





Geography Teachers' integration of Mathematical Concepts in the Teaching of Mapwork skills and calculations

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ABSTRACT

This paper explored geography teachers' integration of mathematical concepts in the teaching of mapwork skills and calculations. A qualitative explorative case study was adopted, and data were generated through field notes and observations of four geography teachers' lessons. The knowledge integration perspective was used to analyse the collected data through thematic analysis. Findings revealed that geography teachers need to translate between mathematics and geography terms, transfer explanatory concepts from the mathematics context to mapwork skills and calculations and transform the integration of interdisciplinary understanding through instructional resources. This study concludes that geography teachers should integrate mathematical concepts when teaching geography to allow learners to understand map skills and calculations effectively. A call for experienced and novice Geographers to collaborate with Mathematics teachers to close the gap in teaching map skills. This study contributes to the existing knowledge of teaching mapwork skills and calculations in secondary schools by influencing pedagogical practices for interdisciplinary teaching.

Keywords: Geography teachers, Knowledge Integration, Mathematical concepts, Mapwork skills

INTRODUCTION

The Curriculum and Assessment Policy Statement (CAPS) for geography aims to guide teachers in developing learners' essential transferable practical skills such as numeracy, literacy, graphicacy and oracy.¹ Numeracy is one of the essential subject-specific skills for learning geography that requires learners to use symbolic and quantitative forms of data, including, among others, text, graphs, tables, diagrams, pictures, maps and working with statistics. Furthermore, learners engage with numeracy skills in geography when they interpret and construct maps, evoke their understanding of numerical grids, distance, area, gradient, and scale.² To achieve this, geography learners should be able to use numbers and mathematical concepts when engaging in map skills and calculations. Hence, geography teachers need to assist learners' ability to develop numeracy skills to progress in the subject and enrich

¹ Department of Basic Education, *Curriculum and Assessment Policy Statement (CAPS): History Grades 10–12* (Pretoria: DBE, 2011).

² Assessment & Reporting Authority (ACARA) Australian Curriculum, *General Capabilities in the Australian Curriculum* (Canberra: Australian Curriculum, Assessment & Reporting Authority, 2013).

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their geographical thinking.³ In addition, provide learners with opportunities that develop the mathematical understanding needed to learn geography successfully.

There are numerous continued challenges that learners encounter in map skills and calculations in geography, which relate to geographical skills and techniques. This is reported by the diagnostic report which narrates that geography learners were unable to calculate the area of a demarcated feature on an orthophoto map, measured their own length distance despite given an estimated length, made use of an incorrect scale, were unable to determine seconds by calculation, were unable to correctly use a protractor, experienced difficulties with understanding and applying the term gradient and were unable to express final answers as a ratio.⁴ These challenges are mainly linked to the mathematical skills that geography learners need to tackle geographical skills and techniques problems that relate to map skills and calculations.⁵ Furthermore, the challenges may emanate from teachers' reported difficulty in making connections between mathematics skills and geography when working on map activities with learners.⁶

The challenges presented above indicate the existence of a problem that needs to be addressed. That is, learners have not been performing well in geography due to the contents of mapwork that are mathematical in nature.⁷ While researchers have recommended a need for other forms of methods to be used during teaching and learning of mapwork, little is said about the benefits that teachers can offer to learners when incorporating mathematical skills during geography teaching. Moreover, geography teachers' knowledge and ability to integrate mathematical concepts and skills when teaching mapwork skills and calculations. This is supported by Anthamatten et al., who argue that integrating mathematics concepts when teaching geography can result in improved measurable learner performance.⁸ This paper reports on geography teachers' knowledge and integration of mathematical concepts and skills necessary for learners to tackle geographical skills and techniques problems that relate to map skills and calculations. The aim is to explore geography teachers' integration of mathematical concepts when teaching mapwork skills and calculations. This study attempts to answer the question, "How do geography teachers integrate mathematical concepts when teaching mapwork skills and calculations?"

LITERATURE REVIEW

Mapwork skills and calculations in geography

Geography is referred to as the mother of all subjects, in which the integration of the nature of the subject between social and natural sciences is emphasised.⁹ This integration further justifies the subject's integration with other related fields, such as mathematics. According to Donnelly and Martin, geography content requires teachers to develop learners' numeracy skills, which would allow them to analyse data statistically and be able to read, interpret maps, graphs and use longitude and latitudes.¹⁰ This is in addition to their ability to calculate exaggeration, gradients, use scales and measure distance, among other mathematical skills. Hence, a map is a tool that is given special emphasis in geography and acquiring mapwork skills is fundamental.¹¹ To achieve this, geography should be looked at as a vehicle through which mathematical skills are integrated during teaching in an engaging, real-life context and are linked to real-life problem solving.

³ Debra Donnelly and Margaret Martin, "Geography and Numeracy," in *Numeracy in Authentic Contexts* (Singapore: Springer Singapore, 2018), 197–223, https://doi.org/10.1007/978-981-10-5736-6_10.

⁴ Department of Basic Education (DBE), *NSC School Performance Report 2024* (Pretoria: DBE, 2024).

⁵ Iik Nurhikmayati et al., "An Ex Post Facto Study of Critical Thinking Skills in Mathematics Learning Based on School Geography," *Al-Jabar : Jurnal Pendidikan Matematika* 15, no. 1 (June 6, 2024): 15–31, <https://doi.org/10.24042/ajpm.v15i1.19330>.

⁶ Peter Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics," *Journal of Geography* 117, no. 5 (September 3, 2018): 183–92, <https://doi.org/10.1080/00221341.2017.1413413>.

⁷ Peter A Amosun, "Group Learning, Gender, Mathematical Ability and Students' Mapwork Skills," *IFE Psychologia: An International Journal* 24, no. 1 (2016): 12–21.

⁸ Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics."

⁹ Philip Kwashi Atiso Ahiaku, Dumisani W Mncube, and Sunday O Olaniran, "Teaching Mapwork in South African Schools: Reflections from Educators' Experiences, Concerns and Challenges," *African Journal of Gender, Society & Development* 8, no. 2 (2019): 19.

¹⁰ Donnelly and Martin, "Geography and Numeracy."

¹¹ Vincent Yohanna Iwah, "Effects of Scale Models on Mapwork Achievement in Lafia, Nasarawa State," *Kashere Journal of Education* 5, no. 1 (2023): 260–75.

Mapwork is a topic in geography that requires teachers to develop learners' understanding of spatial relationships, geographic concepts, and critical thinking skills.¹² These skills play a significant role during the teaching and learning of mapwork, whereby teachers and learners use numbers and mathematical concepts to succeed in mapwork skills and calculations. Furthermore, learners who possess these skills in geography can demonstrate rich comprehension of geographic concepts, spatial relationships, and critical thinking skills.¹³ In addition, have ample opportunities to navigate and interact effectively with their physical environment, calculate actual distance on maps given scale, draw the map's outline scales correctly and insert a feature inside a reduced map. According to Naxweka and Wilmot, maps are essential tools that are required to communicate spatial information during the teaching of mapwork skills and calculations, yet they are more sophisticated graphic representations that use symbols, words, and numbers to encode spatial information.¹⁴ Hence, for learners to have spatial thinking, teachers are required to promote learners' spatial understanding and visualisation.¹⁵ This thinking has the potential to assist learners in organising and solving problems that require them to use processes of reasoning, spatial concepts, graphs, and maps.¹⁶

Challenges in teaching and learning mapwork skills and calculations in geography

The teaching and learning of mapwork skills and calculations in South Africa continue to pose a challenge to many teachers and learners in geography.¹⁷ This is supported by the Grade 12 final examination diagnostic report for geography, in which learners are reported to have struggled when calculating the area of a demarcated feature on an orthophotography map and measuring the length distance despite being provided with it.¹⁸ Additionally, some learners used incorrect scales, did not convert their final answer to the instructed SI units or did not include all the required steps. Furthermore, learners were also faced with the challenge of understanding and differentiating between types of scales and raster and vector data.¹⁹ The main challenges which the report raises were learners' inability to determine seconds by calculation, which indicated that learners did not fully comprehend how to determine the grid reference of a feature. In addition, learners had challenges that related to incorrect subtraction for vertical interval, correct substitution and expressing answers as a ratio and the use of scale in the correct unit. Lastly, learners had difficulties in comprehending and applying the concept of gradient.

The challenges mentioned above continue to negatively affect learners' performance in mapwork skills and calculations, despite their importance in geography.²⁰ Decades ago, the poor performance of learners was reported in countries such as Ethiopia, Nigeria, and South Africa. For instance, Okwilagwe has argued that learners in Nigeria have poor fundamental mapwork knowledge,²¹ while Madiwalar has argued about the nose-dive that causes the decline of academic performance of learners in Ethiopia due to inadequate teaching and learning of map skills.²² Similarly, in South Africa, Larangeira and van der Merwe noted that students lacked map literacy as they struggled to grasp basic

¹² Department of Basic Education, *Curriculum and Assessment Policy Statement (CAPS): History Grades 10–12*.

¹³ Okoro Udochukwu, Suleiman H Aisha, and Ajooku A Asipita, "Jigsaw Learning Model as Determinant of Academic Performance between Public and Private Schools Geography Students in Map Work In Wamakko, Sokoto State," *EDUCATION IN AFRICA*, 2024, 185.

¹⁴ Johanna Naxweka and Di Wilmot, "Namibian Teachers' Perceptions and Practices of Teaching Mapwork," *The Journal of Geography Education in Africa* 2, no. 1 (October 30, 2019): 1–14, <https://doi.org/10.46622/jogea.v2i1.2479>.

¹⁵ B S Balboni, "Making Maps and Atlases an Everyday Tool in School: A Guide to Using My First Atlas of Belize, Atlas of Belize, and Atlas of Belize and the World," *Retrieved February 27* (2013): 2017.

¹⁶ Naxweka and Wilmot, "Namibian Teachers' Perceptions and Practices of Teaching Mapwork"; Sarah Witham Bednarz, Gillian Acheson, and Robert S Bednarz, "Maps and Map Learning in Social Studies," *Social Education* 70, no. 7 (2006): 398.

¹⁷ Ahiaku, Mncube, and Olaniran, "Teaching Mapwork in South African Schools: Reflections from Educators' Experiences, Concerns and Challenges."

¹⁸ Department of Basic Education (DBE), *NSC School Performance Report 2024*.

¹⁹ Udochukwu, Aisha, and Asipita, "Jigsaw Learning Model as Determinant of Academic Performance between Public and Private Schools Geography Students in Map Work In Wamakko, Sokoto State."

²⁰ Udochukwu, Aisha, and Asipita, "Jigsaw Learning Model as Determinant of Academic Performance between Public and Private Schools Geography Students in Map Work In Wamakko, Sokoto State."

²¹ Eugenia A Okwilagwe, "Influence of Teacher Factors on Attitudes of Geography Teachers to Map Work in Nigerian Secondary Schools," *IFE Psychologia: An International Journal* 20, no. 2 (2012): 67–72.

²² Siddu S Madiwalar, "Factors Affecting Students' Performance and Practice on Map Reading Skills: A Case Study of Selected Secondary Schools in Asela Town, Ethiopia," *Science, Technology and Arts Research Journal* 1, no. 3 (2012): 97–105.

concepts and calculation skills that included scale, bearing, altitude and direction.²³ These challenges were also reported by Ahiaku et al. when exploring teachers' experiences, challenges, and concerns about mapwork teaching in South African schools.²⁴

Recently, Uyar et al. have supported the challenges encountered in mapwork skills and calculations in a study on the challenging levels of map reading skills among students in Turkey. They have found that students struggle with fundamental basic skills in map reading, determining direction, locating positions using a map and holding a map.²⁵ Additionally, in Nigeria, Iwah has argued that the performance of learners in geography mapwork has been persistently poor due to factors attributed to the difficulty of the topic, lack of interest by learners, and inadequately trained teachers, to name a few.²⁶ Similarly, Udochukwu et al. have argued that learners in Nigeria continue to demonstrate a persistent weakness in geography mapwork skills, which impacts their performance in the subject.²⁷ Unfortunately, the poor performance in the mapwork aspect of geography is also a concern in South Africa. Schoeman and Chidzingu argued that the poor performance results from learners' lack of geographical skills and techniques such as map interpretation, Geographic Information Systems and map calculations.²⁸

In contrast to learners' challenges in learning mapwork skills and calculations, research has also indicated that poor performance in mapwork emanates from challenges that relate to how geography is taught in schools.²⁹ These challenges include, amongst others, teachers' inadequate pedagogical knowledge and content training, and the availability of maps as resources for teaching mapwork skills and calculations. It is worth noting that these challenges are still imminent despite the significance of teacher preparedness in determining the success of teaching and learning in schools. Additionally, geography teachers have been reported to have been trained towards social sciences teaching, with few who are well-trained in relation to mapwork for geography teaching. This is concerning because Darling-Hammond assessed in a study that teachers who have the highest qualifications in a subject major [geography] are likely to teach learners to the highest potential in their academic performance.³⁰ In a study by Iwah, geography has been perceived as a complex subject due to the abstract way in which it is taught.³¹ This perception still exists even after it was reported decades ago that the cause of poor performance in mapwork is due to the poor teaching in which rural teachers utilise ineffective traditional teaching strategies.³² In a study by Ezeudu and Ojih, it was emphasised that teachers who lack competence in teaching mapwork have a gap that needs to be filled for the teaching of mapwork in geography to be effective.³³

According to Malahay, geography teachers are unable to impart knowledge without necessary preparation, and a contributing factor to this is the deficiency in educational qualifications and subject

²³ Rhoda Larangeira and Clinton David Van der Merwe, "Map Literacy and Spatial Cognition Challenges for Student Geography Teachers in South Africa," 2016.

²⁴ Ahiaku, Mncube, and Olaniran, "Teaching Mapwork in South African Schools: Reflections from Educators' Experiences, Concerns and Challenges."

²⁵ Şeyma Uyar, Onur Yayla, and Hidayet Zünber, "Examination of Map Reading Skills with Orienteering Activity: An Example of Many Facet Rasch Model," *International Journal of Assessment Tools in Education* 9, no. Special Issue (November 29, 2022): 258–82, <https://doi.org/10.21449/ijate.1116273>.

²⁶ Iwah, "Effects of Scale Models on Mapwork Achievement in Lafia, Nasarawa State."

²⁷ Udochukwu, Aisha, and Asipita, "Jigsaw Learning Model as Determinant of Academic Performance between Public and Private Schools Geography Students in Map Work In Wamakko, Sokoto State."

²⁸ T Schoeman and T Chidzingu, "Can the Map Work Content Knowledge (CK) Competence Be Improved among Geography Teachers? Empirical Evidence from the University of Johannesburg in-Service Teacher Training in Gauteng, South Africa," *South African Geographical Journal* 107, no. 4 (October 2, 2025): 565–85, <https://doi.org/10.1080/03736245.2025.2472680>.

²⁹ Ahiaku, Mncube, and Olaniran, "Teaching Mapwork in South African Schools: Reflections from Educators' Experiences, Concerns and Challenges."

³⁰ Linda Darling-Hammond, "Constructing 21st-Century Teacher Education," *Journal of Teacher Education* 57, no. 3 (May 1, 2006): 300–314, <https://doi.org/10.1177/0022487105285962>.

³¹ Iwah, "Effects of Scale Models on Mapwork Achievement in Lafia, Nasarawa State."

³² A E Tshibalo, "Cooperative Learning as a Strategy to Improve the Teaching of Mapwork to Grade 11 and 12 Geography Learners in Region 3 (Limpopo Province): A Case Study Conducted at Ramaano Mbulaheni Inservice Training Centre," in *Poster Presented at 21st International Cartographic Conference, Durban, South Africa, 2003*.

³³ Samuel Agozie Ezeudu and Linus Utazi Ojih, "Competence Gaps among Geography Teachers in the Teaching of Geography Map Work in Secondary Schools in Kogi State," *Journal of Education and Practice* 5 (2014).

specialisation.³⁴ As a result, geography teachers may have a mapwork content knowledge gap that hinders their ability to effectively impart the necessary knowledge and skills learners require to succeed in mapwork. In their study, Shamle et al. support this argument by contending that qualification, subject-matter expertise, specialisation, experience in teaching, in addition to appropriate assessment methods, are some of the factors that determine competence in teaching.³⁵ This is supported by Schoeman and Chidzingu in their study, as they argued that poor performance on geography emanates from teachers' instructional practices that fail to stay up to date with the current developments in the subject. This is in addition to their lack of content knowledge due to not specialising, and the necessary skills and resources to teach mapwork.³⁶ Naxweka and Wilmot have indicated that geography teachers often do not teach mapwork as they fear the mathematical skills, abstract and sophisticated thinking that is required by the topic.³⁷ Similarly, a study by Besele found that geography teachers encounter challenges when teaching mapwork due to their lack of competency and proficiency in mathematics.³⁸ Thus, exploring how mathematical concepts are integrated during geography teaching was necessary in this study. This exploration brings novel insight for teachers to succeed in teaching geography by not depending only on the knowledge gained in the discipline, but on how to use their subject knowledge in teaching and be able to integrate necessary interdisciplinary subjects like mathematics to assist learners learn better.³⁹

The role of mathematical skills in teaching the mapwork topic in geography

The integration of mathematics during geography teaching and learning plays a significant role in improving one's spatial reasoning and thinking skills.⁴⁰ This integration is further advocated by Tomlinson, who emphasised geography teaching through the lens of mathematics by focusing on two areas that are specifically connected in the two subjects.⁴¹ Additionally, when the two subjects are integrated, their intersection promotes the development of learners' understanding and use of spatial information such as depth, breadth, and scope.⁴² Furthermore, they will be able to comprehend deeply essential spatial concepts such as scale, location, and special technologies (GIS), to name a few. These are mapwork practical geography concepts that teachers and learners find difficult, which require mathematical knowledge and skills to comprehend.⁴³ Researchers have long suggested teaching spatial thinking through the lens of mathematics.⁴⁴ However, Anthamatten et al. have reported that teachers overlooked the fact that spatial skills and mathematical concepts are deeply related, despite the benefits that are evident when mathematics is incorporated in geography teaching.⁴⁵

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- ³⁴ Roger S. Malahay, "Area of Specialization and Teaching Performance of the Secondary Science Teachers in Negros Oriental, Philippines," *Journal of Scientific Research and Reports*, December 1, 2021, 97–103, <https://doi.org/10.9734/jsrr/2021/v27i1130461>.
- ³⁵ H Shamle et al., "Solutions to Challenges Confronting Geography Teachers' Effectiveness in Secondary Schools Situated in Akwanga Local Government Area of Nasarawa State, Nigeria," *International Journal of Advanced Academic Research* 8, no. 4 (2022).
- ³⁶ Schoeman and Chidzingu, "Can the Map Work Content Knowledge (CK) Competence Be Improved among Geography Teachers? Empirical Evidence from the University of Johannesburg in-Service Teacher Training in Gauteng, South Africa."
- ³⁷ Naxweka and Wilmot, "Namibian Teachers' Perceptions and Practices of Teaching Mapwork."
- ³⁸ Mphekeleli Johannes Besele, "Assessment of Geography Students' Map Reading and Interpretation Skills, and the Contributing Factors" (National University of Lesotho, 2023).
- ³⁹ Petr Knecht and Michaela Spurná, "Does Specialization in Geography Teaching Determine Teachers' Conceptions of Geography Teaching?," *International Research in Geographical and Environmental Education* 31, no. 3 (July 3, 2022): 242–60, <https://doi.org/10.1080/10382046.2021.1970967>.
- ⁴⁰ Ray Oldakowski and Ashley Johnson, "Combining Geography, Math, and Science to Teach Climate Change and Sea Level Rise," *Journal of Geography* 117, no. 1 (January 2, 2018): 17–28, <https://doi.org/10.1080/00221341.2017.1336249>.
- ⁴¹ Brett Tomlinson, "Integrating Mathematics and Geography into Intermediate Classroom Instruction," *Gazette-Ontario Association for Mathematics* 61, no. 4 (2023): 40–43.
- ⁴² Donnelly and Martin, "Geography and Numeracy."
- ⁴³ Iwah, "Effects of Scale Models on Mapwork Achievement in Lafia, Nasarawa State."
- ⁴⁴ Erica Blatt, "Local Tree Mapping: A Collaborative, Place-Based Activity Integrating Science, Technology, Math, and Geography," *Science Activities: Classroom Projects and Curriculum Ideas* 50, no. 3 (July 3, 2013): 99–109, <https://doi.org/10.1080/00368121.2013.808165>; Oldakowski and Johnson, "Combining Geography, Math, and Science to Teach Climate Change and Sea Level Rise."
- ⁴⁵ Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics."

There has been a notable performance improvement that is demonstrated by learners when mathematical concepts are integrated into geography teaching.⁴⁶ During the integration, mathematical skills were linked with mapwork activities to incorporate spatial thinking in a way that supports the teaching of geography through the lens of mathematics. A study by Golightly supports the significant role that mathematics plays in geography teaching when reporting that the poor teaching of mapwork resulted from teachers' lack of mathematical skills.⁴⁷ In another study by Balakrishna, it was implied that learners' understanding of GIS requires sufficient exposure to mathematics to succeed in learning geography.⁴⁸ Hence, this paper seeks to gain insight into geography teachers' integration of mathematical concepts in their teaching of mapwork skills and calculations.

THEORETICAL FRAMEWORK

The purpose of this study was to explore geography teachers' integration of mathematical concepts when teaching mapwork skills and calculations. As such, an interdisciplinary teaching approach that integrates two or more subjects into a meaningful connection to enhance and enrich learning within each subject is deemed relevant.⁴⁹ Hence, this study borrows from Linn's knowledge integration perspective that focuses on interdisciplinary understanding to frame this study.⁵⁰ This framework emphasises the facilitation of learners' knowledge integration to assist them in eliciting, evaluating, and sorting out ideas.⁵¹ This study focuses on interdisciplinary knowledge integration, where teachers can achieve knowledge integration across disciplinary boundaries. The study looks at interdisciplinarity not as a simple additive to knowledge integration, as one discipline may impose unique perspectives and constraints. When looking at the same phenomenon, teachers should identify, coordinate and switch between these disciplinary perspectives. During map skills and calculations, teachers can use the skills to understand the concept of Area in mathematics to calculate the area in geography mapwork.

This study adopted three processes of the interdisciplinary knowledge integration considered by Shen et al., namely translation, transfer and transformation, to explore teachers' integration of mathematical concepts in geography teaching.⁵² In translation, teachers are required to translate interdisciplinary knowledge when using language during geography teaching. Geography shares a set of basic terminologies with mathematics, which are specialised terms and jargon developed within mathematics. In some instances, mathematics may assign different meanings or interpretations to the same terms in geography. When this happens, teachers need to translate between geography terms and mathematical terms to communicate effectively with their learners coming from different disciplines. The concept of gradient in mathematics refers to the measure of how steep a line of slope is. In contrast, in geography, it relates to the measure of how much the elevation changes over a horizontal distance. These two terms are similar, yet they can be interpreted differently in mathematics and geography.

In the transfer of interdisciplinary knowledge integration, context should be considered for the transfer to occur. This process refers to the teachers' ability to apply explanatory concepts, tools, and models they have learned from one disciplinary context to another. Teachers conceptualise one discipline's core structures or models and use their connections to interpret in another discipline a new scenario. Such a transfer goes beyond the surface level and falls within the deep transfer category.

⁴⁶ Philip K.A. Ahiaku and Dumsani W. Mncube, "Geography Educators' Perceptions of Learner Performance in Grade 12 Geography in Public Schools," *Alternation: Interdisciplinary Journal for the Study of the Arts and Humanities in Southern Africa* SP, no. 21 (December 1, 2018): 68–90, <https://doi.org/10.29086/2519-5476/2018/sp21a4>; Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics."

⁴⁷ Aubrey Golightly, "South African Geography Teachers' Involvement in Self-Directed Professional Development Activities in Geography Education," in *Geography Teacher Education and Professionalization* (Springer, 2022), 305–22.

⁴⁸ Sundar Balakrishna, "Whither Haversine, and Whither Orthodromic? Inclusivity in Geographical Information Systems Education: Lessons from India," in *Proceedings of the 16th International Conference on Theory and Practice of Electronic Governance* (New York, NY, USA: ACM, 2023), 291–99, <https://doi.org/10.1145/3614321.3614361>.

⁴⁹ Hye Sun You, "Why Teach Science with an Interdisciplinary Approach: History, Trends, and Conceptual Frameworks.," *Journal of Education and Learning* 6, no. 4 (2017): 66–77.

⁵⁰ Marcia C. Linn, "The Knowledge Integration Perspective on Learning and Instruction," in *The Cambridge Handbook of the Learning Sciences* (Cambridge University Press, 2005), 243–64, <https://doi.org/10.1017/CBO9780511816833.016>.

⁵¹ Ji Shen, Ou Lydia Liu, and Shannon Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis," *International Journal of Science Education* 36, no. 11 (July 24, 2014): 1773–93, <https://doi.org/10.1080/09500693.2013.879224>.

⁵² Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis."

During the interdisciplinary transfer, teachers rely on mathematical knowledge and skills learned as a primary discipline for the transfer to occur into geography's new concept. When teachers explain the concept of the gradient in geography teaching, they may be able to transfer their knowledge learned from the gradient calculation in mathematics by recognising similar components in the process of gradient calculation. In this process, teachers are required to carefully consider what constitutes a new context in geography and how much additional mathematical knowledge is tied to the new context, which they will need to know to teach the new concept understandably.

Transformation involves teachers' development of an integrated understanding where they have the potential to perform interdisciplinary transformation. This is where they apply explanatory concepts and models from what they have learned in one discipline (in our case, mathematics), and transform a system conceptually or physically that is typically considered in a different discipline into a new system. This process requires a change that will produce a new conceptual or physical entity. It is in this process that teachers will be involved in making changes to an existing system through interdisciplinary thinking or predicting and analysing the effect when a change is typically considered in one discipline is introduced to a system in another discipline.

METHODOLOGY

This paper followed a qualitative approach and adopted an explorative case study of the geography teachers' integration of mathematical concepts in their teaching of mapwork skills and calculations. The qualitative approach was deemed relevant as it allows geography teachers to express their way of teaching rather than hiding true reflection on the observed lesson. According to Sharan, a qualitative case study allows researchers to investigate a social unit or specific phenomenon intensively, descriptively, holistically and analytically.⁵³ Hence, this design was relevant given the focus on the integration of mathematical concepts in geography teaching, a "contemporary phenomenon" that is deeply rooted in geography teachers' actions during the teaching of mapwork skills and calculations. As a result, the researchers managed to produce thick and rich descriptions that contributed to a better understanding of how geography teachers integrate mathematical concepts in their teaching of mapwork. The geography teachers were purposively sampled from four rural secondary schools in Capricorn South Education District, Limpopo province. The purposive sampling technique was used to select the four schools with the four sampled geography teachers. The four schools were selected from the eight targeted secondary schools found in the rural area, because they were considered to have been rural area that has resources to teach Mapwork skills and calculations. The choice of sample was used, looking at their 5-10 years of teaching experience, knowledge of mathematics, qualification and present grade allocated in the year data was collected. The following table shows a breakdown of the purposive sample:

Table 1: Participants' demographics

Codes	Highest Qualification	Age group	Geography Teaching Experience	Allocated Grades
GITM1	ACE (Advanced Certificate in Education)	55-60	30	10-12
GITM2	BEdHONS (Educational Management)	45-50	12	11-12
GITM3	BA and BEd	45-50	15	10-12
GITM4	BEdHONS (Educational Management)	40-45	18	10-12

The geography teachers selected were studied in their schools and classrooms as a natural setting. A qualitative researcher observes people's settings to learn and get insights about why and how

⁵³ Sharan B. Merriam, *Qualitative Research and Case Study Applications in Education: Revised and Expanded from Case Study Research in Education* (San Francisco: Jossey-Bass Publishers, 1998).

things are done.⁵⁴ An explorative case study was used on individual participants to make sense of how they integrate mathematical concepts when teaching mapwork skills and calculations. The participants in this study had more than five years of teaching experience in the geography Classroom. The researcher's role in this explorative case study was able to get the in-depth information regarding the integration of the mathematical concepts when teaching map skills and calculations. The data we used in this paper are from parts of the first author's unpublished doctoral study. It was generated from the participants through taped-recorded observations of their lessons and writing field notes on their actions as they teach geography over a period of three weeks.

The researchers analysed the generated data using thematic analysis, in which they identified, analysed and interpreted patterns of meaning within the data. The themes that emerged were presented in the analysis section. The researchers followed a thematic analysis approach, which involved six steps: Transcription and Familiarisation: Four classroom observation lessons were recorded, checked and reviewed by the researcher. Initial Coding: Line-by-line coding on the interaction of a teacher and learners was conducted to identify meaningful units of data collected from the observation. Theme Generation: Codes were collated and grouped into potential themes through a process of constant comparison of the data from four participants selected for the study. Theme Review and Definition: Themes were reviewed and refined to ensure they are accurately represented as a dataset, resulting in the four core themes presented in the findings and were guided by the research question. The response and verbatim quotations emanate from the lesson interaction of teachers and learners. On the last step, this paper is presented as a final report based on collected data.⁵⁵

Ethical considerations

Permission to carry out the study was obtained from the relevant authorities of the Tshwane University of Technology with reference FCRE/PE/STD/2022/10, and the Limpopo Department of Education. The targeted participants in the study were informed of the purpose of the study and were asked to participate voluntarily, obtaining their consent. Participants of the study were two male geography teachers and two female teachers to prevent bias in data collection. All geography teachers who formed part of the study signed a written agreement to ensure anonymity of the information regarding the study.

PRESENTATION OF FINDINGS AND DISCUSSION

This section presents the findings in three sections to explore how geography teachers integrated mathematical concepts in the teaching of map skills and calculations. The following themes summarise the findings: (a) translating between mathematics and geography terms, (b) Transfer of explanatory concepts from the mathematics context to mapwork skills and calculations, and (c) transforming the integration of interdisciplinary understanding through instructional resources.

Translating between mathematics and geography terms

The results from the data have revealed that geography teachers were unable to integrate mathematical concepts into their teaching of mapwork skills and calculations. This was demonstrated when the teachers failed to translate between mathematics and geography terms such as distance, scale and area. These terms are used in mathematics concepts that require learners to calculate the distance between two points positioned within a particular scale, as well as the area around different points can be calculated. When these mathematical concepts are translated to geography content, geography teachers can use the mathematical concepts, integrating them to assist learners in calculating the distance from one area to another using spot heights as a representation of height. According to Hrynevych et al., geography has questions and problems that can be solved using mathematical concepts.⁵⁶ Teachers' ability to integrate mathematical concepts enables meaningful connections with geography, enhancing

⁵⁴ J Amos Hatch, "Doing Qualitative Research in Education Settings," 2023.

⁵⁵ Virginia Braun and Victoria Clarke, "Using Thematic Analysis in Psychology," *Qualitative Research in Psychology* 3, no. 2 (2006): 77–101.

⁵⁶ L M Hrynevych et al., "STEM Education in the Context of Improving the Science and Mathematics Literacy of Pupils," *Journal of Physics: Conference Series* 2288, no. 1 (June 1, 2022): 012031, <https://doi.org/10.1088/1742-6596/2288/1/012031>.

learners' understanding of the integrated concepts by leveraging synergy between them.⁵⁷ As argued by Bell, this integration allows teachers to support the transfer of knowledge through interdisciplinary knowledge integration.⁵⁸

The inability to transition between mathematical and geography terms is demonstrated in the extract below, where GITMI initiated a classroom discussion with learners placed as individual spectators to use both the topographic and orthophotography maps to *calculate the actual distance on the given map*. In relation to mathematical concepts, *distance is calculated from point A to point B to check the amount of space between two points*. Similarly, in geography content, the *distance is calculated from one area to another using spot heights as a representation of height*. The teacher initiated a question to learners about the definition of distance in the context of geography teaching. However, none of the learners responded positively to give the relevant answer to the question. The teacher presented the responses to the questions below to learners using the Humansdorp topographic and orthophotography map.

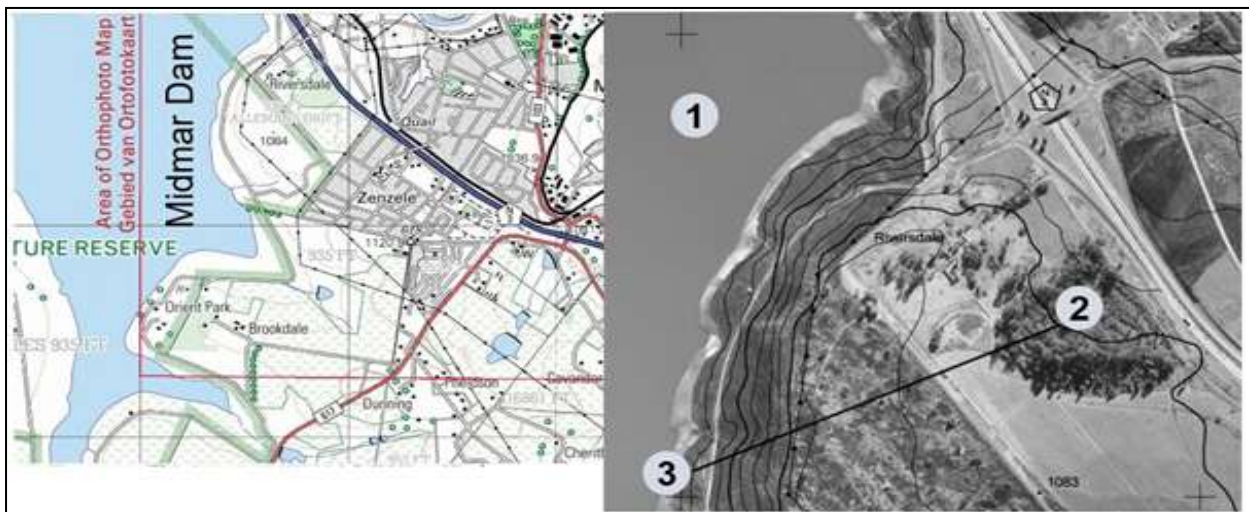


Figure 1: Sample of Humansdorp topographic (left) and orthophotography (right) map

GITMI: What do you understand about the scale of a topographic map?

Class CA:

GITMI: You must understand the formula before calculations in both metres and kilometres to see the distance between two points.

Class CA: Learners could show eagerness to interact in the classroom about the map distance topic.

GITMI: On a topographic map, calculate the distance from Block F1 spot height .78 to Block G4 spot height .33 in metres.

$$\begin{aligned} \text{Actual distance} &= \text{map distance} \times \text{map scale} \\ &= 10,9 \text{ cm} \times 500 \text{ m} \\ &= 5450 \text{ m} \end{aligned}$$

GITMI: On the orthophoto map. Calculating the distance from Area Marked 1 and Area Marked 2 in Kilometres. Remember to use the contour lines that display the heights of the Area marked.

$$\begin{aligned} \text{Actual distance} &= \text{map distance} \times \text{map scale} \\ &= 7,8 \text{ cm} \times 0,1 \text{ km} \\ &= 0,78 \text{ km} \end{aligned}$$

⁵⁷ Anna Kellinghusen et al., "Integrated Teaching in Geography and Mathematics Education: A Systematic Review," *Sustainability* 17, no. 16 (August 12, 2025): 7276, <https://doi.org/10.3390/su17167276>.

⁵⁸ Dawne Bell, "The Reality of STEM Education, Design and Technology Teachers' Perceptions: A Phenomenographic Study," *International Journal of Technology and Design Education* 26, no. 1 (February 8, 2016): 61–79, <https://doi.org/10.1007/s10798-015-9300-9>.

GITM1: OK, that's how you calculate map distance on a topographic map.

In the above extract, GITM1 used both topographic and orthophotography maps to teach learners how to calculate the distance between the given points. In the midst of the calculation, GITM1 did not explain to learners how to find the distance on both maps. As a result, some learners were unable to respond to the question that relates to the calculation of map distance. Additionally, on the orthophoto map, most of the learners could find the contour lines marked to give a relevant answer. However, GITM1 did not give learners the details of how to approach the map section. Hence, most learners fail to answer questions that relate to mapwork skills and calculations. The failure of learners to respond to such questions is also reported in the National Senior Certificate (NSC) examination diagnostic report.⁵⁹ According to Elbaz, teaching geography through interdisciplinary knowledge integration, Mathematics and geography concepts can be beneficial for both teachers and learners during instruction.⁶⁰ Furthermore, learners should first be introduced to mathematical concepts that align with geography content, enabling them to understand mapwork skills and calculations. Consequently, the findings resonate with concept translation in the interdisciplinary knowledge integration, which involves geography teachers' ability to translate interdisciplinary knowledge from mathematics when teaching mapwork skills and calculations.⁶¹

The findings confirm that geography shares a set of basic terminologies with mathematics, which are specialised terms and jargon developed within mathematics. As a result, there is a need for geography teachers to have a broader view of the content scope required for them to translate between the knowledge from the two subjects. Hence, geography teachers need to collaborate with mathematics teachers to effectively achieve the translation process of interdisciplinary knowledge integration when teaching mapwork skills and calculations.⁶²

Transfer of explanatory concepts from the mathematics context to mapwork skills and calculations

Molapo has argued that most geography teachers have specialised in Mathematical literacy in their junior degree.⁶³ As such, it is difficult for them to execute their mandate of teaching mapwork skills and calculations by integrating the necessary mathematical knowledge needed for learners to succeed in learning the geography content. The concept of area calculation is found to be common in both geography and mathematics content. As such, geography teachers' ability to transfer the necessary mathematical knowledge required to solve mapwork skills and calculation problems during teaching is paramount to foster learners' understanding of the content. However, geography teachers without the necessary mathematical knowledge can hinder this transfer, which can lead to misinterpretation of the content during interdisciplinary knowledge integration.⁶⁴ The results from the observation data have demonstrated that geography teachers were not able to transfer explanatory concepts from area calculation in a mathematics context to area calculation in mapwork skills and calculations. These findings are in line with what Anthamatten et al. argued when emphasising that teachers overlook fundamental mathematical concepts that are essential for teaching and learning of spatial skills in geography.⁶⁵ Consequently, this was observed when GITM3 was teaching learners how to calculate the area on the topographic map without incorporating the required mathematical knowledge from the same concept transcribed below.

$$b = 3,1 \text{ km} \times 0,5 \text{ km and } l = 1,75 \text{ km}$$

$$b = 1,5 \text{ km}$$

⁵⁹ Department of Basic Education (DBE), *NSC Examinations 2023: Diagnostic Report, Part 1* (Pretoria: DBE, 2023).

⁶⁰ Freema Elbaz, *Teacher Thinking: A Study of Practical Knowledge* (Routledge, 2018).

⁶¹ Linn, "The Knowledge Integration Perspective on Learning and Instruction"; Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis."

⁶² Linn, "The Knowledge Integration Perspective on Learning and Instruction"; Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis."

⁶³ Karabo Molapo, "Implications of Teacher Articulation Gap on the Interpretation of Geomorphological Maps in Secondary School Geography Teaching in Moletlane Circuit, Limpopo Province" (Tshwane University of Technology, 2023).

⁶⁴ Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis."

⁶⁵ Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics."

$$\text{Area} = l \times b$$

$$A = 1,75 \text{ km} \times 1,55 \text{ km}$$

$$A = 2,78 \text{ km}$$

The presentation of the area calculation was followed by an indication from the learners' responses when they failed to respond positively to area calculations. This failure was due to being unfamiliar with the concept of area calculation from mathematics that is needed to be applied in mapwork skills and calculations. Additionally, the results indicate that these learners failed in their attempt to solve the area calculation problem due to their prior knowledge of mathematical literacy, which does not align with the required mathematical concepts in geography. As a result, it becomes difficult for learners to solve problems that require them to transfer the necessary mathematics knowledge or context in geography. This indicates that mathematics as a compulsory subject is imperative for geography learners for them to succeed in the understanding of map skills and calculations. The DBE diagnostic report supports this by arguing that most of the geography learners struggle to calculate area on the topographic map, despite being given the measurements.⁶⁶ This inability clearly reveals a need for geography teachers to have the mathematics knowledge necessary for learners to apply mathematics concepts required to solve map skills and calculations during teaching. This is supported by Anthamatten et al., who argued that the integration of mathematical concepts in geography lessons can result in measurable learner performance in geography.⁶⁷ This resonates with Shen et al. and Linn, who emphasised that this integration occurs during the interdisciplinary transfer, where teachers rely on mathematical knowledge and skills learned as a primary discipline for the transfer to occur into geography's new concept.⁶⁸ According to Dorn et al., there is a strong relationship between mathematics and geography, yet teachers may shy away from engaging in interdisciplinary knowledge integration between the two subjects during teaching.⁶⁹ Hence, geography teachers need to acquire or have basic mathematical knowledge of the necessary concepts required to be transferred to the geography context when teaching map work skills and calculations.

In another classroom, GITM2 was teaching about the concept of *gradient* calculation on a map, and learners had to respond to the lesson. The teacher grouped learners to work collaboratively and introduced the lesson by asking questions about the *scale and calculation of the distance on a topographic map*. Only a few learners responded to the question on distance as prior knowledge. The teacher did not ask learners a question about what a gradient is before indulging in the lesson on the how part. The teacher only explained the vertical interval and horizontal equivalent to engage learners in the classroom. Learners were asked how to *calculate a gradient on a topographic map*.

⁶⁶ Department of Basic Education (DBE), *NSC Examinations 2023: Diagnostic Report, Part 1*.

⁶⁷ Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics."

⁶⁸ Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis"; Linn, "The Knowledge Integration Perspective on Learning and Instruction."

⁶⁹ Ronald I. Dorn et al., "Learning Geography Promotes Learning Math: Results and Implications of Arizona's GeoMath Grade K-8 Program," *Journal of Geography* 104, no. 4 (July 2005): 151–59, <https://doi.org/10.1080/00221340508978631>.

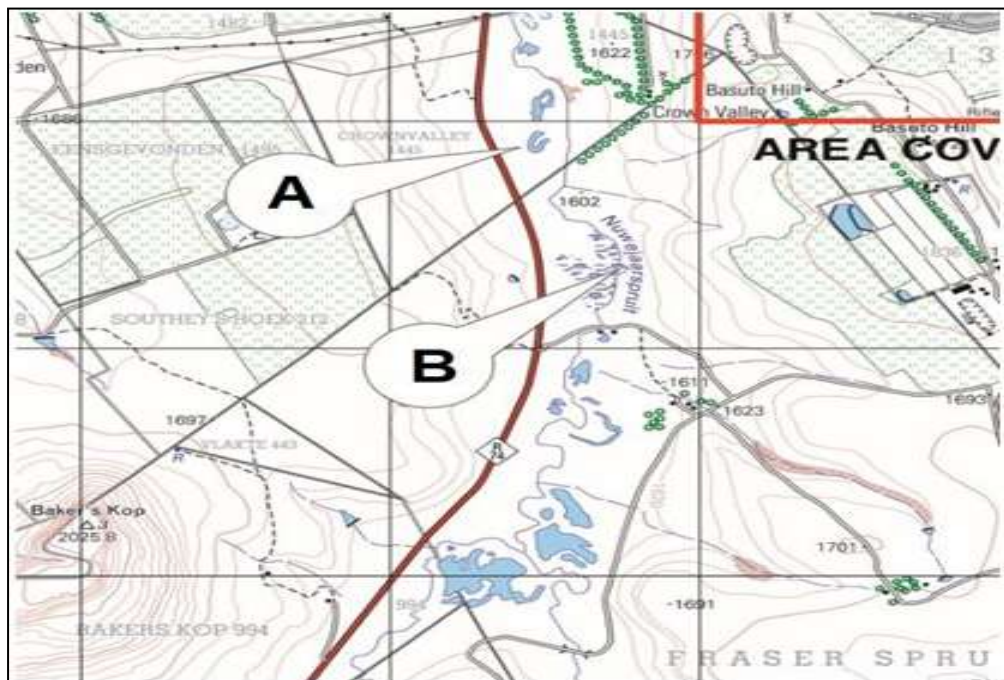


Figure 2: Topographic map

GIMT2: Today, we are looking at the gradient as one of the calculations in teaching map work. Let's gather in groups to work on this calculation.

GIMT2: On a topographic map, calculate the gradient from Block A2 area marked to Block A2 area marked B in Kilometres and explain whether the slope is steep or gentle.

Group A: Ok, teacher, we are using a topographic or orthophotography map?

GIMT2: Let's use both to calculate the gradient from point A to B.

Group B: Our distance is 1.8cm.

Group C: We have placed our ruler from 0cm, and we have 1.9cm.

GIMT2: Remember to place your ruler properly to have a relevant answer. Follow all the steps like in mathematics when you calculate the distance. Remember the ratio which determines the gentleness and steepness of the slope in this area.

$$\text{Gradient} = \frac{\text{vertical interval}}{\text{Horizontal equivalent}}$$

$$G = \frac{60 - 40}{2 \text{ cm} \times 0,5 \text{ km}}$$

$$G = \frac{20}{20}$$

$$G = \frac{1}{1} : \frac{20}{1}$$

$$G = 1:20$$

The slope of this place between A and B is Gentle.

The data shows the teacher explaining how the gradient is calculated using the provided information on the map. However, most of the learners in the classroom are found to have understood the formula without the inclusion of the exact vertical and horizontal equivalents on the topographic map. The whole process from the use of numbers on the map, placement on the ruler, exact point and calculations was not understood in the classroom. Hence, learners in the classroom arrived at a different ratio. This clearly indicates geography teachers' inability to teach and account for the gradient ratio using the contour interval on the map. The findings concur with what the NSC diagnostic report

revealed, when it was reported that most of the learners did not consult the orthophotography map for the contour interval value.⁷⁰ Hence, there is a need for geography teachers to use both maps when teaching intervisibility, contour patterns and types of slopes during the teaching of the gradient concept. Furthermore, the concept of gradient from mathematics was also not integrated into the gradient concept in geography, so that interdisciplinary knowledge integration can take place during teaching. As argued by Anthamatten et al., geography teachers should take advantage of the necessary mathematical skills needed in a geography concept by incorporating such skills in their lessons to assist students in using and applying such skills in mapwork skills and calculations.⁷¹

The interdisciplinary knowledge integration theory confirms the findings by stating that during the interdisciplinary transfer, teachers rely on mathematical knowledge and skills learned as a primary discipline for the transfer to occur into geography's new concept.⁷² While we acknowledge that most geography teachers lack basic knowledge of mathematics that is needed in geography, Ockhuizen suggests that teacher training should develop lifelong learning courses for these teachers so they develop basic mathematics content knowledge required for teaching the subject.⁷³ These courses will play a significant role in providing geography teachers with cartographic and mathematical knowledge needed to integrate mathematical concepts in the teaching of mapwork skills and calculations.

Transforming the integration of interdisciplinary understanding through instructional resources

The use of prescribed mathematical instructional materials required for teaching geography indicates the need for the integration of mathematical concepts in geography teaching. However, it was concerning that GITM4 was observed making use of topography and orthophotography maps when teaching, while learners were without the necessary mathematical instruments, such as a Protractor, ruler and calculator, that are prerequisites for learning mapwork skills and calculations. In some cases, there are arguments that some of these resources are for use in mathematics and not geography. The unavailability of the required resources for learners during teaching is what contributes to their poor skills in using these resources. This resonates with Lang'at, who argued that insufficient use of instructional material during the teaching and learning of geography could negatively impact learners' performance and result in negative attitudes developed towards the subject.⁷⁴ According to Mzingo and Onyango, instructional materials in geography are vital as they are key to both teachers' and learners' performance in the subject, as they facilitate knowledge attainment.⁷⁵ When geography teachers effectively use the instructional materials, it becomes easier for them to explain complex concepts, thereby allowing learners to experience theoretical knowledge practically.⁷⁶ GITM4 made use of a topographic map to teach magnetic bearing and asked learners to calculate true bearing from Point C to D.

⁷⁰ Department of Basic Education (DBE), *NSC Examinations 2023: Diagnostic Report, Part 1*.

⁷¹ Anthamatten et al., "Giant Maps as Pedagogical Tools for Teaching Geography and Mathematics."

⁷² Linn, "The Knowledge Integration Perspective on Learning and Instruction"; Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis."

⁷³ John Abraham Ockhuizen, "Learner-Centred Teaching and Learning Practices in Geography Teaching in Namibian Secondary Schools" (University of the Free State, 2018).

⁷⁴ Charles Lang'at, "Utilization of Instructional Resources in Teaching Practical Geography in Secondary Schools in Kipkelion Sub-County, Kericho County-Kenya" (Kenyatta University, 2016).

⁷⁵ Waziri Mzingo and Daniel Oduor Onyango, "The Role of Instructional Materials in Learning Geography among Secondary Schools in Busega District, Tanzania," *East African Journal of Education and Social Sciences* 2, no. 3 (2021): 29–36.

⁷⁶ E.O. Okobia, "Availability and Teachers' Use of Instructional Materials and Resources in the Implementation of Social Studies in Junior Secondary Schools in Edo State, Nigeria," *Review of European Studies* 3, no. 2 (November 30, 2011), <https://doi.org/10.5539/res.v3n2p90>.

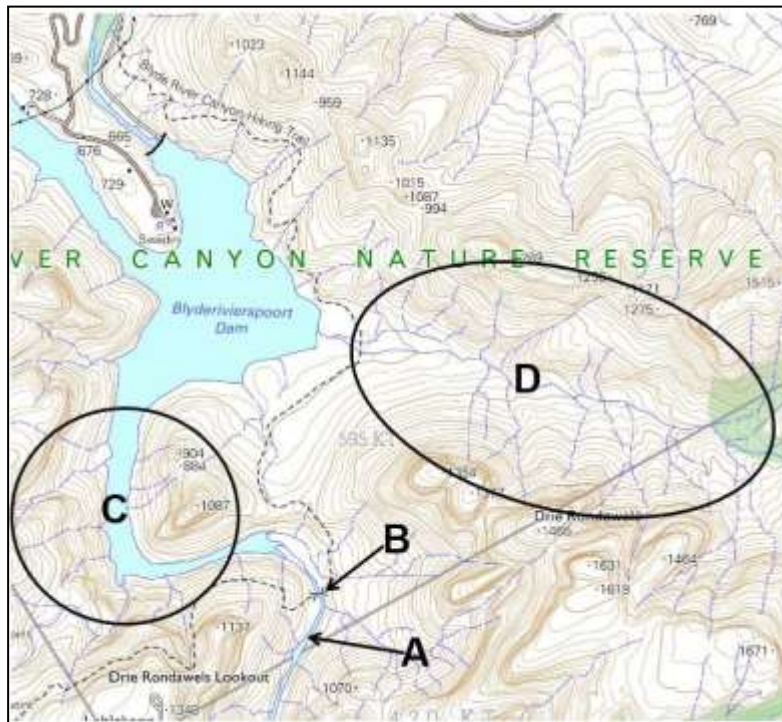


Figure 3: Topography map

GITM4: Let's find the angle of the point D by drawing a line from point C. How many people in this class have a protractor? Position your ruler on C.

Learner A: Eh, we don't have a ruler.....Mumbling.....

GITM4: Look at the chalkboard as we do the calculation together for all of you to understand.

Learner B: How do we put a protractor on the map and find an angle for magnetic bearing?

GITM4: Remember the first instruction given to follow all the procedure of adding magnetic declination and true bearing.

Magnetic bearing = true bearing + magnetic declination

$$MB = TB + MD$$

$$MB = 160^{\circ} + 29^{\circ}5'W$$

$$MB = 189^{\circ}5'W$$

Learner C: Eish, we are doing mathematics in this class yeerrr.....

The results have revealed that learners were unable to use the protractor to measure the angle between points A and B as requested by the teacher. This required learners to make use of knowledge from mathematical instructional materials in geography to measure the angle. Moreover, GITM4 did not give proper instructions on how the mathematical instrument is used to measure the angle to be used when calculating magnetic bearing. The findings corroborate those of Mzinga and Onyango, who reported that the use of instructional materials during geography teaching plays a crucial role in improving learners' productive learning and contributes to their enhanced innovation and creativity.⁷⁷ The interdisciplinary knowledge integration also confirms these findings by arguing that teachers' development of an integrated understanding has the potential to assist them in performing interdisciplinary transformation.⁷⁸ As such, geography teachers should apply explanatory concepts and models from required mathematics concepts to transform a system conceptually or physically that is typically considered in geography. During this stage, geography teachers link mapwork skills and

⁷⁷ Mzinga and Onyango, "The Role of Instructional Materials in Learning Geography among Secondary Schools in Busega District, Tanzania."

⁷⁸ Linn, "The Knowledge Integration Perspective on Learning and Instruction"; Shen, Liu, and Sung, "Designing Interdisciplinary Assessments in Sciences for College Students: An Example on Osmosis."

calculation concepts to mathematics skills with the aim of incorporating the spatial skills necessary to support the mathematics that is needed in geography teaching.⁷⁹ Hanus and Havelková support this by emphasising that geography teachers who are resource-oriented can identify and differentiate the interdisciplinary knowledge integration required for a specific phenomenon.⁸⁰ Therefore, this calls for geography teachers to outsource mathematics teachers to serve as instructional resources that will assist during the integration of mathematical concepts in the teaching of mapwork skills and calculations. This will reduce the misconceptions identified in secondary teaching of map skills and calculations.

RECOMMENDATIONS

The study recommends collaboration between novice and experienced geography and mathematics teachers to be able to have a better strategy, such as collaborative teaching, to teach the integration of map skills and calculations appropriately. The findings suggest an urgent need for schools through the Department of Education in South Africa to embrace the enrolment of mathematics for learners who pursue geography as a specialisation. Additionally, Pre-service geography teachers should be accepted into the geography teaching subject programme, taking into consideration the need for mathematics as one of the major subjects. Moreover, teacher training should focus on teaching the basics of teaching mathematics to existing geography teachers in the education system. To better help teachers have a straightforward approach to teaching the integration of Mathematical concepts in teaching map skills and calculations.

CONCLUSION

This study has explored geography teachers' integration of mathematical concepts when teaching mapwork skills and calculations. Results have shown that most of the teachers do not have a better way to integrate mathematical concepts into geography teaching, revealing the need for teachers to translate between similar mathematical and geography concepts. This was demonstrated by the teachers' difficulties in teaching mapwork skills and calculations, which were influenced by the pre-service training not adequately addressing the specialisation of mathematics so that they would be able to integrate mathematical concepts to teach map skills and calculations. The study also found that there is a need for teachers to transfer mathematical explanatory concepts to the teaching of mapwork skills and calculations, evident in the need to make use of mathematical knowledge when teaching geography concepts, where most teachers were unable to teach gradient, area, magnetic declination, and map distance. Hence, teachers deviate from teaching map skills and calculation to geography theory, such as settlement and economic geography. The finding also revealed the need to transform geography teachers' integration of mathematical understanding on the use of instructional materials required for teaching map skills, such as topographic, orthophotography, globe and atlas. These mathematical instruments, when used effectively, serve a greater purpose in the teaching of mapwork skills and calculations; however, geography teachers do not use such instruments. To this end, teachers are found to have little background in mathematics, use of maps and understanding of making learners understand the application of the directions. Additionally, the implications of using geographical instructional materials to teach map skills in the senior phase have not been explored. Despite that, future research on teaching can focus on the senior phase to look at the impact towards the FET phase.

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⁸⁰ Martin Hanus and Lenka Havelková, "Teachers' Concepts of Map-Skill Development," *Journal of Geography* 118, no. 3 (May 4, 2019): 101–16, <https://doi.org/10.1080/00221341.2018.1528294>.

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