PBGIS in secondary schools. This study is unique in the sense that it argues that geography teachers should use IBL to teach PBGIS in schools. Teachers should collaborate and assist each other with more effective strategies for implementing IBL in teaching PBGIS in secondary schools. In light of this, the study aims to evaluate the implementation and effectiveness of using IBL to teach PBGIS in secondary schools.

[13] Soon Singh Bikar et al., "The Impact of Geography Information System Integrated Teaching on Underachieving Students' Intrinsic Motivation," *International Research in Geographical and Environmental Education* 31, no. 4 (October 2, 2022): 304–19, https://doi.org/10.1080/10382046.2021.2001983.

[14] Jerry T Mitchell et al., "GIS Professional Development for Teachers: Lessons Learned from High-Needs Schools," *Cartography and Geographic Information Science* 45, no. 4 (2018): 292–304.

[15] Thabile Aretha Zondi, "An Inquiry-Based Learning Framework for Teaching Geographic Information Systems in a Rural Ecology," (2022).

[16] Veronika Bernhäuserová et al., "The Limits of GIS Implementation in Education: A Systematic Review," *ISPRS International Journal of Geo-Information* 11, no. 12 (2022): 592.

[17] Samuel Kai Wah Chu et al., *21st Century Skills Development through Inquiry-Based Learning from Theory to Practice* (Springer, 2021).

[18] Thomas Firomumwe, "Evaluating the Implementation of GIS and Remote Sensing in Teaching Geography: A Case of Mangwe District," *Journal of Educational Technology* 18, no. 4 (2022): 21–29.

[19] Sobia Nageen, Khawaja Hisham ul Hussan, and Farhana Akmal, "Role of Teacher for the Successful Implementation Activity Based Curriculum," *VFAST Transactions on Education and Social Sciences* 11, no. 1 (2023): 94–100.

[20] Mkhize, "Teachers' Perceptions of Paper-Based GIS Implementation in The Rural Learning Ecology."

[21] Fleischmann and van der Westhuizen, "The Educational Research Landscape on GIS Integration and Challenges–Globally and in South Africa."

CONCEPTUAL FRAMEWORK

This paper is framed under the Technological Pedagogical Content Knowledge (TPACK) conceptual framework. Mishra and Koehler made the early developments of the theory.[22] They introduced TPACK to educational research as a conceptual framework for understanding teacher knowledge required for technology integration. TPACK is a useful conceptual framework for thinking, analysing, and evaluating what teachers must know to integrate technology into teaching. However, ultimately, it must be understood as a framework for how teachers might best develop this integrated knowledge.[23] The TPACK conceptual framework realises the integration of technology knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) to create a framework that includes the specialised, applied, and situated knowledge that helps us to understand how different aspects of knowledge (may) interact and become integrated.[24] The TPACK conceptual framework was chosen to enable the researchers to evaluate the implementation and effectiveness of IBL in teaching PBGIS in secondary schools.

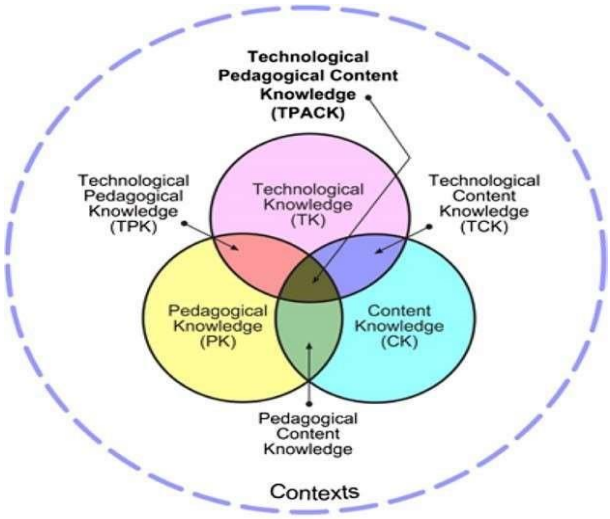

Figure 2.1: Technological pedagogical content knowledge (Santos & Castro, 2021, p 63).

Technology knowledge (TK) refers to the knowledge about various technologies, ranging from low-tech technologies such as pencil and paper to digital technologies such as desktop computers, internet connection, laptops, monitors for projection, television, printer, projector, scanner, speakers, and tablet.[25] For TK, Santos and Castro argue that persons must understand information technology broadly enough to apply it productively at work and in their everyday lives, recognise when information technology can assist or impede the achievement of a goal, and continually adapt to changes in information technology.[26] TK was relevant for the study because the researchers could understand how geography teachers' knowledge of technology assists in effectively teaching PBGIS in secondary schools. Furthermore, TK also allowed the researchers to explore how geography teachers' understanding of topographic maps and orthophoto maps in mapwork and the understanding of technologies involved in GIS led to the effective teaching and learning of PBGIS in secondary schools.

[22] Punya Mishra and Matthew J. Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," *Teachers College Record* 108, no. 6 (2006): 1017–54.
[23] Evrim Baran, Hsueh-Hua Chuang, and Ann Thompson, "TPACK: An Emerging Research and Development Tool for Teacher Educators.," *Turkish Online Journal of Educational Technology-TOJET* 10, no. 4 (2011): 370–77.
[24] Joseline M Santos and Rowell D R Castro, "Technological Pedagogical Content Knowledge (TPACK) in Action: Application of Learning in the Classroom by Pre-Service Teachers (PST)," *Social Sciences & Humanities Open* 3, no. 1 (2021): 100110; Ralph Saubern, "Is TPACK a Theory?," in *Society for Information Technology & Teacher Education International Conference* (Association for the Advancement of Computing in Education (AACE), 2020), 1985–91.
[25] Göran Fransson and Jörgen Holmberg, "Understanding the Theoretical Framework of Technological Pedagogical Content Knowledge: A Collaborative Self-Study to Understand Teaching Practice and Aspects of Knowledge," *Studying Teacher Education* 8, no.2(2012):193-204.
[26] Santos and Castro, "Technological Pedagogical Content Knowledge (TPACK) in Action: Application of Learning in the Classroom by Pre-Service Teachers (PST)."

Content knowledge (CK) is teachers' knowledge about the subject matter to be learnt or taught.[27] Teachers must know about the content they will teach and how the nature of knowledge differs for various content areas.[28] CK was relevant because the researchers could understand the extent of the knowledge the geography teachers possessed for teaching and learning PBGIS in secondary schools. CK also enabled the researchers to explore how PBGIS knowledge varies in different aspects of the content, and this enabled the researchers to understand how to evaluate IBL used to teach different PBGIS content areas. Pedagogical knowledge (PK) is teachers' deep knowledge about the processes and practices or teaching and learning methods.[29] PK enabled the researchers to examine the geography teachers' knowledge about the IBL process and practices for teaching PBGIS in secondary schools. Pedagogical content knowledge (PCK) refers to the content knowledge that deals with the teaching process.[30] PCK is different for various content areas, as it blends content and pedagogy intending to develop better teaching practices in the content areas. PCK was relevant for the study because researchers could evaluate different IBL strategies practised by geography teachers for different content areas in PBGIS.

METHODOLOGY

This qualitative exploratory case study was structured within the interpretive paradigm. The main assumption of this paradigm is that reality is socially constructed and that there are as many intangible realities that people construct.[31] The researchers explored the implementation and effectiveness of IBL in teaching PBGIS in secondary schools using their backgrounds in interpretivism. They could subjectively engage in geography teachers' experiences to understand their journeys. In this way, different interpretations from participants were obtained based on their diverse realities. This paper reports on the data generated from five geography teachers from three schools in the Ugu district in KwaZulu-Natal Province, South Africa. The five geography teachers teaching PBGIS in grades 10-12 were purposively selected based on teaching geography in grades 10-12. These teachers were purposively selected because they were likely to provide in-depth information on the implementation and effectiveness of IBL in teaching PBGIS. Semi-structured one-on-one interviews were used to generate data, which was analysed through thematic data analysis.[32]

This paper is generated from a doctoral thesis, so ethical issues were approved by the University of KwaZulu-Natal and KwaZulu-Natal DBE and schools under study granted permission to conduct research. Participation was voluntary, and participants held a right to withdraw at any time.[33] To ensure confidentiality and anonymity of the participants was guaranteed, pseudonyms were for the schools and participants. In the study, the participants were treated equally irrespective of their race, colour, gender, class, age and the position they might hold at their respective rural schools.

FINDINGS AND DISCUSSION

This section presents the findings according to the sub-themes that emerged after coding the data. This research had five participants; pseudonyms were used to report the findings. The background details of the participants are as follows: 1) Geography teacher 1 (GT1) is a male teacher. He holds a Bachelor of Education degree specialising in geography. He has seven years of teaching experience. 2) Geography teacher 2 (GT2) is a male teacher. He holds a Bachelor of Education degree specialising in geography. He

[27] Fransson and Holmberg, "Understanding the Theoretical Framework of Technological Pedagogical Content Knowledge: A Collaborative Self-Study to Understand Teaching Practice and Aspects of Knowledge."
[28] Santos and Castro, "Technological Pedagogical Content Knowledge (TPACK) in Action: Application of Learning in the Classroom by Pre-Service Teachers (PST)."
[29] Spyridon Doukakis et al., "Measuring the Technological Pedagogical Content Knowledge (TPACK) of in-Service Teachers of Computer Science Who Teach Algorithms and Programming in Upper Secondary Education," in *Readings in Technology and Education: Proceedings of ICICTE 2010* , ed. K. Fernstrom (Corfu, Greece , 2021), 442–52.
[30] Mirjam Schmid, Eliana Brianza, and Dominik Petko, "Self-Reported Technological Pedagogical Content Knowledge (TPACK) of Pre-Service Teachers in Relation to Digital Technology Use in Lesson Plans," *Computers in Human Behavior* 115 (2021): 106586.
[31] Nguyen Cao Thanh and T T Thanh, "The Interconnection between Interpretivist Paradigm and Qualitative Methods in Education," *American Journal of Educational Science* 1, no. 2 (2015): 24–27.
[32] Virginia Braun and Victoria Clarke, "Reflecting on Reflexive Thematic Analysis," *Qualitative Research in Sport, Exercise and Health* 11, no. 4 (2019): 589–97.
[33] Carol Bertram and Iben Christiansen, *Understanding Research. An Introduction to Reading Research.* (Pretoria: Van Schaik Publishers, 2014).

has nine years of teaching experience. 3) Geography teacher 3 (GT3) is a female teacher. She holds a Bachelor of Education degree specialising in geography and life sciences. She has ten years of teaching experience. 4) Geography teacher 4 (GT4) is a female teacher. She holds a Bachelor of Education degree specialising in geography. She has eight years of teaching experience. 5) Geography teacher 5 (GT5) is a female teacher. She holds a Bachelor of Education degree specialising in geography. She has six years of teaching experience.

Implementation of inquiry-based learning to teach paper-based GIS

The findings suggested that certain geography teachers use IBL to teach PBGIS based on research projects, problem-solving, and addressing geographic scenarios. GT1 revealed that at the beginning of the year, he gives learners research projects to complete based on any geography topic. The teacher develops a case study with a scenario around a geography topic. For example, the scenario can be developed around rural-urban migration that has resulted in informal settlements in cities, leading to other effects such as crime, unemployment, urbanisation, and exhaustion of resources. GT1 articulated:

> *"At the beginning of the year, I usually give learners a research project based on broader geography topics, such as climatology, geomorphology, settlement, or economic geography. I develop a scenario about a particular issue in one of these topics, and learners are supposed to follow the instructions in the research project question and do a sequence of activities to complete the project. For example, I might develop an issue around rural-urban migration and informal settlement. I will develop a case study on how rural-urban migration led to informal settlements in the cities, causing several issues such as crime, urbanisation, unemployment, etcetera. I then instruct learners to research by formulating open-ended questions to interview people from a particular informal settlement. Learners should ask questions that seek to answer the research question.*

GT1 added that he instructs learners to state how GIS can be used to identify crime hotspots in the city. GT1 further instructs learners to create a map of the city concerned and apply the process of buffering the city's informal settlements and crime hotspots. After that, learners may also state how they can use GIS to bring solutions to the issues raised about rural-urban migration and informal settlement.

GT1 added:

> *"I then instruct learners to state how GIS can be used to solve several problems emanating from rural-urban migration and informal settlements. For example, learners may state that GIS can be used to find crime hot spots in the city. I then expect learners to create a map of the city concerned and apply the process of buffering the city's informal settlements and crime hotspots. Learners may also state that GIS can be used to identify informal settlements, their causes and effects, and find solutions to the problems."*

Likewise, GT2 uses IBL to execute the research projects. For example, he may give learners a research project based on desertification. Learners are expected to identify an area experiencing densification, identify the causes and consequences, and develop ways to use GIS to solve the problem associated with desertification. GT2 noted:

> *"I give learners a research project, maybe based on desertification. I expect learners to engage in the research question critically by stating the uses of GIS in solving the issue of desertification in a particular area. Having the research question, learners will have to do research and formulate an argument towards answering the research question."*

On the other hand, certain geography teachers use the IBL to integrate GIS concepts with maps and geography theory. Teachers use IBL because it is a form of self-directed learning where learners take responsibility for their learning. Therefore, through IBL, learners are expected to apply GIS concepts and geography theory on maps to solve problems and develop critical thinking skills. GT3 revealed that teachers use IBL to teach and apply GIS concepts on maps. She further demonstrated using sub-concepts of vector data (lines, points, and polygons) in GIS to say a teacher can instruct learners to find such

information on topographic and orthophoto maps. According to GT3, this practice enables learners to see how these different kinds of data look as a sketch in the topographic maps and how they would look in reality when they identify them on the orthophoto map. GT3 Elucidated:

> *"I ask learners to relate these GIS concepts to maps. For instance, if we look at different types of data. Lines, points, and polygons represent the real-life data on the topographic maps. I ask learners to look for different types of data on the topographic maps represented using lines, points, and polygons. For the orthophoto maps, learners work with photographs that show the real world using pixels. I then engage learners in an inquiry process where they work independently to compare and contrast different data sets and find the relationships between them."*

GT5 further argued that learners struggle when asked to apply GIS concepts on maps but find it easier to define them. GT5 pointed out that IBL is a pedagogical approach that assists teachers in discovering learners' difficulties in understanding GIS concepts by making learners take ownership of the whole process of integrating GIS concepts and geography theory on maps. Hence, teachers mitigate the challenges learners face through guidance and lead them towards finding answers by themselves. GT5 argued:

> *"In terms of integrating GIS concepts on maps, let us use, for example, a scenario where a teacher will ask learners a question such as "How can GIS assist a farmer?". Learners may not be able to apply the concept of GIS in assisting a farmer. However, generally, they are comfortable with defining concepts more than the application part of the concepts. The lack of knowledge for learners to apply the GIS concepts is sometimes caused by a lack of understanding of them, which limits the know-how to integrate them on maps to attend to different situations. Inquiry-based learning becomes important to test learners' understanding of the GIS concepts by making learners take ownership of integrating GIS concepts on maps. Teachers then guide learners where they struggle with applying GIS concepts to solve geographic problems on maps."*

Like GT3 and GT5, GT4 indicated that PBGIS is taught using the IBL approach. GT4 asks learners, through the IBL approach, to integrate GIS concepts at the level of identifying features on the maps and distinguish the vector data map from the raster data map. GT4 further indicated that she even instructed learners to use local maps to make mapwork relatable to learners' context for effective teaching and learning of PBGIS in schools. GT4 posited:

> *"PBGIS teaching requires maps. I teach PBGIS using topographic maps and orthophoto maps. For example, when I am teaching about vector data and raster data. Through inquiry, learners must be able to separate a vector data map from a raster data map. Learners are then expected to arrive at the answers by looking at the maps to identify the distinguishing features that separate the vector data from the raster data and vice versa. I even teach them to use local maps to help them identify vacant places that can be used for further development. Local maps assist them in using local examples that learners can relate with."*

From the extract above by GT1 and GT2, it has been made clear that geography teachers use IBL to teach PBGIS based on research projects, problem-solving, and addressing geographic scenarios. GT1 noted that learners are instructed to research by formulating open-ended questions to interview people. Hence, learners should ask questions that seek to answer the research question. GT1's comment corroborates the sentiments of Chu et al. in that the IBL is a pedagogical approach that engages learners actively in a knowledge-building process through the generation of answerable questions.[34] Caswell and LaBrie add that IBL is an instructional practice where learners are at the centre of the learning experience and take ownership of their learning by posing, investigating, and answering questions.[35] Santos and Castro point out that the TPACK conceptual framework assists teachers in being aware of the Pedagogical

[34] Chu et al., *21st Century Skills Development through Inquiry-Based Learning from Theory to Practice*.
[35] Caroline Johnson Caswell and Derek J LaBrie, "Inquiry Based Learning from the Learner's Point of View: A Teacher Candidate's Success Story," *Journal of Humanistic Mathematics* 7, no. 2 (2017): 161–86.

Knowledge (PK) required to teach specific Content Knowledge (CK).[36] Therefore, teachers must know about the content they will teach and how the nature of knowledge differs for various content areas. Therefore, a teacher's knowledge of PBGIS and geography theory content affects how learners understand and ultimately impacts the way learners apply this knowledge to the topographic and orthophoto maps for problem-solving activities.

GT2 added that IBL assists learners in solving geographic issues such as desertification using GIS through the inquiry process. Hence, learners become actively involved and hands-on in mitigating desertification issues and contrasting knowledge by themselves. GT2 resonated with Revin that the IBL directs geography teachers' activities towards a curriculum presenting several issue-based assisted learning schemes, cultivating an active knowledge acquisition attitude whereby learners are required to analyse the problem at hand and develop effective ways to solve it independently and interact in a group.[37] Likewise, Loeng states that IBL is a form of self-directed learning where learners take responsibility for their learning.[38] Thus, IBL allows learners to construct knowledge of how to solve the issue of desertification using GIS through inquiry.

From the extracts above by GT3, GT5, and GT4, it has been revealed that geography teachers use IBL to integrate GIS concepts and geography theory on topographic and orthophoto maps. The IBL pedagogical approach was deemed helpful by geography teachers because it gives learners ownership of their learning by actively and independently engaging them in the integration process. The teacher's responsibility is to guide learners through the integration process, especially in areas where they experience challenges. Jiang argues that during the use of IBL, teachers may direct learners during the learning process, as some beginner learners may need more instruction to hone their inquiry skills.[39] Debbal and Djatit examine inquiry from both a learner's and a teacher's point of view. They explain that from a learner's perspective, IBL focuses on investigating an open question or problem.[40] In contrast, from a teacher's perspective, inquiry-based teaching focuses on moving learners beyond basic curiosity into critical thinking and understanding. Therefore, using the IBL approach to integrating GIS concepts, maps, and geography theory, geography teachers direct learners to think critically to develop understanding.

From the extracts above by GT3, GT5, and GT4, we also learn that the use of the IBL to integrate GIS concepts, maps, and geography theory is not only done at the level of solving geographic problems but is also practised at the level of identifying vector and raster data on the topographic and orthophoto maps. Therefore, certain geography teachers use IBL to instruct learners to identify vector data (line, point, and polygon) and raster data on topographic maps. According to Santos and Castro on the TPACK conceptual framework, pedagogical content knowledge (PCK) is different for various content areas, as it blends content and pedagogy to develop better teaching practices in the content areas.[41] Hence, geography teachers see the IBL as suitable for engaging learners in identifying vector and raster data on maps and problem-based learning for solving geographic problems using GIS concepts and geography theory.

Effectiveness of inquiry-based learning to teach paper-based GIS

The evidence shows that geography teachers view inquiry-based learning (IBL) as effective in teaching PBGIS in secondary schools. GT1 believes that IBL is effective when he engages learners in research projects. IBL enables learners to formulate open-ended questions, conduct interviews with participants,

[36] Santos and Castro, "Technological Pedagogical Content Knowledge (TPACK) in Action: Application of Learning in the Classroom by Pre-Service Teachers (PST)."
[37] F. G. Revin, "Philosophical Underpinnings of Teaching Science through Inquiry-Based Approach," *Вісник Житомирського Державного Університету Імені Івана Франка. Філософські Науки*, no. 90 (2021): 94–102.
[38] Svein Loeng, "Self-directed Learning: A Core Concept in Adult Education," *Education Research International* 2020, no. 1 (2020): 3816132.
[39] Yemeng Jiang, "Challenges of Implementing Inquiry-Based Learning in Chinese Secondary School Efl Classrooms: A Review of Teachers' and Students' Perceptions," *Journal of Studies in the English Language* 16, no. 2 (2021): 1–21.
[40] Kenza Debbal and Selma Djatit, "An Analysis of Teachers 'Views about the Implementation of Inquiry Based Learning in FEL Classes The Case of the Department of English at MMUTO" (Mouloud Mammeri University of Tizi–Ouzou, 2022).
[41] Santos and Castro, "Technological Pedagogical Content Knowledge (TPACK) in Action: Application of Learning in the Classroom by Pre-Service Teachers (PST)."

and probe further when needed to construct knowledge. Learners also develop problem-solving skills. GT1 stated:

> *"IBL is effective in teaching PBGIS in schools because the approach assists learners in formulating open-ended questions for their research questions to interview people from the informal settlement of the city learners chose to do the project on. IBL also develops learners with GIS skills to solve the problem of rural-urban migration that leads to informal settlement in the cities and many other consequences*."

GT1 added that IBL develops learners' problem-solving skills based on geographic issues. IBL also develops learners' creativity and knowledge about drawing maps in a standardised format. This is because learners are taught to draw the symbols appearing on the topographic maps. GT1 also added that IBL becomes more effective when geography allows learners to do the research project based on a city of their choice. This may develop interest as learners may relate more with the city of their choice when doing the research project.

> *"Through inquiry-based learning, learners develop problem-solving skills. In this case, learners may solve problems emanating from rural-urban migration." Learners also develop creativity and knowledge of drawing maps. This is because they do not just draw these maps, but they draw following the symbols that are supposed to appear on topographic maps. This makes them familiar with the term of standardisation on PBGIS. Inquiry-based learning can be more effective if teachers allow learners to choose the cities where they want to base their research. In this way, learners may find a city they can relate to and be more effective in doing the research project."*

Similarly, GT2 also note that IBL is effective in the execution of the research project. GT2 noted that IBL makes learners active in doing the activity and develops critical thinking skills for solving GIS-related problems. Learners also develop skills in formulating an argument to answer the research question. GT2 pointed out:

> *"The inquiry-based learning method is effective because learners develop the skill of using GIS to solve the issue of desertification in a particular area. Learners learn to do research and formulate arguments based on the research findings."*

GT3 highlighted that IBL is effective when geography teachers use research projects to prepare learners for the examinations. This is because examiners phrase questions in the GIS section in the examination in different ways. The examiners use the GIS concepts to develop scenarios around geography topics that require learners to develop solutions by using the concepts to address the problem. The research project would have prepared learners as they actively engage with different kinds of questioning, critically analyse them, and develop responses using GIS concepts. Hence, it might be easier for learners to address the scenarios in the examination. GT3 mentioned:

> *"The inquiry-based learning method is very effective when using research projects to prepare learners for the examinations. Questions are asked in different ways in the examination and are always new in different exams. During the research project, learners acquire skills in using GIS concepts to attend to different geographical scenarios. The GIS section in mapwork also uses scenarios for learners to solve problems embedded in geography topics using GIS concepts. Learners would have learnt how to deal with scenarios through the research project. Therefore, it becomes easier for them to answer any GIS question with a scenario requiring learners to use GIS concepts to find solutions to the problems."*

Likewise, GT4 also believes that IBL effectively engages learners to integrate GIS concepts with maps and geography theory. The geography teacher may group learners and use inquiry by asking learners to identify line, point, and polygon data on the topographic maps. After that, instruct learners to find their uses. Learners will then undergo the inquiry process by engaging in critical thinking and asking questions from the teacher and one another to develop responses. GT4 (semi-structured interview) posited:

"I can safely say inquiry-based learning effectively engages learners to integrate GIS concepts with maps and geography theory. I sometimes group learners and make them identify line, point, and polygon data in a particular block on the topographic maps. After that, instruct learners to find their uses. Through inquiry, learners critically think, analyse the maps, interact with each other by asking questions and also from the teacher to develop responses."

In the same way as GT1 and GT2, GT5 believe IBL effectively teaches PBGIS application to learners. GT5 noted that learners face challenges when applying the GIS concepts to topographic and orthophoto maps to solve geographic problems. GT5 indicated that learners are more comfortable with defining the GIS concepts than the application of these concepts. Therefore, GT5 stated that she uses research activities based on the learners' communities as they are best for motivating learners to deal with issues that must be solved by applying GIS concepts. GT5 (semi-structured interviews) stated:

"As I said before, learners can define GIS concepts easily but fail to provide answers for questions that expect them to state how GIS can assist in activities such as farming or settlement. This shows that teachers need to do more work applying GIS concepts rather than asking learners to define them. Therefore, inquiry-based learning assists me in identifying learners' weaknesses in applying GIS concepts to maps to find mitigation strategies for their challenges. I make my learners do the research activity based on their community as it is the best for capacitating learners to deal with issues that need to be solved through application".

The excerpts above show that geography teachers find IBL effective in teaching PBGIS in secondary schools. GT1, GT2, GT3 and GT5 believe IBL is effective when learners do research projects. During the research project, the teacher and learners critically develop a set of questions that learners use to ask questions from the participants in the field to answer a research question. Learners develop skills to address the problems embedded in the geography topics. This is consistent with the sentiments of Chu et al. that the IBL approach is related to problem and project-based learning, in which learners adopt an inquiry mindset in addressing epistemic issues or in developing and completing projects with a relatively open-ended set of answers.[42] For instance, an IBL project may comprise an interest-driven research question developed by the learner and assigned in a school context. The IBL approach assists geography learners in becoming critical thinkers and developing skills to question their curiosity to construct knowledge through research projects. The IBL also develops open-minded geography learners who understand that the research question can have multiple open-ended answers.

The IBL may also involve a more structured problem-based scenario designed by the teacher to teach learners specific principles, requiring the learner to engage in inquiry, subject knowledge immersion and perhaps research and creation of an artefact to complete the task.[43] It could also be a more open-ended, interest-driven project in which learners pursue an idea or question that taps their innate curiosity (whether in or out of school).[44] Therefore, when geography teachers develop research projects, they specify by guiding learners on activities to equip learners with specific skills. For example, learners may be requested to draw a map of the city on which they are basing their research project and buffer the informal settlements and crime hotspot areas on the map. In this way, learners will develop map-drawing skills and become knowledgeable about how the process of buffering works in PBGIS using maps.

The excerpt above by GT4 shows that IBL also works when engaging learners in classroom activities. Learners actively engage with classroom activities based on PBGIS to construct knowledge and develop skills in answering questions. This resonates with Chou et al., who stated that IBL is a pedagogical approach that engages learners actively in knowledge-building by generating answerable questions.[45] Such inquiry-based tasks share a theoretical underpinning in social constructivism, presuming that

[42] Chu et al., *21st Century Skills Development through Inquiry-Based Learning from Theory to Practice*.
[43] Kaili Lu, Feng Pang, and Rustam Shadiev, "Understanding the Mediating Effect of Learning Approach between Learning Factors and Higher Order Thinking Skills in Collaborative Inquiry-Based Learning," *Educational Technology Research and Development* 69, no. 5 (2021): 2475–92.
[44] Chu et al., *21st Century Skills Development through Inquiry-Based Learning from Theory to Practice*.
[45] Ren-Jye Chou et al., "The Impacts of Online Skeuomorphic Physics Inquiry–Based Learning with and without Simulation on 8th Graders' Scientific Inquiry Performance," *Journal of Science Education and Technology* 31, no. 3 (2022): 357–71.

geography learners are active agents in building knowledge through constructing their understanding and meaning-making, requiring an inquiry mindset. Research has found that more formalised, well-designed inquiry-based approaches promote positive learning outcomes such as deep thinking, knowledge application and logical reasoning. Therefore, geography teachers should ensure that research projects are well-designed and part of the formal assessment so that learners take them seriously when executing them. A well-designed research project with clear and straightforward instructions can help minimise learners' confusion when doing a research project.

PBGIS involves GIS technological concepts that require effective pedagogical approaches to teaching technological content. Hence, the TPACK conceptual framework assists geography teachers in using IBL to teach GIS concepts.[46] TPACK refers to the intersection between technological, pedagogical, and content knowledge in teaching a particular subject.[47] Therefore, TPACK assists geography teachers in using IBL to design PBGIS lessons so that learners will actively use GIS concepts to do problem-solving activities embedded in the geography content. Therefore, the TPACK conceptual framework helps learners understand how GIS concepts are implemented in the classroom while learning the usefulness of GIS technologies in real life through IBL.

RECOMMENDATIONS

This research proposes that geography teachers should use IBL to teach PBGIS in schools. Teachers should collaborate and assist each other with more effective strategies for implementing IBL in teaching PBGIS in secondary schools. Teachers should base learner's research projects on real-life issues in learners' communities. In this way, learners may relate to the research question and be motivated to complete the project. During workshops, geography subject advisors and lead teachers should emphasise the implementation and effectiveness of using IBL to teach PBGIS in secondary schools.

CONCLUSION

This research concludes that IBL is effective in engaging learners in the inquiry process. Through IBL, learners solve problems and construct knowledge. IBL engages learners in authentic problem-solving activities by applying GIS concepts. Hence, it is essential that in classrooms where teachers emphasise IBL, learners are actively involved in solving authentic (real-life) problems within the context of the curriculum and community. The teacher's primary responsibility in an inquiry-based educational setting is to filter the world for the learner, which goes beyond simple information processing, transmission, and storage.

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