

https://dspace.org/

Map literacy and spatial cognition challenges for student geography teachers in South Africa

Larangeira, Rhoda; Van der Merwe, Clinton David

2016

https://hdl.handle.net/10539/26795

Map literacy and spatial cognition challenges for student geography teachers in South Africa. Perspectives in Education, 34(2), 120-138.

Downloaded from a DSpace repository. https://dspace.org/

Rhoda Larangeira
Department of Geography, University of South Africa

School of Education, Department of Geography, University of the Witwatersrand, Johannesburg

Clinton David van der Merwe
School of Education, Department of Geography, University of the Witwatersrand, Johannesburg, 27 St Andrews Road, Parktown, 2193
Email: clinton.vandermerwe@wits.ac.za

ISSN 0258-2236
Perspectives in Education 2016 34(2): 120-138
© UV/UFS

Map literacy and spatial cognition challenges for student geography teachers in South Africa

Abstract

South African geography student teachers should master map skills to teach mapwork effectively in their future classrooms. Spatial cognition, prior learning of map skills and map interpretation at secondary school-level are highlighted as being important in furthering map literacy, which is required by geography student teachers. A mixed-method research framework investigated the causes of map literacy difficulties experienced by first year geography student teachers. Lecturers who train prospective teachers should be aware of the conceptual and/or skills-based difficulties associated with poor map literacy amongst their own students in order to address these problems. This paper outlines problems experienced by first year geography student teachers associated with their own acquisition and understanding of mapwork. Furthermore, it argues that without deeper comprehensive development of their own mapwork content knowledge, the geography student teachers' ability to teach map skills effectively will be adversely affected.

Keywords: *Curriculum Assessment Policy Statement (CAPS); geography student teachers; map literacy; prior learning; secondary education; spatial cognition.*

1. Introduction

Understanding maps and interpreting the vast amount of information contained in maps is considered an essential part of geography (Bonnet, 2008). Moreover, spatial literacy is becoming more important to daily work and life at a time when so much digital data is mapped visually on hand-held devices. Map literacy and spatial cognition is no longer confined to printed atlases. Most geographers support Bednarz's (2011) claim that maps are an indispensable part of geography, an informative core around which geographical data can be understood. Map literacy is an essential communication tool necessary to interpret complex information displayed visually through maps, a competence that cannot be ignored in the development of geographers (Burton & Pitt, 1993). Not surprisingly then, map literacy is an important aspect within the geography curriculum in South Africa (Wilmot, 1999; 2004; Wilmot & Dube, 2015). According to Liben and Downs (2003: 677), "there is a way of thinking – spatial thinking – that is

pervasive, significant, and powerful, and yet it is under-recognised, underappreciated, and therefore under-instructed". If learning to think geographically implies learning to think spatially and being able to decode the complexity of information found on maps (Bednarz, 2011; Burton & Pitt, 1993), then it is fundamentally important that future geography teachers have a sound ability to read and interpret maps in multiple renderings. It is also important that they are equipped with the correct and effective teaching methodologies to ensure the development of sound map literacy of themselves and their learners.

As geography teachers, and a skilled tutor and another a skilled lecturer, whilst lecturing a mapwork module in 2012 to first year geography student teachers at the Wits School of Education (WSoE) in Johannesburg, we noted a lack of map literacy amongst many students. Some students struggled to grasp basic map concepts and calculation skills including direction, bearing, co-ordinates, scale and altitude. This inability among student teachers to read maps was simultaneously intriguing and frustrating, as these very students would be responsible for the future teaching of sound map literacy in schools. Why do some students find spatial literacy so challenging whilst others have a seemingly well-developed spatial aptitude? Are mapwork skills adequately taught at secondary school-level thereby ensuring that students' mapwork skills are sound at first year university level? Are struggling first year students unable to access the learning because their own spatial cognition is underdeveloped? Have these students not yet mastered the ability to recognise and interpret spatial patterns found on maps?

The mapwork module, taught by a single tutor/lecturer over a 6-week period, is offered to first year geography students. The only exposure they have to develop map skills in the academic component of the Bachelor of Education (B.Ed.), a 4-year professional degree. This paper reviews central aspects pertaining to the importance of map literacy acquisition. The mixed method research framework utilised for data collection is then outlined. Presentation, analysis and discussion of data, follows. Finally, recommendations are given about how to remedy poor map literacy in initial teacher education (ITE) institutions.

2. Literature review

Map literacy and geographic thinking

> *"There are some specific practises associated with geography. The best known is mapping."*
>
> *(Bonnet, 2008: 81)*

Geographers rely on maps in order to study "the world, both near and far" (Bonnet, 2008: 1). For many seasoned geographers this study of "the far" is facilitated and enhanced using visuals and maps. Furthermore, Jackson (2006) refers to four geographical concepts namely space and place, scale and connection, proximity and distance and rational thinking that lend themselves to map-support. This facilitates and visually enriches the complexity of relationships that exist between places and processes. The innate need for humans to understand and represent their surroundings (Bonnet, 2008) shows a historic link between geography and cartography. The Rediscovering Geography Committee (1997: 4) states that the "traditional tool in geography for the display of spatially referenced information is the map" and Bergman and Renwick (2003: 30) claim that, "one of geographers' most characteristic tools is a map". More recently, Masden and Rump (2012) include maps as one of the artefacts

used by geographers as a tool for spatial thinking. The ability to think spatially is intertwined with map reading and interpretation and is found in every sphere of geographical analysis.

Lloyd and Bunch (2010) identify many variables that affect map learning including biological factors, the learning environment and individual spatial cognition. Bonnet (2003) stresses the importance of sound geographical skills being taught at secondary level schooling in order to facilitate understanding and the application of prior knowledge at tertiary level and throughout life. The ability to identify, interpret, analyse and manipulate information found on maps involves visual perception and skills in logic and language usage, requiring the use of both hemispheres of one's brain (Burton & Pitt, 1993). Spatial literacy is one component of geography that can be acquired through the development of mapwork skills and plays a vital part in developing graphicacy (Wilmot, 2002). Wilmot (1999; 2002) argues that graphicacy, together with oracy, literacy and numeracy is recognised as one of the four vital components of effective communication. Bonnet's (2008: 91) claim that a map "is the distinctive visual expression of the geographical imagination" reiterates the importance of map literacy in developing graphicacy. If organising and plotting one's world in graphic form allows one to communicate information to a variety of people, then interpreting this information using map skills is a vital element in education. Bednarz (2011) draws attention to spatial thinking when she claims, "[o]ne of the key differences between expert and novice geographers is the ability to think spatially". Geographers use maps to organise and analyse information about space and place, as they are a powerful means of displaying and communicating geographic information (Innes, 1999). It follows then that learning how to read and interpret maps is an essential skill for any geographer to acquire. Accordingly, it is also essential for geography teachers, if they are to empower their learners to become geographically literate.

If spatial information found on maps is conveyed in a graphical way then "communicating in graphic form requires an ability to encode and decode spatial information using symbols which require the utilisation and application of spatial perception skills and concepts" (Wilmot, 1999: 91). As spatial information is expressed in various ways on maps, a map is a communication system (figure 1) that requires taught and practised map encoding and decoding of the map language in order for understanding and interpretation to take place (Weeden, 1997). Gardner's theory of multiple intelligences (Shaffer & Kipp, 2010) draws attention to the importance of spatial intelligence and logical-mathematical intelligence, which are both necessary for the perception of visual-spatial relationships and the interpretation of symbolic representations of reality that are found on maps. Tkacz (1998: 238) supports this view, stating that the ability to read a map "is facilitated by some spatial aptitudes (e.g. visualisation), strategic processes (e.g. execution of appropriate encoding and integrating processes) and an adequate cognitive map (e.g. knowledge organised by routes or landmarks, procedures for processing environmental knowledge)". In short, map literacy and spatial cognition facilitates the ability to logically interpret one's physical, human and abstract surroundings and create a medium for effective geographical communication (Uttal, 2000).

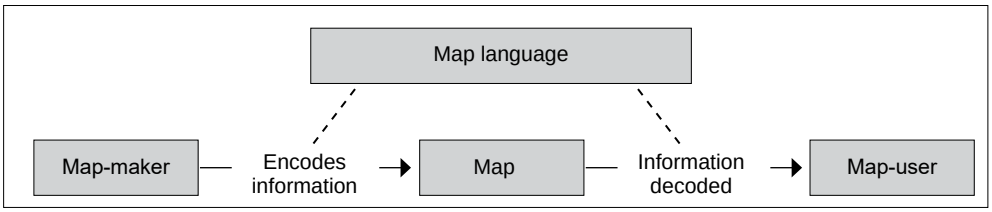


Figure 1: A simple map communication system (Weeden, 1997: 169)

Spatial cognition

> *"Different types of spatial thinking involve different parts of the brain"*
> *(Manning, 2014: 110)*

Liben and Downs (2003: 668) argue that many cognitive challenges are faced when attempting to understand graphic and symbolic representations found on maps and claim that, "children who have not yet developed advanced projective concepts might have difficulty understanding maps that use viewing angles different(ly) from daily perceptual experience". This lack of advanced projective concepts can also be found in adults who have not been exposed to spatial processing skills through their education and as a result cannot draw on metacognition to facilitate further understanding of what maps represent (Weeden, 1997). This idea relates to cognitive development theories that focus on the correlation between a child's spatial concept ability and the various stages of intellectual development (Weeden, 1997; Wiegand, 2006).

Piaget (1964) proposed that cognition is a form of environmental adaptation (equilibrium). Through assimilating new information and accommodating it, a child will develop knowledge that can be constructed and organised into logical systems. In terms of spatial cognition, through encoding map symbols and their representations, a child will learn to understand the world around him/her (Wiegand, 2006). Vygotsky (1967) argues that learning is a socially mediated activity in which a more knowledgeable 'other' (such as a teacher) organises activities to help children acquire knowledge they would not have learnt if left to their own devices. Hence, cognitive development occurs in sequences and is linked to a child's age, stage of development and prior learning at school level. It follows then that if a first year geography student was not taught sound mapwork skills during schooling – encouraging thorough spatial cognitive development – then the ability of that student to think spatially would be considerably reduced (Lane, 2015). Broader cognitive development theories appear to underpin map literacy progression through the South African schools geography curriculum, as outlined in the Curriculum and Assessment Policy Statement (CAPS), implemented in 2012 (Beets & Le Grange, 2005; Beets & Le Grange, 2008; Le Grange & Beets, 2005; DBE, 2011; Wilmot & Dube, 2015; Wilmot & Dube, 2016a). Learners are introduced to basic map skills and concepts in grades 4 to 9 (10 to 15 year olds) and are then taught progressively higher-order map skills and concepts as they advance to grades 10, 11 and 12 (16 to 18 year olds) in the further education and training (FET) phase (DBE, 2011).

The attention to the importance of mastering mapwork skills and techniques and the integration of these skills with geography theory is encouraging. This supports Lee and Bednarz's (2009: 183) assertion "that spatial thinking can and should be taught at all levels in the educational system" as it facilitates spatial cognition by reinforcing spatial thinking in the three important areas namely, understanding space, the manner in which spatial information

is represented and how to develop spatial reasoning. Maps are an integral part of geography as they facilitate the study of space, place, processes and human interaction within the environment. Map skills reinforce graphicacy and develop spatial cognition. Map skills and digital technologies have also become a major focus of geographical education in the last decade (Wilmot, 1999).

3. Methodology

A mixed method approach combining the strengths of quantitative and qualitative approaches, methodologies and appropriate paradigms was utilised for this study. Participants in the case study were first year student teachers of mixed gender, varied ethnicity, aged between 18 and 30, originating from diverse socio-economic backgrounds. The 6-week module encompasses all mapwork necessary for these B.Ed. students to teach geography from grade 8 to 12. A double lecture (2 hours), twice a week was used to teach the content and concepts of mapwork and one practical session (3 hours long) per week – to consolidate skills and knowledge in a hands-on session. No tutors were available for this course; a single tutor/lecturer does all the teaching and marking. All the students in this course were issued with informed consent forms and could withdraw from the study at any time; university ethical clearance was obtained to pursue this study.

To identify the map skills most difficult to attain, we conducted a quantitative analysis of the students' June 2012 examination answers to questions addressing different spatial and map skills. We used the marks awarded to the students' answers to indicate which map skills they understood and had mastered and those map skills that they understood poorly and had not mastered. The patterns of performance for this study aimed to highlight the overall performance (total percentage) obtained per student in the examination and the performance (percentage) obtained per examination question focused on a particular map skill.

- Question 1: Map projections – the ability to visualise a representation of the 3D Earth in various 2D formats (categorical spatial information).
- Question 2: South African provincial map – Manipulation of spatial data using symbols and scales (coordinate spatial information, spatial intelligence).
- Question 3: General map skills – Manipulation of visual data using direction, time calculation, gradient, cross-section and vertical exaggeration (categorical and coordinate spatial information, logical-mathematical intelligence and spatial intelligence).
- Question 4: Interpretation of spatial data – sketch map and interrelationships, geographic information systems (GIS) (coordinate spatial information and spatial intelligence).
- Question 5: Statistics – calculations and graphing skills (categorical spatial information and logical-mathematical intelligence).

Ninety-nine first year geography student teachers wrote the examination as part of their B.Ed. at the University of the Witwatersrand, School of Education, in Johannesburg. Sub-topics relating to the main concepts taught in the module were assessed within each examination question in order to test the levels of mastery per map skill. The examination was internally moderated (in the department by moderators who had previously taught the module themselves) and externally moderated by an expert in mapwork at another university. Errors made by the students reflect an overall difficulty in mastering the manipulation and interpretation of spatial data, which is elaborated on later in the paper. Qualitative

semi-structured focus-group interviews with 64 of the 99 students were conducted after the examination. This was utilised to uncover students' exposure to mapwork at secondary school level and to evaluate their attitude and perceptions towards map literacy. The interviews attempted to discover differences in teacher methodology, the amount of time spent on map skills in the secondary school classroom and the degree of mapwork exposure, as not all registered first years elected to study geography to grade 12.

Responses and findings from these interviews were collated using a combination of verbatim quotations and summaries of the responses. Statistical data and focus-group responses were compared and analysed for general trends. From these trends, recommendations on how to improve competency in problematic areas for teaching and learning of mapwork at ITEs emerged. The participants involved in this study were university students lectured by one of the author-researchers. This made the study a potentially sensitive one as it was based on students' examination results and their perceptions of the problems associated with their lack of map skills. Ethical considerations would eliminate any risk involved and would ensure anonymity of the participants. The study commenced after results were published and ethical clearance was approved. As a result, correlating individual student results to individual voluntary focus-group participants was considered a breach of ethics and did not form part of the focus of the study.

4. Data analysis and findings

An analysis of the June 2012 examination results revealed that 60% of the students were unable to achieve 50% (the minimum mark required to pass) in the map skills examination – see table 1 for comparison purposes.

Table 1: Class averages of the mapwork module, June exams, 2008 to 2014

2008	2009	2010	2011	2012	2013	2014
52%	46%	45%	48%	54%	41%	45%

Overall performance

Of the 99 students who wrote the examination, 40 passed and 59 failed. The average score for the examination was 43%, 7% below the required pass mark of 50%. Total percentage range was 70% (7%-77%), with a modal mark of 51%. A wide range in student performance in map skills was evident, supporting the need for this research. It was noted that students performed worst in questions 3 (general map skills) and 4 (application) and best in question 5 (statistics) as shown in figure 2. Students who had done geography to grade 12 did well in all three of these questions, whereas students without a background in mapwork fared worse. Interpretation and analysis (decoding visual information from the map) proved difficult for many students. Further analysis and discussion on questions in which students underachieved was important to gain an understanding of the relationship between performance and spatial cognition.

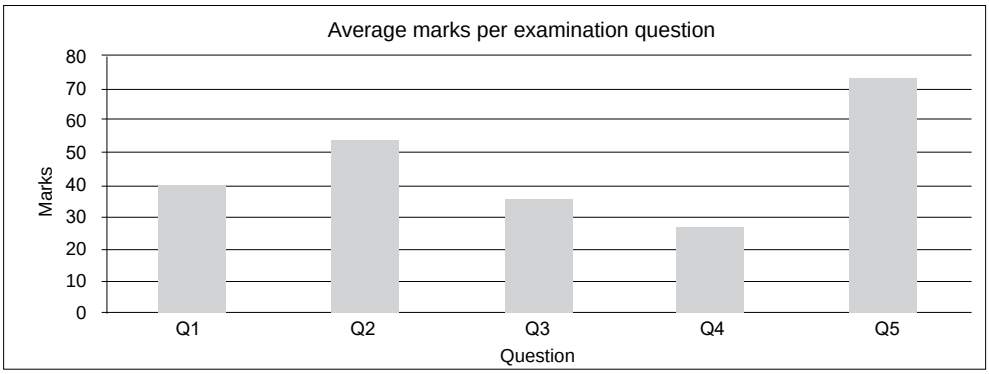


Figure 2: Graph showing average marks per examination question

Question 3 examined four sub-categories, namely direction, bearing, distance-time and altitude (gradient, cross-profiles/cross-sections and vertical exaggeration). The average for question 3 was 36%, 7% lower than the total examination average. Marks ranged from 0% to 98%. Sixty-eight students failed this question while only 31 passed. Common errors made by students revealed difficulties with regard to understanding, interpreting and manipulating map data representing altitude. Students were unable to imagine height visually and misinterpreted contour lines on maps. Average failure scores ranged from 0% to 48%; six of the 68 students who failed question 3 scored 0%. Of particular concern was the difficulty students experienced in drawing cross-profiles (cross-sections). This relates to an inability to decode two-dimensional information and encode it as three-dimensional reality, as noted by Wilmot (1999). For the examination, the correct cross-profile of the landscape between two points is shown in figure 3. Students seemed to go through the motions of this exercise without making real world associations to the landscape but simply seeing a map rather than the visual representation of the real world on paper.

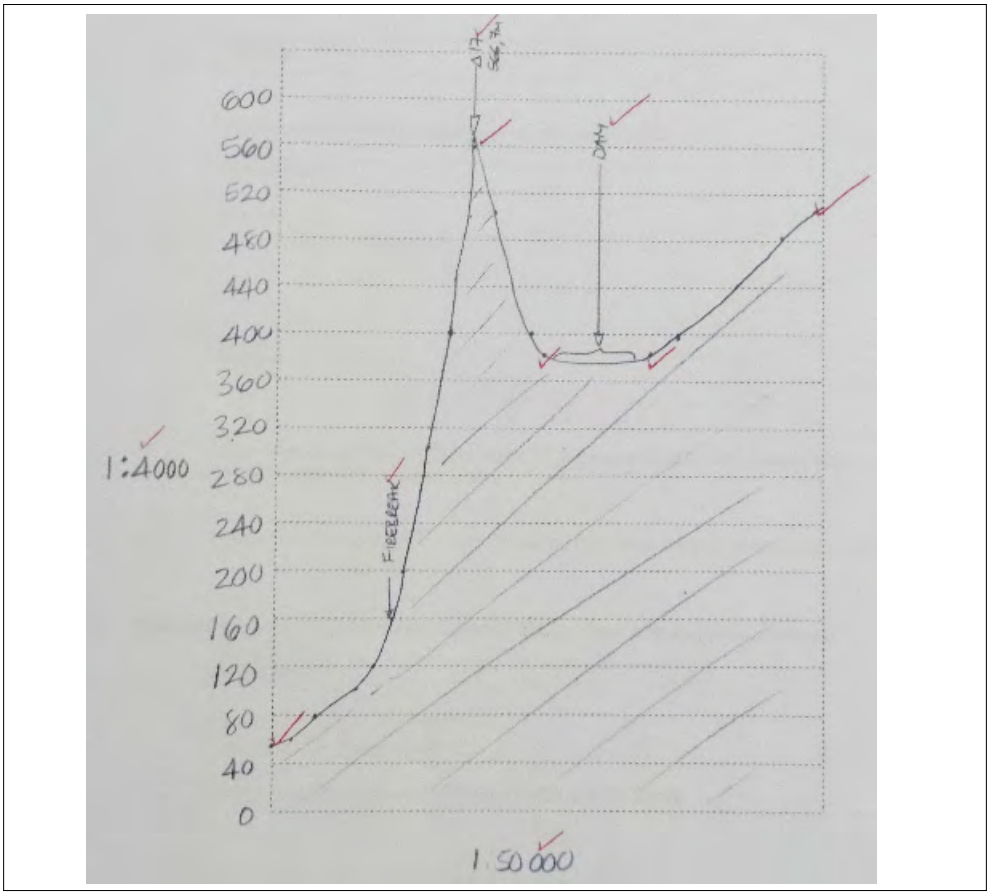
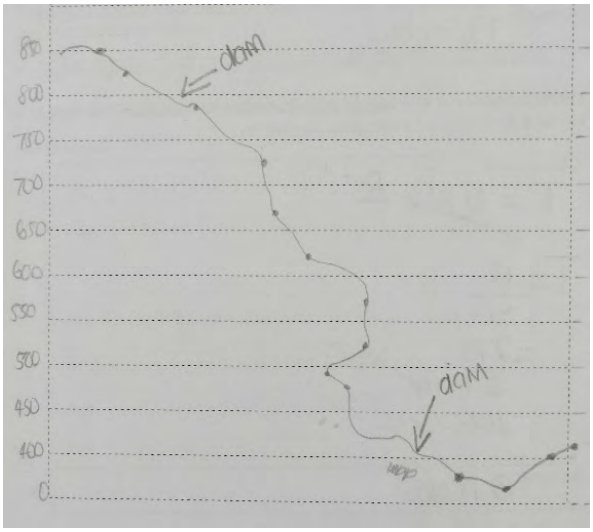
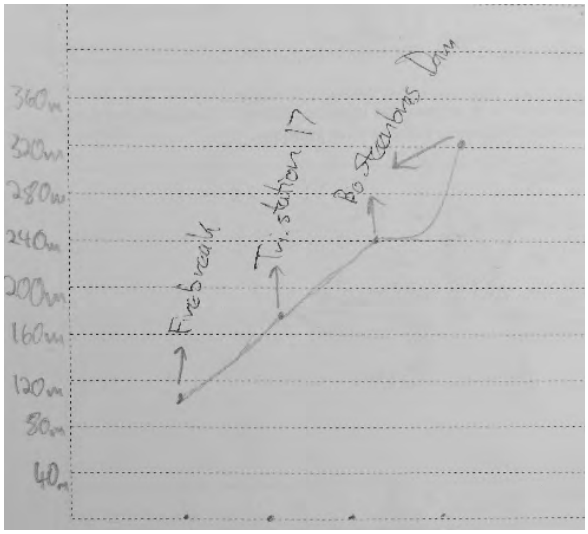


Figure 3: Example of correctly drawn cross-profile

Two examples of incorrectly drawn cross-profiles (figures 4a & b) show that many students struggle to associate the 2-dimensions of height (vertical scale) and distance (horizontal scale) to linked and logical concepts. Students did not spot the impossibility in their own work: a dam located on high-lying land – which defies that water flows under the influence of gravity and accumulates on the low-lying ground in reality – represented on the cross-profile below.





Figures 4a and 4b: Examples of incorrectly drawn cross-profiles

Students had trouble with the procedure and logic of drawing a cross-profile, being unable to visualise the landscape from the side, after seeing it in map view, as represented on the topographical map. The student who drew figure 4a was unable to access the concept of a vertical scale correctly, unlike the student who drew figure 4b, which did this rather well. Figure 4b shows that this student was able to identify a firebreak, a trig beacon and a dam, moving left to right across the landscape profile, whereas figure 4a shows how this student confused the concept of relief (shape or topography of the land).

Question 4 examined the ability to interpret spatial data through focusing on the students' skills to draw a sketch map showing two main topographic features and identifying interrelationships shown on their sketch map. Question 4 was the worst performing question in

the examination. The average for question 4 was 27%, 16% lower than the total examination average. Marks ranged from 0% to 84%. Eighty-four students failed this question whilst 15 passed. The average failure scores ranged from 0% to 47% and it was noted that 4 of the 84 students who failed question 4 scored 0%. A correct sketch map (figure 5) can be compared to the two examples of incorrect sketch maps (figures 6a and 6b). Common errors made by students included an inability to manipulate scale and to identify conventional symbols on a topographical map correctly. The ability to encode and decode information (Wilmot, 1999) is again highlighted by this, as was the ability to utilise both hemispheres of the brain to facilitate spatial thinking (Lloyd & Bunch, 2010). Abstract as they are, perspective and scale remain difficult concepts to master for students in their first year of tertiary education.

Figure 5 is a good example of a sketch map showing a student who has a sound grasp of scale and perspective as well as the relationship between physical and human features on the landscape. In figure 6a, the student has a poor conception of scale, a misunderstanding of conventional signs and a general sense of spatial distortion. In figure 6b, the student was unable to understand the concept of a map being an aerial perspective of the landscape, although the dam is represented as a 2D shape, the mountains were drawn in an oblique view. In addition, a great deal of detail is neglected, which shows that this student is unable to decode the conventional symbols correctly, which depicts real-life features on the actual landscape.

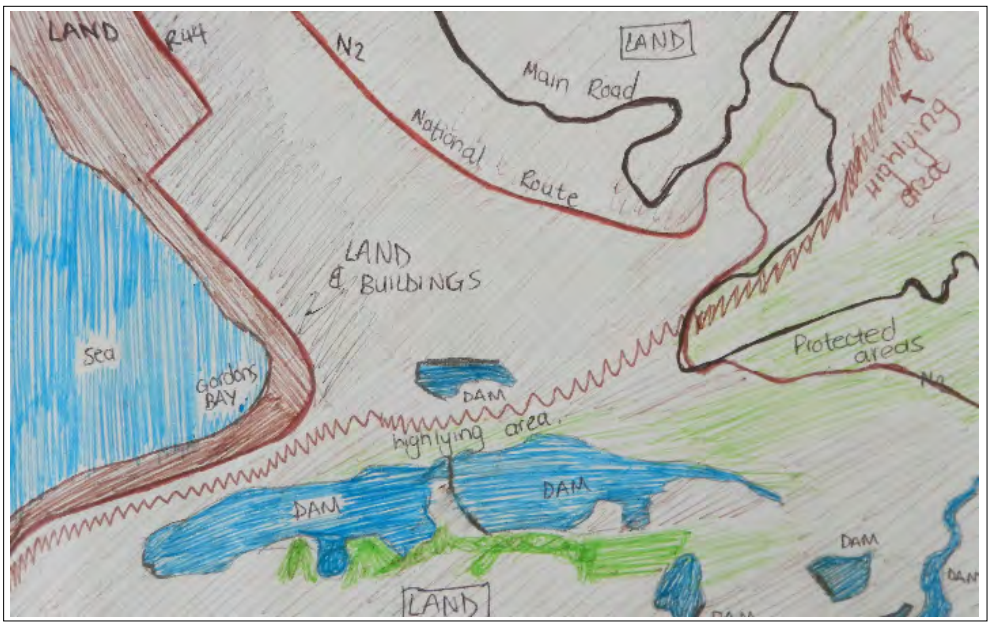
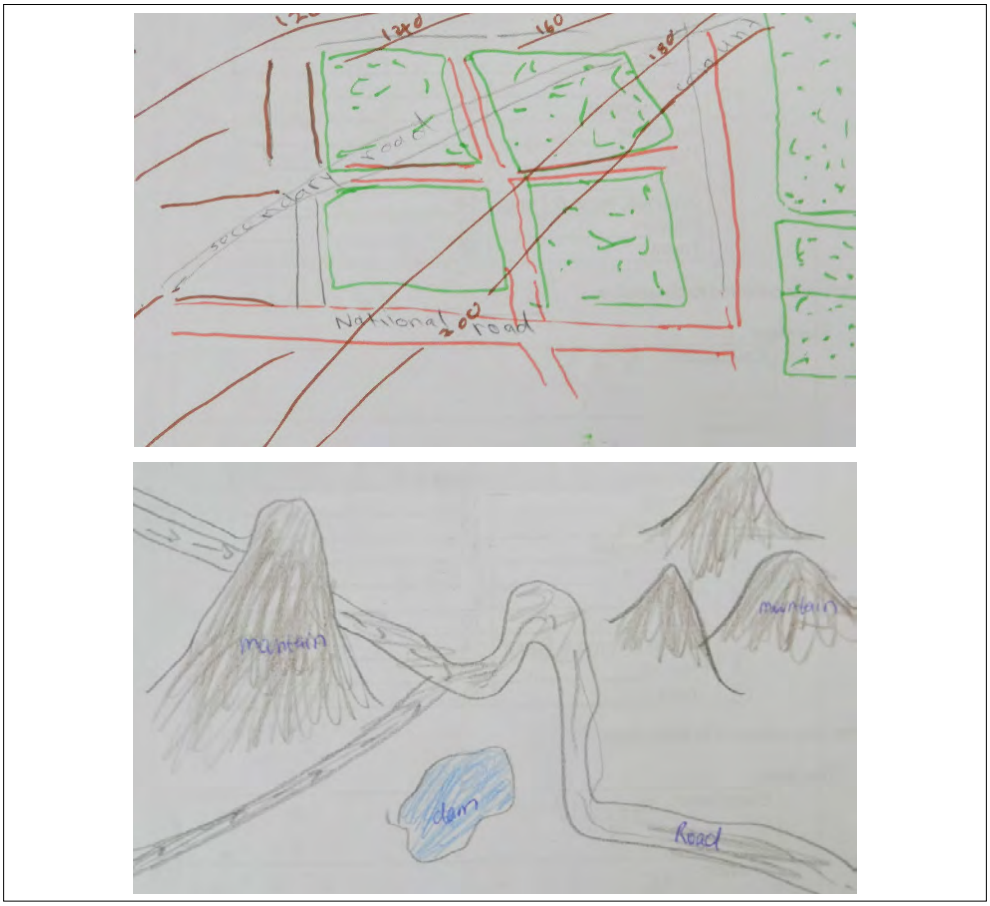


Figure 5: Example of correctly drawn sketch map



Figures 6a and 6b: Examples of incorrectly drawn sketch maps

Semi-structured focus group interviews

The focus-group interviews afforded the first year students who volunteered an opportunity to clarify the difficulties or challenges presented by map skills and to suggest solutions to the problems. Sixty-four of the 99 assessed students participated in the process and 10 groups were formed to make data analysis more manageable. No direct correlation between participants and examination results or their qualitative responses in the focus groups were made to ensure students' anonymity. Thematic analysis was used to analyse the responses to the main questions. These are presented below.

The results obtained from the analysis of the June examination paper and the semi-structured focus-group interviews showed many difficulties faced by students with regard to map literacy and skills. The results highlight the interpretation of spatial data and general map skills as being the main difficulty. The semi-structured focus-group interviews reinforced this finding, as students identified cross-profiles, irregular area calculations and co-ordinates as being the most difficult skills to master. Table 2 relates the most problematic map skills to deficiencies in schooling and/or spatial cognition. Mastering these specific map skills requires further attention to the role spatial cognition plays in developing spatial literacy, effective teaching at secondary school level and additional support at university level.

Table 2: Problematic map skills with possible reasons for underachievement

Category	Specific map skill	Schooling concerns	Spatial cognition concerns
General map skills	Cross-sections	Drawing of cross-sections is taught incorrectly in some schools.	Difficulty in visualising a profile from contour lines on a 2D map. Inability to understand how contour lines represent altitude.
	Irregular area	Insufficient time in class to practise skill. Most students able to calculate regular area, yet non-standardisation of formulas/ techniques used in schools.	Students struggle to convert an irregular shape into a grid showing regular area.
	Co-ordinates	Non-standardisation of teaching methodology of skills in various schools. No maps in classrooms.	Difficulty in visualising earth divided into hemispheres.
Spatial data interpretation	Co-ordinate spatial information	Rote-taught map skills, hence right brain hemisphere thinking neglected.	Difficulty to understand what maps represent if right brain hemisphere not utilised to comprehend or encode map data.
	Spatial intelligence	Limited practical reinforcement of what is taught. No application and comparison of skills to different or real situations.	2D and 3D views are not shown as being linked to each other. Inability to visualise what a map represents as it is in 2D and is scaled.

Which map skill do you find the most difficult and why?

A variety of responses was recorded and multiple map skills were identified as being difficult to master. Cross-profiles appear most frequently as an area of concern for many of the groups. Co-ordinates and irregular area calculations were also highlighted as skills difficult to master. Table 3 summarises the recorded responses, correlating them to the marks achieved in the June examination for each concept that was tested. Reasons for the difficulties faced are varied. One student drew attention to the pedagogical differences at secondary schools and university:

> *Teaching methods and formulas that were taught at school were very different from the way we are taught at Varsity.*

Another student was concerned with the mental challenge of viewing representations of reality and referred to the lack of "ability to view symbols on a map in 2D/3D form".

A different student was particularly bewildered by her inability to recall and apply the numerous formulas required in map calculations being "unable to remember the formulas and steps of solving the formula".

Table 3: Identification of the map skills students found the most difficult

Group	Most difficult skill	Other skills causing difficulties	
F1	Co-ordinates	GIS	Distance calculations
F2	Co-ordinates	Map interpretation	Cross-sections
F3	Irregular distance	Magnetic Bearing	Vertical Exaggeration
F4	Irregular Area	Map interpretation	Cross-sections
F5	Irregular Area	GIS	Magnetic declination
F6	Cross-sections	Map interpretation	Standard deviation
F7	Cross-sections	Co-ordinates	Gradient
F8	Cross-sections	Irregular Area	Standard deviation
F9	Cross-sections	none	none
F10	Magnetic Declination	Sketch maps	Cross-sections

Table 4 reflects the frequency of varied focus group responses to question 1. A lack of background knowledge in geography in secondary school is problematic and an important issue to be addressed in future reviews of admission requirements to geography in the B.Ed degree at the WSoE.

Table 4: Frequency of focus-group responses for question 1

Type of response	Frequency of Focus group responses	
No geography background	F1, F2, F4	3
Different teaching methodology of skills	F1, F2, F4	3
Spatial Cognition (2D/3D interaction) (Visualisation and scale)	F1, F2, F3, F4, F5, F6, F8, F9, F10	9
Practical activities not taking place in schools	F2	1
Lack of passion for geography	F3	1
Unable to remember and apply formulas	F3, F5, F10	3
Different content at University vs. school	F5	1
Actual drawing/construction of cross-sections	F5, F6, F7	3

From table 4 it becomes apparent that students in nine of the ten focus groups had trouble visualising reality as represented on a map. This difficulty with spatial cognition presents a challenge for many students who struggle to apply prior knowledge and skills taught in different contexts.

Which map skills are the least challenging and why?

Students in the focus groups identified statistics, distance calculations and bearing as being the least challenging map skills. The responses indicated that mathematical literacy and skills were an advantage when mastering map skills. Table 5 summarises the focus groups' responses.

Table 5: Summary of focus-groups responses for question 2

Group	Least challenging skill	Reason
F1	Statistics	Good mathematics skills
F2	Bearing	*"No practical thinking is necessary"*
F3	Statistics	*"Mathematics is easy"*
F4	Distance calculations	Basic mathematics skills acquired in school
F5	Statistics	*"The rules are easy to follow and formulas are simple"*
F6	Statistics	*"It is logical and formulas are easy to follow"*
F7	Bearing	Mathematically literate
F8	Distance calculations	Skills were well taught and familiar
F9	Distance calculations	*"Maths is easy"*
F10	Statistics	*"It's common sense"*

Did you study geography in the FET phase and how often and well integrated was it with theory?

The question's purpose was to ascertain the degree of exposure students had to map literacy at secondary school level. The responses highlighted teacher methodology, amount of time spent on map skills in the classroom and the degree of map skill exposure. Not all first-year students in the focus groups studied geography in the FET phase. Of the 64 participants, 20 students (31%) had not elected to study geography in grades 10 to 12. Interestingly, in the recorded responses, no standardisation of map skills methodology was implemented in the schools of participants in this study.

> *"Only in grade 11"*
>
> *"Only for two weeks in matric"*
>
> *"Only towards an exam"*
>
> *"In the first term"*
>
> *"At the beginning of the year"*
>
> *"Once a term"*
>
> *"Was included in lessons on a weekly basis"*
>
> *"Linked to theory because the teacher thought it made more sense using mapwork terms in theory for suitable physical structure evident in mapwork".*

This inconsistency in the teaching of map skills, identified by the participants in this case study is a possible facet in their inability to achieve good results in the mapwork course offered at university.

Discussion

Identification of the most problematic map skill

Findings from this study revealed that drawing cross-profiles was the most problematic. This skill required students to encode and decode visual information at a high cognitive level. It relied on their ability to identify, interpret, analyse and manipulate map information and

thus required the utilisation of the left- and right-brain hemispheres as referred to by Lloyd and Bunch (2010). The map skills required by students to construct a cross-profile included identifying and understanding map symbols, applying map scale and understanding and interpreting altitude on a map. Thereafter students needed to manipulate the 2-dimensional map information into a profile view – a skill that utilised coordinate spatial information and processing and relied heavily on spatial cognitive ability. This task required the culmination of spatial aptitudes, strategic processes and adequate cognitive maps (Tkacz, 1998). In order to construct a cross-profile successfully, students needed to apply an amalgamation of simpler, scaffolded map literacy skills that could not be mastered if taught poorly and not practised often.

Map skills and prior learning

This study reinforced the premise that acquiring sound map skills at secondary school level is an advantage. Students who had trouble with map literacy were not taught map skills on a regular basis at school level and the methodology was different to that of lectures at university level. Furthermore, some students did not elect to study geography in the FET phase at secondary school level, which proved to be disadvantageous. Until very recently, with the implementation of the CAPS document, not much standardisation in terms of the teaching and content of map skills has occurred in South African schools. One of the implications of this is that many first year student teachers struggle with map skills. Not enough sound teaching is in place to ensure the much-needed mastering of map skills through carefully scaffolded map literacy lessons, repetitive exposure to maps and guided map skill practise (Innes, 2012).

Spatial cognition and map literacy

Many students struggled to understand and interpret maps, as they are a 2-dimensional representation of reality, supporting the findings that some students are "unaware of their own abilities in this area or of the fact that spatial abilities can be improved through study and practice" (Hesphanha, Goodchild & Janelle, 2009: S21). The ability to understand or encode map information relies heavily on coordinating spatial information and the utilisation of the right-brain hemisphere (Masden & Rump, 2012). If students are rote-taught and not encouraged to apply map skills, then their spatial cognition with regard to map literacy is impeded (Tkacz, 1998; Uttal, 2000). In many instances, students have never been taught in a manner that facilitates the comparison of maps and reality using photographs and practical fieldwork tasks. If learning to think geographically means learning to think spatially as implied by Bednarz (2011) and Burton and Pitt (1993), then it is apparent that many first year student teachers are not yet geographical thinkers and the methodologies that lecturers utilise need to be re-thought.

5. Recommendations

Geography relies on educators to teach map skills to facilitate spatial thinking in future generations (Jackson, 2006; Bednardz, 2011; Innes, 1999, 2012; Wilmot, 2016b). Consequently, lecturers offering a mapwork course to first year students need to take cognisance of the difficulties faced by their students and implement an effective variety of approaches to teach map skills. The pedagogy of teaching map skills is an important area that requires further research (Lane, 2015). In addition, future research endeavours within this field can consider the effect that variables such as age, socio-economic background and gender have on map skills and spatial cognition acquisition. The following recommendations regarding the findings from this study for ITE are suggested:

- A bridging course at the onset of the academic year, aimed at students enrolled for geography who have not studied geography at secondary school level;
- Re-structuring of mapwork lectures to reflect continuity and progression of map skills from the simple to the complex, allowing students to build on prior knowledge;
- Mapwork concept development and the teaching of map skills as a series of procedures (focussing on why and what you are doing, sequentially);
- Weekly lecturer-supervised tutorial classes (in smaller groups) enabling the practise of skills acquired during academic lectures (see McKay, 2016);
- Weekly practical lessons focussed on fieldwork and modelling tasks to reinforce map skills, especially with regard to altitude and problems associated with 2-dimensional representations of reality on maps;
- Integration of photography and local environmental examples with topographic maps to facilitate the known to the unknown;
- Continued integration of map skills with theory courses in the academic component of the B.Ed. social sciences and geography degree;
- Inclusion of map skills methodology modules in all social sciences and geography courses across the four years of the B.Ed. degree; and
- Further research into why students coming from non-geography backgrounds struggle with mapwork and spatial cognition.

6. Conclusion

Our study shows that geography student teachers' struggle to understand mapwork is procedural and conceptual. The identified causes of map literacy difficulties experienced by first year geography student teachers, although a small case study, suggests that further research is necessary to investigate the challenges that these South African students experience in the development of their spatial literacy. It is important therefore that lecturers undertake error analysis from a statistical point of view but they should also delve into the logic or misunderstandings underpinning student teacher errors in spatial cognition (Brodie, n.d.). Prior learning is important in the development of any geographical skill (Dolan *et al.*, 2014). We suggest that admission requirements to geography in higher education needs to take cognisance of prior learning or institutions of higher education need to put academic support programmes in place (for students who have not studied geography to grade 12). The major findings of this case study suggest that some students who studied geography in high school still struggled to manipulate and decode the 2-dimensional map information from topographic maps as their spatial literacy was inadequately developed through the practise and teaching of map skills in a structured and standardised manner at secondary school level (Weeden, 1997; Wilmot, 1999; Wiegand, 2006; Lloyd & Bunch, 2010).

Lecturers involved in ITE programmes need to ensure that sufficient support is offered to students enrolled in first year mapwork courses and that lectures, tutorials and practical lessons are structured in a manner that builds on prior knowledge and facilitates practical, relevant methods to improve students' map abilities and skills (Jo & Bednarz, 2014; McKay, 2016). It is also important to identify gaps in student teachers' prior knowledge (such as the ability to conceptualise landscapes in 2D), which has the potential to undermine more complex conceptual and procedural learning that follows. More time and energy, invested in carefully

revising admission requirements for geography in the B.Ed. degree in South Africa, based on the poor prior learning in mapwork education students receive is necessary – to improve the teaching and learning of geography in higher education. Re-establishing academic support programmes for students who have not studied geography to grade 12 also needs to be revisited. Otherwise, higher education institutions need to make a tough decision and only admit those who have completed geography to grade 12 into the FET geography teaching specialisation programmes.

Acknowledgements

Profs Melanie Nicolau and Gordon Pirie's support and mentorship. Drs Paul Goldschagg and Lee Rusznyak's helpful suggestions towards this paper. This research was presented at the International Geographical Union Regional Conference, Krakow, Poland (2014). The Faculty of Humanities, University of the Witwatersrand, Johannesburg provided financial support. This paper is partially based on research done towards Rhoda's Honours degree in 2012.

References

Bednarz, S.W. 2011. *Maps and spatial thinking skills in the AP human geography classroom.* Available at: http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/151317.html [Accessed 10 May 2011].

Beets, P. & Le Grange, L. 2005. Continuity and progression: The Achilles' heel of the national curriculum statement for geography? *South African Journal of Education*, 25(3), 190-197.

Beets, P. & Le Grange, L. 2008. Has geography curriculum reform in post-apartheid South Africa strengthened continuity and progression? *South African Geographical Journal*, 90(2), 68-79. http://dx.doi.org/10.1080/03736245.2008.9725315

Bergman, E.F. & Renwick, W.H. 2003. *Introduction to geography: People, places and environment.* New Jersey: Pearson Education.

Brodie, K. n.d.. Using assessment data to improve practice: Findings from the DIPIP project (2011-2013), Data informed practice improvement project (DIPIP), learning brief. Unpublished Research Report, Johannesburg, South Africa.

Bonnet, A. 2003. Geography as a world discipline: Connecting popular and academic imaginations. *Area*, 35(2), 123-138. http://dx.doi.org/10.1111/1475-4762.00110

Bonnet, A. 2008. *What is geography?* London: Sage Publications..

Burton, M. & Pitt, I. 1993. *South African mapcraft.* Cape Town: Shuter & Shooter.

Department of Basic Education (DBE). 2011. Curriculum and assessment policy statement (CAPS) geography. Available at http://www.education.gov.za/Curriculum/CurriculumAssessmentPolicyStatements/tabid/419/Default.aspx [Accessed 19 July 2011].

Dolan, A.M., Waldron, F., Pike, S. & Greenwood, R. 2014. Student teachers' reflections on prior experiences of learning geography. *International Research in Geographical and Environmental Education*, 23(4), 314-330. http://dx.doi.org/10.1080/10382046.2014.946324

Hesphanha, S.R., Goodchild, F. & Janelle, D.G. 2009. Spatial thinking and technologies in the undergraduate social science classroom. *Journal of Geography,* 33(S1), S17-S27.

Innes, L.M. 1999. The role of geography education in developing map literacy in South Africa. *Paper presented at the Biennial Conference of the Society of South African Geographers (SSAG)* 5-9 July 1999. Windhoek: University of Namibia.

Innes, L.M. 2012. South African school geography: Underpinning the foundation of geospatial competence. *South African Journal of Geomatics,* 1(1), 92-108.

Jackson, P. 2006. Thinking geographically. *Geography,* 91(3), 199-204.

Jo, I. & Bednarz, S.W. 2014. Developing pre-service teachers' pedagogical content knowledge for teaching spatial thinking through geography. *Journal of Geography in Higher Education,* 38(2), 301-313. http://dx.doi.org/10.1080/03098265.2014.911828

Lane, R. 2015. Experienced geography teachers' PCK of students' ideas and beliefs about teaching and learning. *International Research in Geographical and Environmental Education*, 24(1), 43-57. http://dx.doi.org/10.1080/10382046.2014.967113

Lee, J. & Bednarz, R. 2009. Effect of GIS learning on spatial thinking. *Journal of Geography in Higher in Education*, 33(2), 181-198. http://dx.doi.org/10.1080/03098260802276714

Le Grange, L. & Beets, P. 2005. Geography education in South Africa after a decade of democracy. *Geography,* 90(3), 267-277.

Liben, L. & Downs, R.M. 2003. Investigating and facilitating children's graphic, geographic, and spatial development: An illustration of Rodney R. Cocking's legacy. *Applied Developmental Psychology,* 24, 663-679. http://dx.doi.org/10.1016/j.appdev.2003.09.008

Lloyd, R.T. & Bunch, R.L. 2010. Learning geographic information from a map and text: Learning environment and individual differences. *Cartographica,* 45(3), 169-184. http://dx.doi.org/10.3138/carto.45.3.169

Manning, A. 2014. Gersmehl and Gersmehl's 'Wanted: a concise list of… spatial thinking skills'. *Geography*, 99(2), 108-110.

Masden, L. M. & Rump, C. 2012. Developing spatial thinking skills. *Journal of Geography in Higher Education,* 36, 97-116.

McKay, T.M. 2016. Do tutors matter? Assessing the impact of tutors on first-year academic performance at a South African University. *Journal of Student Affairs in Africa*, 4(1), 53-64. http://dx.doi.org/10.14426/jsaa.v4i1.144

Piaget, J. 1964. Development and learning. *Journal of Research in Science Teaching,* 2, 176-186. http://dx.doi.org/10.1002/tea.3660020306

Rediscovering Geography Committee. 1997. *National research council rediscovering geography: New relevance for science and society*. Available at http://www.nap.edu/catalog/4913.html [Accessed 20 October 2012].

Shaffer, D.R. & Kipp, K. 2010. *Developmental psychology,* Eighth edition. Belmont, USA: Wadsworth Cengage Learning.

Tkacz, S. 1998. Learning map interpretation: Skills acquisition and underlying abilities. *Journal of Environmental Psychology,* 18, 237-249. http://dx.doi.org/10.1006/jevp.1998.0094

Uttal, D.H. 2000. Seeing the big picture: Map use and the development of spatial cognition. *Developmental Science,* 3(3), 217-286. http://dx.doi.org/10.1111/1467-7687.00119

Vygotsky, L.S. 1967. *Play and its role in the mental development of the child.* Available at http://www.mathcs.duq.edu/~packer/Courses/Psy225/Classic%203%20Vygotsky.pdf [Accessed 10 February 2016].

Weeden, P. 1997. Learning through maps. In D. Tilbury & M. Williams (Eds.). *Teaching and learning geography.* London: Routledge.

Wiegand, P. 2006. *Learning and teaching with maps.* London: Routledge.

Wilmot, D. 1999. Graphicacy as a form of communication. *South African Geographical Journal,* 81(2), 91-95. http://dx.doi.org/10.1080/03736245.1999.9713668

Wilmot, D. 2002. Investigating children's graphic skills: A South African case study. *International Research in Geographical and Environmental Education*, 11(4), 325-340. http://dx.doi.org/10.1080/10382040208667500

Wilmot, D. 2004. Emerging models of teacher training: The case of South Africa. *International Research in Geographical and Environmental Education*, 13(2), 153-158. http://dx.doi.org/10.1080/09669580408668507

Wilmot, D. & Dube, C. 2015. School geography in South Africa after two decades of democracy: Teachers' experiences of curriculum change. *Geography*, 100(2), 94-101.

Wilmot, P.D. & Dube, C. 2016a. Opening a window onto school geography in selected public secondary schools in the Eastern Cape Province. *South African Geographical Journal*, 98(2), 337-350. http://dx.doi.org/10.1080/03736245.2015.1028989

Wilmot, D. 2016b. Advancing geography in Southern Africa: The role of the Southern African Geography Teachers' Association and the Journal of Geography Education for Southern Africa. *Journal of Geography Education for Southern Africa*, 1(1), 9-23.