A strategy for the improvement of spatial thinking in undergraduate Geography at South African universities

by

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DECLARATION

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A strategy for the improvement of spatial thinking in undergraduate Geography at South African universities

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Abstract

Spatial thinking allows a person to use space to structure problems, model the real world, and identify and communicate possible solutions to challenges. Research proved a strong correlation between students studying Geography modules and their ability to think spatially.

This research aims to develop a strategy for improving the teaching and learning of spatial thinking in undergraduate Geography modules presented at South African universities. The first objective was to determine the extent and nature of the incorporation of spatial thinking into the syllabi of undergraduate modules. The second objective was to critically assess the methods used by lecturers to convey module content to students and their disposition towards teaching spatial thinking. The third objective critically reflects on the spatiality of the assessment questions and the students' spatial thinking capabilities. The last objective was to develop a strategy for improving spatial thinking in undergraduate Geography modules.

The AQAL model of Integral theory was used to deal with the complexity of this research, which involves multiple perspectives and various data collection methods. Purposive sampling was used to identify geography departments that would participate in this research. The taxonomy of spatial thinking was used to evaluate the spatiality of module outcomes and assessments. In-depth interviews were conducted with lecturers, and their disposition to teach spatial thinking was determined through a questionnaire. The students' spatial thinking capabilities were gauged by completing the spatial thinking ability test (STAT).

The results indicate that the outcomes and assessments of the selected modules may not contribute towards developing students' spatial thinking skills. Encouraging is that the lectures employ various teaching methods that should contribute towards developing students' spatial thinking skills and demonstrate a positive disposition to do so. Although the sample size was small, the results of the STAT indicated that students have relatively poor spatial thinking skills.

The strategy for spatial thinking allows for the inclusion of spatial thinking in module outcomes, conveying content to students, the lecturers' disposition and improving the spatiality of assessment questions. This research calls on universities to implement the strategy for improved spatial thinking as part of undergraduate Geography curricula and recommit to teaching spatial thinking to undergraduate students.

Keywords: Spatial thinking, Geography, teaching and learning, taxonomy of spatial thinking, spatial thinking ability test, disposition to teach spatial thinking, higher education, South Africa, undergraduate modules, formative assessments, summative assessments

Opsomming

Ruimtelike denke laat 'n mens toe om ruimte te gebruik om probleme te struktureer, die werklike lewe te modelleer, en moontlike oplossings tot uitdagings te identifiseer en te kommunikeer. Navorsing het bewys dat daar 'n sterk verband is tussen studente wat Geografiemodules studeer en hulle ruimtelike denkvermoë.

Hierdie navorsing het gepoog om 'n strategie te ontwikkel om die onderrig en aanleer van ruimtelike denke in voorgraadse Geografiemodules van Suid-Afrikaanse universiteite te verbeter. Die eerste doelwit was om die omvang en aard van die insluiting van ruimtelike denke in die leergange van voorgraadse modules te bepaal. Die tweede doelwit was om die metodes wat dosente gebruik om die inhoud van die module aan studente oor te dra, sowel as hul ingesteldheid om ruimtelike denke te onderrig, te evalueer. Die derde doelwit was om krities na te dink oor die ruimtelikheid van die assesseringsvrae wat in sulke modules gestel word, asook die student se ruimtelike denkvermoë. Die laaste doelwit was om 'n strategie te onwikkel om ruimtelike denke in voorgraadse Geografiemodules te verbeter.

Die AQAL-model van integrale teorie is gebruik om die kompleksiteit van hierdie navorsing te behartig, wat veelvuldige perspektiewe en verskillende data-insamelingsmetodes ingesluit het. Doelgerigte steekproefneming is gebruik om 'n Geografiedepartement te identifiseer om aan hierdie navorsing deel te neem. Die taksonomie van ruimtelike denke is gebruik om die ruimtelikheid van module-uitkomste en assesserings te evalueer. Indringende onderhoude is met dosente gevoer, en hulle ingesteldheid oor die onderrig van ruimtelike denke is met behulp van 'n vraelys bepaal. Die studente se ruimtelike denkvermoëns is deur middel van die ruimtelikedenkvermoënstoets bepaal.

Die resultate dui aan dat die uitkomste en assessering van die geselekteerde modules kan bydra tot die ontwikkeling van studente se ruimtelike denkvaardighede. Dit is bemoedigend dat die dosente verskillende onderrigmetodes gebruik wat sal bydra tot die ontwikkeling van studente se ruimtelike denkvaardighede en dat hulle 'n positiewe ingesteldheid het om dit te doen. Alhoewel die steekproefgrootte klein was, het die uitslae van die ruimtelikedenkvermoënstoets aangedui dat die studente relatief swak ruimtelike denkvaardighede gehad het.

Die strategie vir ruimtelike denke maak dit moontlik om ruimtelike denke by module-uitkomste in te sluit, inhoud aan student oor te dra, en die dosente se ingesteldheid en die ruimtelikheid van assesseringsvrae te verbeter. Hierdie navorsing doen 'n beroep op universiteite om die strategie te implementeer om ruimtelike denke te verbeter as deel van die leergange van voorgraadse Geografiemodule en om hulle te herverbind tot die onderrig van ruimtelike denke aan voorgraadse studente.

Sleutelterme: Ruimtelike denke, Geografie, onderrig en leer, taksonomie van ruimtelike denke, ruimtelikedenkvermoënstoets, ingesteldheid om ruimtelike denke te onderrig, hoëronderwys, Suid-Afrika, voorgraadse modules, formatiewe assessering, sommerende assessering

Isifinqo

Ukucabanga ngendawo kuvumela umuntu ukuthi asebenzise indawo ukuze ahlele izinkinga, enze imodeli yomhlaba wangempela, futhi akhombe futhi axhumane nezixazululo ezingaba khona ezinseleleni. Ucwaningo lufakazele ukuhlobana okuqinile phakathi kwabafundi abafunda amamojuli eJografi kanye nekhono labo lokucabanga ngokwendawo. Lolu cwaningo luhlose ukwakha isu lokuthuthukisa ukufundisa nokufunda kokucabanga ngendawo kumamojuli angaphansi kweJografi ethulwa emanyuvesi aseNingizimu Afrika. Inhloso yokuqala kwakuwukunquma izinga kanye nemvelo yokufakwa kokucabanga kwendawo kusilabhasi yamamojuli yabenza iziqu okokuqala. Inhloso yesibili kwakuwukuhlola ngokucophelela izindlela ezisetshenziswa abafundisi ukuze badlulisele okuqukethwe kwemojuli kubafundi kanye nesimo sabo sokufundisa ukucabanga ngendawo. Inhloso yesithathu ikhombisa ngokujulile ubungako bendawo bemibuzo yokuhlola ebekwe kulawo mamojuli kanye nekhono lokucabanga lendawo labafundi. Inhloso yokugcina bekuwukusungula isu lokuthuthukisa ukucabanga kwendawo kumamojuli angaphansi kweJografi.

Imodeli ye-AQAL yethiyori Edidiyelwe yasetshenziswa ukuze kubhekwane nobunkimbinkimbi balolu cwaningo, olubandakanya imibono eminingi kanye nezindlela ezihlukahlukene zokuqoqa idatha. Kusetshenziswe amasampula okuhlosiwe ukuhlonza iminyango yeJografi ezobamba iqhaza kulolu cwaningo. Ithakzonomi yokucabanga kwendawo yasetshenziselwa ukuhlola indawo yemiphumela yamamojuli nokuhlola. Izingxoxo ezijulile zenziwa nabafundisi, futhi isimo sabo sengqondo ekufundiseni ukucabanga kwendawo sanqunywa ngohlu lwemibuzo. Amandla okucabanga ngendawo wabafundi akalwa ngokuthi baqedele ukuhlolwa kwekhono lokucabanga lendawo (UKLL).

Imiphumela ibonisa ukuthi imiphumela nokuhlolwa kwamamojulI akhethiwe kungase kungabi negalelo ekuthuthukiseni amakhono abafundi okucabanga ngendawo. Kuyakhuthaza nokho ukuthi abafundisi basebenzise izindlela ezahlukene zokufundisa okufanele zibe negalelo ekuthuthukiseni amakhono abafundi okucabanga ngendawo, nokuthi babonise isimo sengqondo esihle ekwenzeni kanjalo. Nakuba usayizi wesampula wawumncane, imiphumela yo-UKLL ibonise ukuthi abafundi banamakhono ampofu okucabanga ngendawo.

Isu lokucabanga ngendawo livumela ukufakwa kokucabanga ngendawo emiphumeleni yamamojuli, ukudlulisa okuqukethwe kubafundi, isimo sabafundisi kanye nokwenza ngcono indawo yemibuzo yokuhlola. Lolu cwaningo lwelula isandla nakwamanye amanyuvesi ukuthi asebenzise isu lokucabanga okuthuthukisiwe ngendawo njengengxenye yezifundo zeJografi futhi azibophezele ekufundiseni ukucabanga ngendawo kubafundi abenza iziqu zokuqala.

Amagama abalulekile: Ukucabanga ngendawo, iJografi, ukufundisa nokufunda, ithakzonomi yokucabanga ngendawo, ukuhlolwa kwekhono lokucabanga ngendawo, isimo sokufundisa ukucabanga ngendawo, imfundo ephakeme, iNingizimu Afrika, amamojuli eziqu zokuqala, ukuhlola okwakhayo, ukuhlola okufingqiwe

Dedication

A PhD is not a journey one tackles on one’s own. I am thankful to all my friends and family who supported and cheered me on along the route.

To my supervisor, Prof Rudi Pretorius, thank you for your guidance in allowing me to complete this journey successfully.

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Chapter 1: Background to the research

1.1 Introduction

The importance of spatial thinking in the teaching and learning of Geography has been highlighted by many researchers (National Research Council, 2006; Bednarz & Bednarz, 2008; Jo, Hong and Verma, 2016). Geography is an ideal subject for teaching spatial thinking skills to students (Bednarz, 2019; Jo & Bednarz, 2009; Verma & Estaville, 2018). In addition, it has been proven that as opposed to students who have not studied Geography modules, those who have completed Geography modules tend to present with better spatial thinking skills (Verma, 2015). The benefits of spatial thinking extend beyond the discipline of Geography and may affect a person's ability to deal with daily challenges such as wayfinding and solving challenges in an unfamiliar context(National Research Council, 2006).

Despite the proven importance of spatial thinking and the availability of geospatial tools to assist a person in spatial thinking, it is reported that many individuals still lack spatial thinking abilities (Metoyer & Bednarz, 2017). Spatial thinking is a skill that an individual can learn at any age (National Research Council, 2006; Newcombe & Stieff, 2012). To think spatially, an individual requires knowledge about space, data representation, and reasoning processes (National Research Council, 2006). Students who are spatially literate know when to apply their spatial thinking skills, possess a broad and deep knowledge of spatial concepts and have adopted a critical stance toward spatial thinking (Ibid).

Spatial thinking cannot be taught as a stand-alone subject but is a way of thinking that should form an integral part of many academic disciplines (National Research Council, 2006). Various tools such as geographical information systems (GIS), global positioning systems (GPS), augmented reality, web mapping, static maps, charts and graphs can be used to teach spatial thinking to students (National Research Council, 2006; Manson et al., 2014; Carrera and Asensio, 2017; Collins, 2018b; Verma & Estaville, 2018). These teaching tools should be incorporated into Geography modules in such a way that students are provided with the opportunity to learn to think spatially (Metoyer & Bednarz, 2017).

Despite the importance of spatial thinking, the fact that it can be taught, and the availability of teaching and geospatial tools, research suggests that undergraduate Geography students in South Africa still lack spatial thinking skills (Pretorius, 2017). This research contributes to the teaching and learning of Geography in that its aim is to propose a strategy for improving spatial thinking in undergraduate Geography at South African universities.

This chapter sets the background for the thesis. The importance of geographical knowledge and spatial thinking skills in an ever-changing world is discussed. This is followed by the formulation of the problem that has led to this research, whereupon the aim and objectives are set. The theoretical paradigm, Integral Theory, forms the framework for this research and is briefly discussed. The significance and value of this research in the discipline of Geography and the knowledge field of spatial thinking are highlighted. To round off this chapter, an outline is provided of the chapters of the thesis, and a brief indication is given of what can be expected in each of the chapters.

1.2 Setting the scene: Geography and spatial thinking

The importance of geographical knowledge has been repeatedly proven in an ever-changing world (Bednarz, 2019; De Blij, 2012; Moolman & Donaldson, 2016), as also the encompassing nature of the discipline (De Blij, 2012; Holt-Jensen, 2018). Geography encompasses social and natural sciences and is ideally positioned to contribute to sustainability goals from a transdisciplinary perspective (Fu, 2020). The discipline has been proven to be invaluable in addressing day-to-day global and local challenges (De Blij, 2012; Holt-Jensen, 2018). These challenges include but are not limited to climate change, terrorist attacks, wars, economic crises (De Blij, 2012), the spread of diseases ─ as in the context of the recent COVID-19 world pandemic (Kuchler et al., 2022), food insecurity (DeWitt et al., 2020) and the management of water resources (Du Plessis, 2019). Therefore, it is crucial for Geography curricula to remain current, relevant and in line with the changing world and application of geospatial technologies (GSTs). Geography curricula for undergraduate modules need to be outward-looking, demand-led, outcome-orientated, and not introspective ─ that is, they should not be based only on the lecturer's research interests (Whalley et al., 2011). Geography curricula should relate to the importance of Geography in a natural, social and economic environment, the student's experience of his/her environment, and also improve the employability of the student (Ibid). Geography knowledge should strengthen an understanding of changes occurring within a country, region or world and the interaction between social and physical phenomena within a geographical space (Nursa'Ban et al., 2020). Geography, per definition, is a discipline that studies relationships, patterns, systems and the distribution of phenomena on Earth. Studying complex environmental challenges requires higher-order thinking skills (Ichsan et al., 2019). Although various factors and skills should be considered when designing a Geography curriculum, the importance of spatial thinking in studying and understanding the interaction between different phenomena in a changing world should be emphasised, as was propounded by Johnston (1997) more than 20 years ago, and is currently still relevant (Metoyer & Bednarz, 2017; Nursa'Ban et al., 2020). Bednarz (2019) describes spatial thinking, together with geographic thinking and geospatial thinking as the "secret powers" of a Geographer that could potentially save the world. The three ways of thinking are described as secret powers, since there is a general misconception of the powerful knowledge Geography as a discipline could offer to deal with challenges and solve problems (Bednarz, 2019). Spatial thinking, in short, is described as the use of spatial concepts, spatial representations and processes of reasoning to identify and solve geographical problems (National Research Council, 2006) (Chapter 2 presents a more comprehensive discussion on the definitions of the different ways of thinking and shows how these different ways of thinking relate to one another.)

While the availability of spatial tools and spatial information has increased substantially over the 20 years, Metoyer and Bednarz (2017) suggest that many individuals still lack spatial thinking abilities for tackling and solving geographical problems. The availability of spatial tools plays an essential role in fostering the spatial thinking skills of individuals, and as such, tools of representation are required (National Research Council, 2006; Baker et al., 2015). The successful use of GSTs, such as GIS, remote sensing imagery and GPS, to develop the spatial thinking skills of individuals has been proven through research (Flynn, 2018; Ghaffari et al., 2018; Kim & Bednarz, 2013a). However, recent research has indicated that spatial thinking can close achievement gaps in Science, Technology, Engineering and Mathematics (the STEM subjects) and assist with the development of participatory and emancipated individuals (Bednarz, 2019; Uttal & Cohen, 2012). This process is termed *spatial citizenship* (Bednarz, 2019), with a spatial citizen defined as an individual who is able to participate as a useful member of society through the critical use of geospatial technologies (such as GIS, maps and digital globes) (Gryl et al., 2010). In fact, the vision is for the establishment of a new generation of spatial citizens by improving on the teaching and learning methods of a brand of Geography that includes the development of spatial thinking competencies (Bednarz, 2019). As opposed to other students, students majoring in Geography and those who have studied several Geography modules have shown themselves to have superior spatial thinking competencies (Verma, 2015). The research by Bednarz (2019) and Verma (2015) emphasise the importance of an education in Geography for improving the spatial citizen competency of students.

Spatial thinking abilities enable a person to identify spatial data sets needed in decision-making, to assess the quality of the data at hand and to use the spatial data to make decisions within space. A spatial thinking ability test (STAT) to determine the spatial thinking abilities of a person has been developed by Lee and Bednarz (2012). Furthermore, a taxonomy to assess the inclusion of spatial perspectives on specific issues and an inventory that can be used to determine the disposition educators generally have toward teaching spatial thinking have been developed by Jo and Bednarz

(Jo & Bednarz, 2009, 2014). The STAT, the taxonomy of spatial thinking and the disposition inventory will be used in this research to determine to what extent it is possible for students to acquire spatial thinking abilities within the undergraduate Geography curriculum offered at South African universities.

1.3 Problem statement

The importance of spatial thinking in Geography and the benefits of possessing these abilities have been proven repeatedly (National Research Council, 2006; Bearman et al., 2016; Metoyer & Bednarz, 2017). Metoyer and Bednarz (2017) indicate that many individuals still lack the essential spatial thinking abilities for using GSTs to understand and solve problems and formulate or influence policies (Metoyer & Bednarz, 2017). Since modern society needs individuals with the ability to deal with non-routine challenges, individuals need to be equipped with skills such as spatial thinking to overcome such challenges (Charcharos et al., 2016). Differences occur in how quickly and easily individuals are able to learn spatial thinking skills, but it has been proven that they are learned skills that can be acquired at any age (National Research Council, 2006).

Research conducted by Verma and Estaville (2018) to determine the role of Geography courses in improving the geospatial thinking skills of undergraduate students in the United States of America (USA) indicates a strong correlation between students studying Geography and their ability to think spatially. Geography is, therefore, a subject that can be used effectively to teach spatial thinking skills to students. Although it has been proven that certain geographic tools such as maps, GIS and GSTs can be used to teach spatial thinking skills (Verma & Estaville, 2018), research that focuses specifically on effective methods for teaching spatial thinking is lacking in the area of undergraduate teaching and learning of Geography. An example of this is provided by the situation in the United States of America, as highlighted by Metoyer and Bednarz (2017) and Verma and Estaville (2018). Also, the effectiveness of teaching spatial thinking depends on the disposition of the lecturer towards incorporating spatial thinking into his/her teaching practice, materials and supporting documents (Jo & Bednarz, 2014). Research conducted by Pretorius (2017) and an initial desktop study by the researcher suggest that spatial thinking is not sufficiently incorporated into the curricula of undergraduate Geography modules at South African universities. Therefore, it is essential to determine whether and how spatial thinking can be included in undergraduate Geography modules at South African universities and to gauge the current spatial thinking abilities of Geography students. A proposal can then be made for a strategy to improve spatial thinking in undergraduate Geography at South African universities which would contribute to developing future geographers with the necessary spatial thinking skills, thus enabling them to solve or contribute to solutions to complex problems in a changing world.

1.4 Aim and objectives

This research aims to develop a strategy for improving the teaching and learning of spatial thinking in undergraduate Geography modules presented at South African universities. While referring only to spatial thinking — to avoid repetition, it should be noted that both the teaching and learning aspects of spatial thinking form the focus of this research. Teaching and learning are two separate but related processes. Within the context of this research, teaching refers to the process of conveying or imparting knowledge to students while learning refers to the process of acquiring new knowledge.

To achieve this aim, the following objectives have been formulated for this research:

1. Determine the extent and nature of the incorporation of spatial thinking into the syllabi of undergraduate Geography modules at South African universities.
2. Conduct a critical assessment of the methods used by lecturers of a selection of undergraduate Geography modules at South African universities to convey the content of modules to foster the spatial thinking abilities of students and the disposition of these lecturers towards teaching spatial thinking.
3. Critically reflect on the spatiality of the questions posed in formative and summative assessments and the spatial thinking capabilities of undergraduate Geography students at a selection of South African universities.
4. Develop a teaching and learning strategy for the improvement of spatial thinking in undergraduate Geography modules at South African universities.

1.5 Theoretical paradigm

The theoretical paradigm that has been selected for this research is grounded in Integral Theory. This paradigm acknowledges the interconnected nature of all things and that in order for research to be relevant, a narrow scientific view of reality cannot be taken. The teaching and learning of the discipline, as well as the skills–based context of this research, cannot be addressed within the constraints of only one specific methodology or through the lens of only one worldview. This is also due to the multiple dimensions involved, namely behavioural (lecturing, studying, etc.); personal (understanding, thoughts, etc.), cultural (appropriateness, shared meanings, etc.); and systemic (curriculum, policies, etc.). To this end, Integral Theory, which acknowledges the value of multiple paradigms and includes, for example, positivism, structuralism, interpretivism and Marxism, provides a suitable theoretical framework for this research.

Integral Theory is supported by a well-developed methodological basis, which guides researchers in selecting the most relevant tools, techniques and methods for data capturing and for the analysis of the results of a particular research project (Esbjörn-Hargens, 2009). This is grounded in the AQAL model, through which Integral Theory provides researchers with a content-free framework that is suitable for most fields of application and can be used on any scale (Esbjörn-Hargens, 2010a). AQAL is the acronym for "all quadrants", "all levels', "all lines", "all states" and "all types", and with these five elements representing the most basic recurring aspects of reality and forming the essence of the integral research space (Esbjörn-Hargens, 2006a). This approach ensures that the research is conducted holistically and that all aspects that could contribute to solving the problem at hand are integrated into the research methodology.

Integral Theory lends itself to research in an educational environment, where research results are influenced by a spectrum of observations, experiences and perspectives, varying, in the case of this research, from the perspectives of Geography lecturers to the outcomes of quantitative tests (such as the taxonomy of spatial thinking and the STAT), as well as the perceptions of the researcher, who has extensive experience in the field of GSTs in higher education. Integral Theory also allows for the inclusion of all perspectives ranging from objective to subjective (Esbjörn-Hargens, 2010a). Examples of the successful implementation and use of Integral Theory in the context of Geography education include research by Haigh (2013), Murray (2009), and Esbjorn-Hargens (2006b). The theoretical paradigm for this research and how this paradigm feeds into the methodology are discussed in detail in Chapter 3.

1.6 Significance and the intended value of the research

Spatial thinking is a collection of cognitive skills that are beneficial to a wide array of disciplines, including Geography. Geography is inherently interdisciplinary and requires students to think spatially (Bearman et al., 2016). In general in schools, emphasis is placed on mathematical and literacy skills, whereas spatial thinking often lags in this respect. The National Research Council (2006) describes spatial thinking at educational institutions as 'under taught and under recognised'. Bednarz and Bednarz (2008) emphasise the importance of spatial thinking and geospatial technologies and indicate that insufficient attention to these areas and their inclusion as part of Geography curricula characterises all levels of study in the USA. Although the importance of spatial thinking has been proven through various studies, those researchers interested in the field of spatial thinking are few and far between and generally include only a small number of specialised individuals who could contribute to creating opportunities for further research in this field (National Research Council, 2006; Bednarz & Bednarz, 2008; Jo & Bednarz, 2009; Verma, 2015).

An initial desktop study conducted by the researcher and a study conducted by Pretorius (2017) indicate that the situation in South Africa in terms of spatial thinking concurs with that of the USA. By conducting comparative studies to find common ground and compare challenges, further research could include collaborations with universities in the USA. In addition, the literature indicates a lack of research into spatial thinking at African universities, and thus there is scope for pursuing research opportunities in this field on the continental scale as well.

The contribution of this research lies in the unique approach taken to apply Integral Theory to the investigation of the *status quo* in terms of the level of inclusion of spatial thinking in undergraduate Geography in South Africa. Since spatial thinking improves self-efficacy and problem-solving skills, the students trained effectively in this aspect may potentially be led along a successful academic path and ultimately enjoy a higher level of employability. Spatial thinking should, therefore, form an integral part of all Geography modules at the tertiary level.

Related research by Pretorius (2017) indicates that undergraduate Geography modules at South African universities fall short in terms of teaching spatiality and improving the development of spatial thinking. This research will make a unique contribution to the teaching and learning of Geography in that it proposes a strategy to improve spatial thinking in such modules. The strategy, based on the results of the spatial thinking ability test (STAT), includes spatial perspectives in terms of the taxonomy of spatial thinking and the disposition of lecturers towards spatial thinking.

A comprehensive approach to the research is required to fully understand the multi-faceted nature of the problem at hand, namely, individuals' lack of spatial thinking abilities to deal effectively with geographical problems and ways to find solutions for them. Since a diversity of equally important perspectives will be required to understand this problem, methodological pluralism has been adopted as a guiding principle. Methodological pluralism acknowledges the value of multiple perspectives in respect of research on a specific topic (Davis, 2019a). In the case of education, these perspectives could be those of the students and educators, and the experiences of the researcher (Ibid). Methodological pluralism refers to the use of a range of methods for collecting data (e.g. through questionnaires, interviews and the researcher's personal experiences). Integral Theory, often referred to as the AQAL approach, provides a multi-perspective framework in which a researcher can select the relevant methodological tools and techniques suitable for the research project (Esbjörn-Hargens, 2006a). Therefore, Integral Theory suits this research well and is used as a conceptual framework to develop a strategy to improve the spatial thinking skills of undergraduate Geography students at South African universities.

1.7 Chapter outline

This thesis follows an approach to the chapter layout that differs slightly from the norm. The in-depth literature review is not limited to one chapter in the introductory portion of the thesis only. In fact, the complexity and multifaceted nature of the research has made it necessary to include and highlight some pertinent literature that informs the research in all the chapters of the thesis. The current literature and related research topics are, therefore, presented, discussed and reflected upon at the stage where they prove to be relevant and where they support the analysis and interpretation of the collected data and the development of a strategy to improve the teaching and learning of spatial thinking in undergraduate Geography at South African universities.

Chapter 1 deals with the background of this research and emphasises the importance of spatial thinking in the Geography curriculum. The aim and objectives are specified, and the significance of the study is explained. Chapter 2 introduces the most pertinent literature relevant to this study, and some of the terminology that features in the thesis is defined and explained. The two research instruments that are used to determine the spatiality of the Geography modules and students' spatial thinking skills, namely the taxonomy of spatial thinking and the STAT, are explained in more detail. Chapter 3 focuses on the theoretical framework and shows how this feeds into the methodology used to conduct this research. The methods applied to reach the aim and objectives of this research are explained.

The background to Geography teaching at South African universities and the findings of Objective 1, namely, the extent and nature of incorporating spatial thinking into the syllabi of undergraduate Geography modules at South African universities, are presented and analysed in Chapter 4. The initially identified modules are critically assessed against the taxonomy of spatial thinking to determine whether they are suitable to contribute to this research. The important outcomes of this chapter are to identify the specific Geography departments to invite to participate in this research and to determine the spatiality of their respective module outcomes by using the taxonomy of spatial thinking.

Chapter 5 focuses on Objective 2. This chapter starts with an in-depth review of current literature on research regarding the inclusion of spatial thinking in teaching methods for the purpose of conveying Geography content to students. Following this, a qualitative analysis of the interviews with the lecturers of the identified departments is presented. Finally, the teaching methods employed in the selected modules to convey the module content to students are critically assessed against the taxonomy of spatial thinking, with the disposition of the lecturers towards teaching spatial thinking also being presented.

Chapter 6 starts with an in-depth literature review concerning the spatiality of the questions asked in the formative and summative module assessments of the selected modules and measures the students' spatial thinking skills as applied in various studies. The outcome of this chapter indicates whether the questions in the assessments would likely contribute toward developing spatial thinking skills in the students enrolled for the selected modules (Objective 3).

Chapter 7 proceeds by integrating the research results flowing from chapters 4, 5 and 6 to develop a strategy for the improved facilitation of spatial thinking in undergraduate Geography at South African universities (Objective 5). This chapter demonstrates how objectives 1 to 3 were achieved and how these feed into the strategy for the improvement of spatial thinking in undergraduate Geography at South African Universities.

Chapter 8 concludes the thesis and presents recommendations regarding the improved facilitation of spatial thinking in undergraduate Geography at South African universities.

1.8 Summary

This chapter sets the background for the thesis by explaining the importance of geographical knowledge in an ever-changing world and why any layperson should be able to think spatially. It is suggested that the various tools that can be used to teach spatial thinking should be included in Geography teaching in such a way that students are provided with the opportunity to optimally develop their spatial thinking skills. Despite the importance of possessing spatial thinking skills, the reality is that individuals still lack the necessary spatial thinking skills to solve complex problems.

An outline of the research problem and the aim and objectives of this research is provided. The aim is namely to develop a teaching and learning strategy for improving spatial thinking in undergraduate Geography modules presented at South African universities. The aim is followed by the three research objectives that form the framework for this research and the subsequent chapters. To understand the multifaceted nature of this research, the theoretical framework to be adopted for this research is based on Integral Theory. Integral Theory lends itself to research in a multi-dimensional environment such as education. Integral Theory is discussed in detail in Chapter 3.

An initial desktop study and supporting research indicate that spatial thinking might not be sufficiently incorporated into Geography curricula at South African universities. This research fills in on essential gaps in the research field of spatial thinking, especially on the African continent, and seeks to investigate how spatial thinking can be incorporated into the undergraduate Geography curriculum to improve students' spatial thinking skills. The unique contribution of the research focuses on investigating the inclusion of spatial thinking in undergraduate Geography teaching at South African universities and on gauging the spatial thinking skills of undergraduate Geography students. This research aims to develop a strategy for improving spatial thinking in teaching and learning in undergraduate Geography modules at South African universities.

This chapter concludes with an outline of the thesis and provides a brief review of each of the chapters for the remainder of the thesis. The next chapter, Chapter 2, further expands upon the pertinent literature relevant to understanding the context of this research.

Chapter 2: Connections with the literature

2.1 Introduction

Since we live in an era of 'super complexity', a fresh look at Geography curricula is needed to prepare students for the demands of the 21st century (Bednarz, 2019; Whalley et al., 2011). The value of Geography as a subject to address and solve challenges within this complex environment should not be underestimated (Bednarz, 2019; De Blij, 2012). Bednarz (2019) describes Geography as a science with 'secret powers' that could potentially save the world. These 'secret powers' refer to three ways of thinking, namely, geographic thinking, geospatial thinking and spatial thinking. Spatial thinking forms the focus of this research. There are subtle but important differences in these three ways of thinking which are discussed, illustrated and reflected upon in this chapter.

Geography curricula from various countries have adopted unique approaches regarding the geographical content, knowledge and skills taught to students (Whalley et al., 2011). However, many researchers agree that one skill that should be included in all Geography curricula is spatial thinking (National Research Council, 2006; Bearman et al., 2016; Verma & Estaville, 2018; Bednarz, 2019). Acquiring spatial thinking skills will enable future geographers to make well-informed decisions in an ever-changing world once they enter the workforce. Therefore, it can be reasoned that spatial thinking should be incorporated as part of the instructional material of Geography modules and in terms of the way in which the content is presented and how questions and assessments are set up (Jo & Bednarz, 2009; Lee & Bednarz, 2012). To this end, a taxonomy of spatial thinking that was developed by Jo and Bednarz (2009) to measure the inclusion of spatiality in questions and assessments has been incorporated into this research. Further research has also indicated that spatial thinking can be taught successfully only if the lecturer has a positive disposition towards teaching spatial thinking (Jo & Bednarz, 2014). To determine whether the teaching of spatial thinking is successful and whether the learners or students are in fact able to acquire the necessary spatial thinking skills, a spatial thinking ability test (STAT) has been developed to evaluate the spatial thinking skills of individuals (Lee & Bednarz, 2012).

While mapping the context for this research, this chapter makes some connections with the literature. The first section of this chapter, taken from a global and a local perspective, focuses on the changing role of higher education, with a specific focus on Geography. The second section focuses on the importance of spatial thinking and the tools that could be used to measure the inclusion of spatial thinking in teaching material, as well as the resultant spatial thinking skills that could be acquired by the individual learners or students. This section on spatial thinking also touches on the essential role of an educator's disposition toward spatial thinking. The third section explains why spatial thinking should form an integral part of the Geography curriculum at the undergraduate level. It is followed by the fourth section, which describes the benefits of spatial thinking in other study fields, after which a short summary concludes the chapter by reflecting on the most important aspects which have been covered. This chapter also explains and defines some of the terminology used in this research.

2.2 The changing role of higher education and Geography teaching and learning

Higher education worldwide is under constant pressure for change. The changes at higher education institutions are influenced by pressures such as governmental changes and student demands in terms of what they learn from a higher education institution (Whalley et al*.*, 2011). Thus, universities exist in a competitive market and play a critical role in national economies (Ibid).

Within this changing role of higher education, the quantitative revolution of Geography has, without a doubt, had an influence on Geography (Fotheringham et al., 2007). The quantitative revolution in Geography occurred during the two decades over the 1950s and 1960s, and caused Geography to shift its focus from a regional to a spatial science (Murayama, 2004). During the 1980s, the methodology of quantitative Geography saw its demise (Fotheringham et al., 2007). The growth in Geographical information systems (GIS) and Geographical information science (GISc) from the mid-1980s had a negative impact on quantitative geography. GIS has since then grown within the discipline of Geography to become an essential skill for employment (Ibid). The growth and development of GIS in South African Geography departments are further discussed in Chapter 4.

Many calls have been made since 2000 for changes in the Geography curriculum worldwide (Spronken-Smith, 2013; Alderman, 2018; Walkington et al., 2018), including South Africa (Knight, 2018; Long et al., 2019; Van der Merwe et al., 2020). In the light of the availability and accessibility of information on the worldwide web and increased global interconnectedness, knowledge is no longer a commodity owned exclusively by universities (Whalley et al., 2011). This increased availability and accessibility of information have had far-reaching implications for Geography curricula to be more outward-looking and demand-led rather than to be introspective and research-led (Ibid). Five years ago, Alderman (2018) had already called for a change in the Geography curriculum towards a more 'radical geographic literacy'. The call to move in this direction was to emphasise the importance of significant discipline-wide advancement and to strengthen Geographic education to understand the diversity and complexity of the world (Ibid).

2.2.1 The global perspective

During the last two decades, the world has continued to change substantially and at an increased rate. Some of these changes have been introduced through challenges such as climate change, tsunamis, terrorist attacks, wars, failing and emerging economies, changing boundaries, differences in political ideologies (De Blij, 2012) and most recently, the Covid-19 pandemic. All of these changes and challenges pose obstacles, from the local to the global scale, which decision-makers, communities and individuals have had to deal with (Ibid). The constant call for changes in the Geography curriculum is driven by this ever-changing context and is also due to economic and societal changes (Hegarty & Waller, 2004; Knight, 2018), as well as the emergence of new technologies (Kerski, 2015; Walkington et al., 2018). It is argued that Geography teaching should not only focus on traditional definitions and factual information in textbooks, and the memorisation thereof, but should rather be seen as imparting critical knowledge that could potentially safeguard the world within this ever-changing environment (Alderman, 2018; Bednarz, 2019). As future geographers, decision-makers and community members, students should be prepared to make decisions in an ever-changing world (Bednarz, 2019).

As indicated by Bednarz (2019), Geographers should engage in three powerful ways of thinking, namely, spatial thinking, geographic thinking and geospatial thinking, that should prepare them for an ever-changing world. Geography teaching (together with the different thought processes) should be conveyed to students in such a way that they are encouraged to become spatial citizens. Students who are spatial citizens are productively engaged with the challenges of society, such as social justice and the environment (Bednarz, 2019) and understand the value of geographical knowledge in an ever-changing society (Walkington et al., 2018). It has also been proven that there is a link between spatial citizenship and a person's ability to think critically (including spatial thinking) within an ever-changing world (Carlos & Gryl, 2013). Spatial citizenship is an important notion in Geography teaching, and Chapter 7 will demonstrate how this research contributes towards developing spatial citizens.

Geography had already positioned itself as a 'science of the spatial' in the mid-sixties. More than 30 years ago, Massey (1984) indicated that Geography - specifically Human Geography - focuses on spatial laws, spatial processes, spatial causes and spatial relationships. It is rightfully so that Geography does not 'own' the concept of space or spatiality (Massey, 1984) but has been proved as the only encompassing discipline that can address all of the above-mentioned changes and challenges (De Blij, 2012). An understanding of Geography provides the conceptual framework to accommodate and understand transformation and interconnectedness and thus to inform thoughts and decisions in an ever-changing world (De Blij, 2012; Moolman & Donaldson, 2016).

To prepare students to make decisions in an ever-changing world, it is important for Geography curricula to stay current and to be reviewed and updated regularly. Although it is impossible to propose one overarching curriculum for what should be covered in undergraduate Geography (Whalley et al., 2011), various factors and skills should be considered when designing a curriculum in Geography for undergraduate teaching and learning. The same applies to the syllabi for specific Geography modules. Research focusing on these factors and skills includes the employability of students (Şeremet & Chalkley, 2016), vocationalism (Dowling & Ruming, 2013), graduate attributes and graduateness (Spronken-Smith et al., 2016), self-efficacy (Songer, 2010), visual literacy (De Jager, 2014) and spatial thinking (Lee & Bednarz, 2012). Also, Geography curricula should develop subject-specific skills such as spatial reasoning, spatial thinking, the representation of spatial data, the design of sample data, and also present the different theoretical perspectives of Physical and Human Geography (Whalley et al., 2011)

Some lecturers from tertiary teaching institutions in the United States of America report that students often ignore the facts conveyed through Geography teaching while holding on to misconceptions or wrong facts (Bednarz, 2019). These misconceptions are often attributed to a person's cultural beliefs and might result in a debate over the analytical interpretations of the data and facts (Ibid). Geography lecturers should develop curricula and teaching content that are sensitive to these biases and support/empower students to overcome preconceived ideas and ideas based on personal experiences that are not supported by geographical facts. Bednarz (2019) suggests that one way to alleviate preconceived ideas and misconceptions is to make students aware of their own thinking processes, specifically spatial thinking.

Critical thinking and problem-solving skills are regarded as the most needed skills for geographers in the workplace but have proved to be largely lacking (Whalley et al., 2011). Skills that are usually related to Physical and Human Geography and GIS and technology are generally regarded as less important. Geography curriculum offered by academic departments in the USA does not develop the appropriate skills, such as spatial thinking, which are needed in the workplace (Solem et al., 2008; Whalley et al., 2011). Therefore, it is critical that Geography curricula become current by developing relevant skills, such as spatial thinking, to appropriately empower future geographers in the workplace (Whalley et al., 2011). The current trends in Geography research, specifically those concerning spatial thinking, are further discussed in Chapter 4

2.2.2 The local perspective

Over the past decade, higher education in South Africa has been facing fundamental challenges concerning access, retention and success in respect of the educational experience of many students from disadvantaged educational backgrounds (Speckman & Mandew, 2014). South African universities, similar to international universities, have also been under pressure to change and adapt, specifically in the context of student perspectives and curriculum content, and in their quest to meet societal challenges (Whalley et al., 2011; CMoloi et al., 2017). A recent societal challenge that undoubtedly had a significant influence on the higher education landscape in South Africa was the #Feesmustfall campaign that reached its peak in October 2015 (CMoloi et al., 2017). During the #Feesmustfall campaign, many students protested in favour of free higher education for all citizens of South Africa and the decolonisation and Africanisation of tertiary curricula (CMoloi et al., 2017; Ndelu et al., 2017).

The #Feesmustfall campaign and the call to Africanise and decolonise the curricula of all modules (Ndelu et al., 2017) (including Geography modules) confronted all universities in South Africa with the challenge to transform the content of their curricula, but concurrently also presented some opportunities (CMoloi et al., 2017). For universities to remain current, education in South Africa should be ethically responsive to evolving complexities in an ever-changing world that are relevant to South Africa (Ibid).

A desktop study by the researcher in 2019 indicated up to then, no research regarding the inclusion of spatial thinking in the undergraduate Geography curriculum had been conducted in South Africa. However, related research about problem-based learning in undergraduate Geography in South Africa had already been conducted in 2013 by Golightly and Muniz (2013). Their study concluded that Geography education students experience problem-based learning (a method of learning that is linked to spatial thinking) as an effective teaching and learning method (Ibid). Another study by Larangeira and van der Merwe (2016) outlined the challenges first-year Geography education students at a South African university experience in understanding the mapwork component of the curriculum. Their study outlines the importance of spatial thinking concerning the reading and interpretation of maps and indicates that future teachers cannot teach and develop spatial thinking skills as long as they themselves have not mastered these skills (Larangeira & Van Der Merwe, 2016). Research published by Mather (2007) indicates that the Geography curricula of South African universities have become increasingly localised, focusing on development challenges in the region in question.

An overview of the titles of modules and descriptions of syllabi, as collated and analysed by Pretorius (2017), indicates that most universities teaching undergraduate Geography in South Africa follow a sub-disciplinary approach or a combination of a sub-disciplinary and an integrated approach. Pretorius (2017) also indicates that a strong and in-depth representation of spatiality in South African Geography modules appears to be largely lacking. To address and solve the complex challenges experienced in South Africa, it is crucial for Geography students to be provided with the opportunity to develop and practise spatial thinking skills. Trends in Geography research in South Africa are discussed in greater detail in Chapter 4.

2.3 Spatial thinking

Although spatial thinking is not a new concept, it is more complex than was previously thought (Gersmehl & Gersmehl, 2011). Spatial thinking consists of eight to 11 distinct processes occurring in different parts of the brain and involves different memorisation processes (Ibid). More than a decade ago, the Committee on Support for Thinking Spatially conducted ground-breaking research on spatial thinking (National Research Council, 2006). This research, conducted on behalf of and under the auspices of the National Research Council in the USA, is still frequently cited and forms the basis of many publications about this topic.

For this research, it is important to distinguish between the concepts of critical thinking, spatial thinking, geospatial thinking and critical spatial thinking. The relationships between these four thought processes are illustrated in Figure 2.1.

Critical thinking can be defined as the way in which data and evidence are used in decision-making. The decision-making process involves interpreting data, drawing conclusions from the data, comparing models and data, evaluating methods, and deciding how to proceed with a study (Walsh et al., 2019). Critical thinking involves higher-level cognitive skills such as analysis, synthesis, self-reflection and the identification of perspectives, and leads to logical and appropriate actions (Papp et al., 2014) within the specific application field of the critical thinker.

The National Research Council (2006) describes spatial thinking as a combination of three components, namely, the concept of space, the tools of representation and the processes of reasoning. To bring these three components into play, people should possess the appropriate spatial thinking skills. Spatial thinking allows a person to use space to structure problems, model the real and theoretical world, and identify and communicate possible solutions. The inclusion of space in the thought process distinguishes spatial thinking from other types of cognitive processes (National Research Council, 2006). The spatial ability of a person is his/her ability to process spatial thinking (Cheng, 2016). A person with a high level of spatial thinking will also possess highly developed spatial abilities (Ibid). Geospatial thinking is a specialised form of spatial thinking: it focuses on patterns and processes at a specific location on or near the earth's surface and on different scales (Baker et al., 2015). Geospatial thinking uses geographic space on different scales to identify problems, provide answers and propose solutions by using geospatial concepts, representational tools and reasoning processes (Verma & Estaville, 2018).

Kim and Bednarz (2013a:351) define critical spatial thinking as the 'reflective evaluation of reasoning processes while using spatial concepts and spatial representation'. Critical spatial thinking is an extension of spatial thinking and a deeper understanding of the spatial relationships among phenomena (Gordon et al., 2016). Critical spatial thinking involves an understanding of spatial concepts at a more advanced level than by the general public or even by some highly educated people (Goodchild et al., 2014; Sinton, 2017). A critical spatial thinker can appropriately use geographic information to identify problems, deal with challenges and communicate results (Sinton, 2017). Therefore, critical spatial thinking and geospatial thinking are specialised ways of thinking that develop and focus on specific concepts of space and constitute a component of spatial thinking.

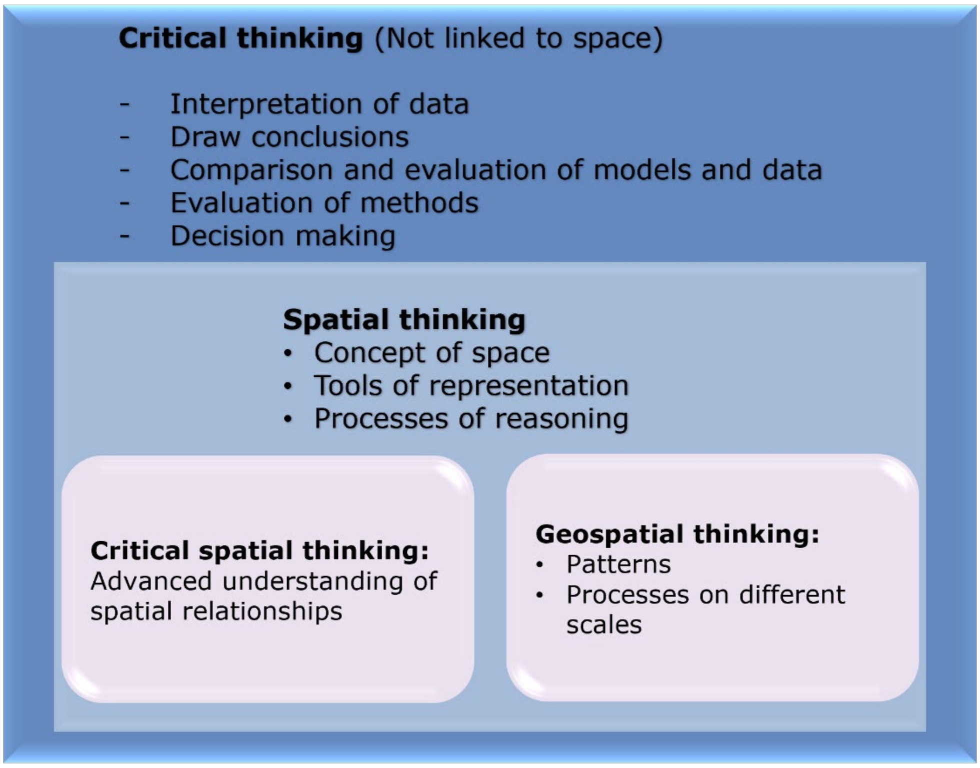


Figure 2.1: Four thought processes - critical thinking, spatial thinking, geospatial thinking and critical spatial thinking.

The definitions of critical spatial thinking, as determined by Kim and Bednarz (2013a) and Gordon, Elwood and Mitchell (2016), also refer to the definition of spatial thinking as defined by the National Research Council (2006). Owing to this overlap and similarities in terms of the understanding of spatial thinking, geospatial thinking and critical spatial thinking, the researcher decided to standardise and refer throughout this thesis to "spatial thinking", which includes the notion of critical spatial thinking and geospatial thinking.

2.3.1 The importance of spatial thinking

Two decades ago, Johnston (1997) made a strong case for the importance of spatial thinking in the Geography curriculum. Although spatial data and geospatial tools have become more readily available since 1997, students currently still lack the ability to think effectively in spatial terms in order to solve complex geographical questions (Metoyer & Bednarz, 2017). It has also been proven that spatial thinking contributes to a student's self-efficacy, motivating him/her to solve complex problems, confront challenges and resolve them (Songer, 2010).

Over the last two decades, various studies have been conducted to demonstrate the importance of spatial thinking (National Research Council, 2006; Bednarz & Bednarz, 2008; Goodchild & Janelle, 2010; Jo et al., 2016; Metoyer & Bednarz, 2017). Spatial thinking allows students to understand the spatial relationships among different phenomena and enables them to analyse these relationships. A spatial thinker can assess the quality of spatial data, use spatiality as a way of reasoning when solving problems and substantiate conclusions based on spatial information (National Research Council, 2006). Spatial thinking should, therefore, form an integral part of all education curricula at all levels (Ibid). Research by the National Research Council (2006) and Jo, Bednarz and Metoyer (2010) has indicated that spatial thinking skills can be taught and improved through teaching and learning processes.

Various tools can be used to teach spatial thinking. These include globes, maps, graphs, sketches, diagrams, flow charts, images, models, virtual globes and GIS (National Research Council, 2006; Jo et al., 2016; Duarte, 2018). These tools are used to identify, describe, explain and communicate information about phenomena and the spatial relationships between them and with other phenomena. Recent studies emphasise the powerful role that GIS and other geospatial tools can potentially play in developing spatial thinking skills (Songer, 2010; Whalley et al., 2011; Jo et al., 2016).

While spatial thinking can be taught by applying the above-mentioned tools, the ways in which questions are posed in assessments and the means whereby the disposition of lecturers to teach spatial thinking to students are determined are equally important. The rote learning of Geography subject matter only will not develop the spatial thinking ability of students (Ishikawa, 2013; Bearman et al., 2016; Bednarz, 2019). Questions need to be posed in such a way that the concepts of space, the tools of representation and the cognitive process enhance and develop the spatial thinking process of students

(Jo & Bednarz, 2009). To measure whether and how spatial thinking is incorporated into the questions used in assessments, Jo and Bednarz (2009) developed a taxonomy of spatial thinking. The importance of spatial thinking in Geography teaching and learning is pivotal to this research and is discussed in detail in the chapters that follow.

2.3.2 A taxonomy of spatial thinking

Spatial thinking requires students to know, understand and remember spatial concepts and information and also to recall such knowledges in order to solve problems when necessary (Jo & Bednarz, 2011). Therefore, questions in assessments should be designed to foster spatial thinking by using spatial concepts, spatial representations and spatial reasoning skills.

Jo and Bednarz (2009) developed a taxonomy that can be used to evaluate the spatial perspective of questions in Geography textbooks and assessments. (Refer to Figure 2.2.) This taxonomy consists of three categories: the various concepts of space, the tools for representing such spatial phenomena and the process of reasoning in the spatial context.

These three categories are based on the definition of spatial thinking, as defined by the National Research Council (2006). Each of the three categories is further subdivided into varying levels of abstractness or difficulty. Jo and Bednarz (2009) used the three levels of abstraction, as defined by Golledge (1995, 2002), as the basis for their classification of spatial thinking, namely, spatial primitives, simple spatial concepts and complex spatial concepts. This classification distinguishes between spatial and non-spatial concepts (Jo & Bednarz, 2009). The tools of representation are the second component in the taxonomy. The visual representation of geographical information through graphs, maps and diagrams is an important tool for understanding and communicating module content, and thus the taxonomy acknowledges the use of visual representations. The taxonomy, therefore, indicates the use or non-use of visual representations.

Sinces spatial thinking requires complex reasoning, the taxonomy must also distinguish between higher-level and lower-level cognitive processes. Jo and Bednarz (2009) therefore based the taxonomy on three cognitive levels, namely, an input, a processing and an output level of thinking. Questions on the input level are at a low level and require a person to recall information from memory (e.g., to create a list or name the characteristics of a feature). The processing level requires a person to make sense of information (e.g., to classify or explain a phenomenon or to compare phenomena). The output level requires a person to create new information by formulating a hypothesis or making a prediction based on given information or a scenario.

The taxonomy is represented in a three-dimensional model consisting of cubes, as shown in Figure 2.2. Each cube has a unique number based on the inclusion of the concepts of space, the use of tools for the representation of information, and the processes of reasoning. The value of each cube represents the spatiality of each question (Jo & Bednarz, 2009). A higher value of spatiality is associated with a higher level of spatial thinking.

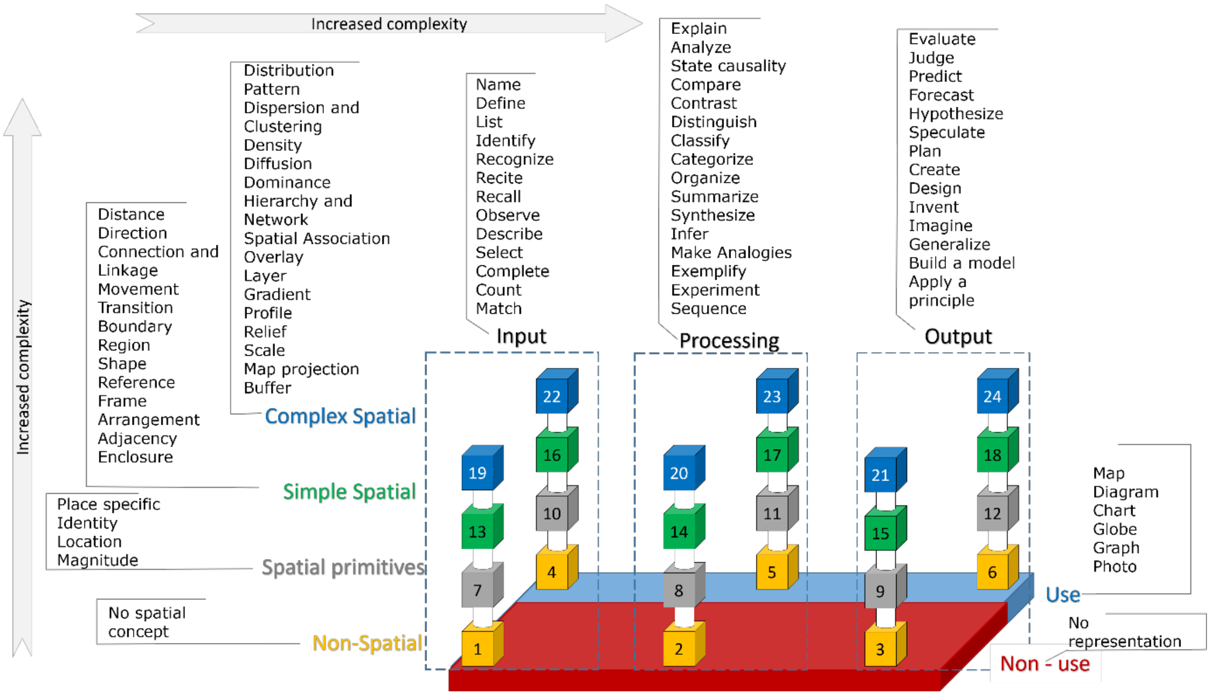


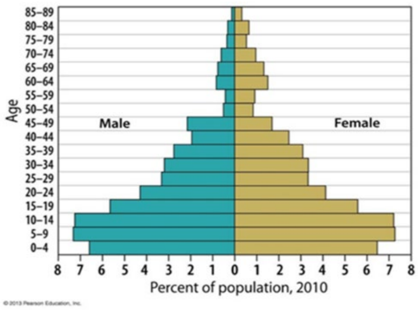
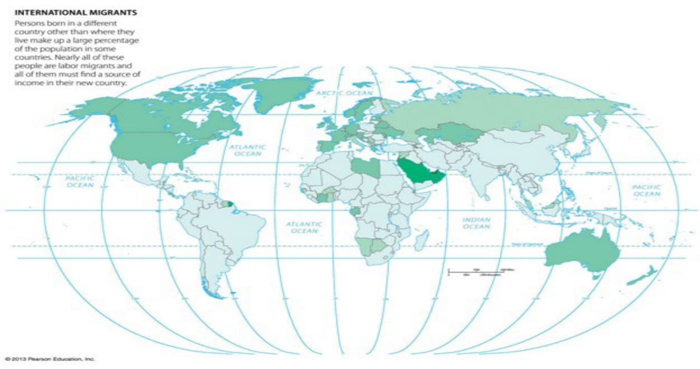
Figure 2.2: Taxonomy of spatial thinking.

Adapted from Jo and Bednarz (2009)

The use of the taxonomy of spatial thinking can be best described through an example of a question used for assessment, e.g. "Define the concept of climate change.". A definition of a concept requires a person to recall rote learning and is pitched at a low cognitive level, namely, the input level. No concept of space is involved in this question; furthermore, no representation tool is used. This puts this question at the lowest possible spatiality value, namely, 1, on the taxonomy of spatial thinking. If the question is rephrased as follows: "Use the given maps to hypothesise how climate change will influence the activities of the community located at Point X", this assumes that the maps representing the variables that contribute to climate change are provided to the student for him/her to answer the question. To hypothesise is listed as an output and is a high-level cognitive process. The overlay of various maps and the detection of patterns is a complex spatial problem with various map layers that are used to represent the information. If rephrased in this way, the question can, therefore, be put at the highest possible value, namely 24, on the taxonomy of spatial thinking.

Table 2.1 contains two more examples of questions with a low value on the taxonomy of spatial thinking and shows how these questions can be adjusted to assume a higher value.

Table 2.1: Adjustment of questions to a higher value on the taxonomy of spatial thinking. (Based on questions in an examination for an entry-level Geography module. Used with permission)

Examples of questions	Value on the taxonomy of spatial thinking
Question 1: Name a country in the second stage of demographic transition.	7
Adjusted Question 1: Evaluate the population pyramid displayed in the figure. Then, explain the transition phase depicted in the demographic transition model. Name a country in this phase of demographic transition.  	23
Question 2: Describe global migration patterns.	19
Adjusted Question 2: Based on the map below, analyse and explain global migration patterns.  	23

Question 1 requires a student to recall and name a country in the second phase of demographic transition. The question could be interpreted as place-specific, uses no representation tool and is asked on an input level. This question has a value of 7 on the taxonomy of spatial thinking. Suppose the question is rephrased in such a way that a student needs to evaluate the population pyramid before explaining the answer. In that case, the question is pitched at a higher cognitive level in that a complex spatial concept and a representation tool are used. As a result, the value of the question in the taxonomy of spatial thinking changes to 23.

Question 2 requires a student to describe global migration patterns. This question includes a complex spatial concept (pattern), is asked on an input level and includes no tool of representation. Such a question has a value of 19. Should the question be rephrased as indicated in the adjusted question 2, the cell value increases to 23 on the taxonomy of spatial thinking.

2.3.3 The measurement of spatial thinking abilities

The spatial thinking ability test (STAT) is a standardised pre- and post-test for measuring spatial thinking abilities and integrates geographical and content knowledge with spatial skills (Lee & Bednarz, 2012). Spatial ability is defined as a person's ability to process spatial thinking (Cheng, 2016).

The STAT was developed to evaluate a person's growth in spatial thinking skills (Lee & Bednarz, 2012). These authors (Ibid) based the development of the STAT on a set of concepts identified by Gersmehl and Gersmelh (2007), Golledges (2008) and Goodchild and Janelle (2010). (These concepts are summarised in Table 2.2) Each concept from the list was used to develop test items to measure the components of spatial thinking.

The STAT consists of 16 multiple-choice questions. A pre-test and post-test were developed to determine a person's spatial thinking abilities over time. Furthermore, any one of these tests may be used to gauge the spatial thinking skills of an individual (Lee & Bednarz, 2012)

Tomaszweski et al. (2015) summarised the 16 questions posed in the STAT according to the eight spatial thinking components that are tested by the questions. Table 2.3 summarises the question numbers of the STAT according to the eight spatial thinking components. Tomaszeksi et al. (2015) describe the STAT as a 'rigorously evaluated, conceptually robust and thoroughly validated spatial thinking assessment device' which can, therefore, successfully determine a person's spatial thinking ability. Not all individuals may perform equally well in all aspects of the STAT.

Table 2.2: Geographical concepts used to develop the STAT.

(Lee & Bednarz, 2012:17).

Gersmehl and Gersmehl (2007)	Golledge et al. (2008)	Jannelle and Goodchild (2009)
Condition	Identity	Object and fields
Location	Location	Location
Connection	Connectivity	Network
-	Distance	Distance
-	Scale	Scale
Comparison	Pattern matching	-
Aura	Buffer	-
Region	Adjacency, classification	Neighbourhood and region
Hierarchy	-	-
Transition	Gradient, profile	-
Analogy	-	-
-	Coordinate	-
Pattern	Pattern, arrangement, distribution, order, Sequence	-
Spatial association	Spatial association, overlay/dissolve, interpolation, projection, transformation	Spatial dependence, Spatial heterogeneity

Some individuals perform well in certain aspects of the spatial thinking tasks (e.g. direction and orientation), while the same individuals may perform poorly in other aspects (e.g. the visualisation of 3-D images) (Lee & Bednarz, 2012). The result of the STAT is, therefore, not a pass or a fail as one would typically expect from an assessment, but rather an indication of the cognitive level at which a person can answer the questions successfully. It serves as an indication of components where spatial thinking skills need to be developed (Verma & Estaville, 2018). The application of the STAT to determine the spatial thinking abilities of students at selected South African universities is further discussed in Chapters 3 and 6.

Table 2.3: Spatial thinking skills measured by the STAT.

(Lee & Bednarz, 2012; Tomaszewski et al., 2015)

Question number	Spatial thinking component
1 and 2	Comprehending direction and orientation
3	Comparison of the map and graphic information
4	Selecting the best location when given several spatial factors
5	Visualisation of a slope profile from a topographic map
6 and 7	Connecting spatially distributed phenomena
8	Visualisation of 3-D images from 2-D images
9, 10,11 and 12	Overlaying and dissolving map layers
13,14, 15 and 16	Comprehending geographic features represented as points, lines or polygons

2.3.4 Disposition towards spatial thinking

Disposition is defined as a teacher's behaviour toward certain knowledge and skills to achieve teaching goals (Jo & Bednarz, 2014). Disposition is regarded as essential for effectively teaching spatial thinking and is equally important as well-organised teaching practices, curricula and teaching and learning materials (Ibid). A positive disposition toward including spatial thinking in Geography teaching and learning is not necessarily spontaneous and needs to be nurtured and developed through teacher training and awareness programmes (Lee et al., 2018).

Lee and Bednarz (2014) developed an assessment tool that can be used to determine the disposition of an educator toward spatial thinking. The assessment tool consists of 40 questions divided into categories of disposition: the teaching of thinking skills, the teaching of spatial thinking skills, the teaching of spatial thinking in Geography and the explicit teaching of spatial concepts, as well as the adoption of spatial representations and of geospatial technologies (Jo & Bednarz, 2014). The development of the disposition assessment tool fills in on the lack of research on educator dispositions (Jo, 2016; Jo & Bednarz, 2014; Lee et al., 2018). The importance of having a positive disposition toward teaching spatial thinking and applying the tool within this research is further discussed in Chapters 3 and 5.

2.4 Spatial thinking in Geography teaching and learning

Since spatial thinking plays an essential role in everyday life (National Research Council, 2006; Sinton, 2017), any degree offered in Geography should provide students with spatial thinking skills, abilities and knowledge. Furthermore, since spatial thinking can be taught to students by applying appropriately designed tools, technologies and curricula (Goodchild and Janelle, 2010), these researchers raise the important question as to why spatial intelligence has not been accorded the same level of importance in education as reading, writing and numerical reasoning (Ibid). Although spatial thinking can be taught to students, emphasis should be placed on problem-solving activities and not on traditional pedagogic approaches, such as repetition and memorisation (Metoyer & Bednarz, 2017). Employers are also seeking graduates with the ability to think about and critically analyse issues on scales ranging from the global to the local level. Research has, in fact, confirmed the importance of spatial thinking for a successful academic and career path (Wright et al., 2008). Indeed, spatial thinking enables students to better understand modules across curricula (Nursa'Ban et al., 2020).

The purpose of integrating spatial thinking in the teaching of Geography is to critically engage students with spatial thinking processes, develop a habit of spatial thinking and practise spatial thinking in the context of geographic knowledge (Ibid). There is also a strong link between spatial thinking and geographic thinking (Metoyer & Bednarz, 2017). Spatial thinking involves a combination of cognitive skills, such as understanding the concepts of space, applying tools of representation and engaging in the processes of analysis and reasoning. Geographic thinking extends beyond spatial thinking and includes the ability to comprehend and analyse relations among spatial phenomena, the interpretation of the associations determined from the relationships between the relevant phenomena and linking these associations with theories and generalisations (National Research Council, 2006). Recent research has provided supporting evidence that a higher level of spatial thinking is correlated with a higher level of geographic thinking (Metoyer & Bednarz, 2017). Geographic thinking requires spatial thinking, but spatial thinking does not necessarily require geographic thinking. Geographic thinking can be described as the application of spatial thinking to solve complex geographic problems or to understand geographic concepts (Metoyer & Bednarz, 2017). An example is to predict a change in crop yield because of a change in weather patterns. Recognizing complex concepts such as a change in weather patterns requires spatial thinking but not necessarily geographic thinking (Ibid).

Spatial thinking has been proven to be a critical skill for academic success in Geography, as well as in other sciences (Goodchild & Janelle, 2010; Wright et al., 2008). Geography is an academic subject that can effectively teach spatial thinking (Verma, 2015; Verma & Estaville, 2018). However, a desktop study performed by the researcher suggests that the inclusion of spatial thinking in the Geography curricula at South African universities has been inadequate. This observation provides the basis for the problem statement for this research.

2.5 The application and benefits of spatial thinking in different study fields

Spatial thinking is not only for geographers and should not only be included in Geography curricula. The general public increasingly uses spatial data, and specialised fields outside Geography have made it essential for spatial thinking to be included in various other application fields (Goodchild & Janelle, 2010). Spatial concepts such as generalisation, scale and pattern are seen as cross-cutting terminologies, thus overcoming the boundaries between these different application fields (Charcharos et al., 2016).

One application field where spatial thinking can play a crucial role is to improve on the pass rates in Science, Technology, Engineering and Mathematics (STEM) modules (Atit et al., 2020). The low student enrolment in STEM modules is a challenge worldwide (Sithole et al., 2017), and is experienced in South Africa as well (van der Merwe et al., 2020).

In terms of the teaching of spatial thinking, there is no 'one-size-fits-all' approach (Janelle et al., 2014). Compared to Geography, spatial thinking may have a different meaning and application in the STEM modules (e.g. Chemistry examines three-dimensional images on a micro-scale.) (Ibid).

While other modules such as those in Nursing, Criminal Justice, Education or Economics may aim to develop students' spatial thinking skills, they will not equal the competency in this regard that can be achieved by Geography students (Verma & Estaville, 2018). Therefore, non-Geography undergraduate students should be encouraged to take Geography modules to develop their spatial thinking skills for everyday use (Verma & Estaville, 2018).

2.5.1 The benefits of spatial thinking in other study fields

Various other application fields will also benefit from the teaching of spatial thinking skills; for example, experts in the fields of Geology, Chemistry and Surgery often work with the mental rotation of three-dimensional images (e.g. the mental rotations of atom and molecule structures used in Chemistry) and the relative locations of phenomena (e.g. the location of the kidneys relative to other organs), and complex problem-solving situations that require spatial thinking skills (Atit et al., 2020).

Sithole et al. (2017) suggest strategies for reducing dropout rates in STEM programmes. These strategies include orientation programmes, early warning systems to identify at-risk students and Mathematics review sessions. No reference is made to the importance of spatial thinking in improving the success rates of STEM modules. It has been shown that including the teaching of spatial thinking in the curricula positively affects the pass rate in the case of STEM modules (Uttal & Cohen, 2012). From a Mathematics teaching point of view, it has been proven that spatial thinking can be included in the proficiency strands of the curriculum to develop the spatial thinking skills of students (Fowler et al., 2019). Other fields related to STEM subjects that also report on the positive effect of spatial thinking include Astronomy (Cole et al., 2018), Landscape Design (in respect of the use of augmented reality) (Carrera and Asensio, 2017) and Chemistry (Stieff et al., 2020).

The development of a Geology workbook to intentionally improve students' spatial thinking skills has proved to be successful and has improved the overall pass rate of the students at the two universities in the USA that took part in the research (Ormand et al., 2017). In this case, the workbook focuses on improving the three-dimensional visualisations and mental rotations of advanced students in Sedimentology and Stratigraphy. The teaching tools that proved to be effective in developing students' spatial thinking skills included hand gesturing, predictive sketching, analogies and alignment (Ibid).

Spatial thinking is also a relevant tool used by social workers to assist them in problem-solving and exploring human relationships (Steiner et al., 2014). In addition, spatial thinking skills enable social workers to connect people with the environment (Ibid).

2.6 Summary

This chapter emphasises the importance of spatial thinking on a global and local scale in facing challenges in a rapidly ever-changing world. Within this ever-changing world, there is a constant need for changes in Geography curricula. These changes are driven by societal pressure, environmental challenges and students' demands. It is, therefore, essential for Geography curricula to remain current and to be updated regularly. The demand for change creates an opportunity to review Geography curricula and incorporate teaching methods that will improve the spatial thinking abilities of students. Although universities in South Africa are under the same pressure to change as in the rest of the world, initial research indicates that spatial thinking appears to be largely lacking in the Geography curriculum. Geography students must be provided with the opportunity to develop spatial thinking skills to solve the country's complex environmental, economic and societal challenges.

Having spatial thinking skills will allow students to understand spatial relationships among phenomena, to assess the quality of data and to use spatiality as a way of reasoning to solve complex problems. Geography teaching and learning should, therefore, move beyond the rote memorisation of facts and focus on the development of the spatial thinking skills of students.

Various research tools, such as the taxonomy of spatial thinking, the STAT and a tool to determine a lecturer's disposition toward teaching spatial thinking, have been developed by several researchers. These tools can be used to incorporate spatial thinking in Geography teaching and learning material and to motivate lecturers to include spatial thinking in the curricula of the modules taught by them. The application of these research tools, considered in conjunction with the complicated nature of spatial thinking and its inclusion in teaching and learning, the professional experience of the researcher and the perspectives of Geography lecturers, demonstrate the multifaceted nature of this research. To address this aspect, methodological pluralism has been accepted as a guiding principle for this research. A theoretical paradigm that provides a framework for methodological pluralism is Integral Theory. Chapter 3 focuses on Integral Theory as a framework for this research and includes an explanation of how it feeds into the methodology used to conduct this research.

Chapter 3: Theoretical and methodological framework

3.1 Introduction

The world we live in is complex and apparently becomes more complex and chaotic as researchers attempt to solve challenges such as environmental degradation, inadequate education systems, volatile financial markets and religious fundamentalism (Esbjörn-Hargens, 2010a). To understand, link and find solutions to these complex challenges requires many views, perspectives and investigations into numerous disciplines (Ibid). What is required within this complex world of challenges is a theoretical framework with a global vision grounded in the mechanisms and experiences of our daily lives (Ibid).

Through extensive research spanning more than three decades, Ken Wilbur has developed one such theoretical framework, namely Integral Theory, that recognises the world's complexity (Esbjörn-Hargens, 2009). Integral Theory represents an all-inclusive study of an aspect or aspects of reality. It includes insights from all of the leading disciplines of knowledge acquisition, such as the Arts, Humanities, and the Natural and Social Sciences (Esbjörn-Hargens, 2010a). Integral Theory is regarded as a framework that can be applied on a disciplinary, multidisciplinary, interdisciplinary and transdisciplinary level (Esbjörn-Hargens, 2006b). Owing to the relevance of Integral Theory within and across these disciplines, this theory has been applied in various fields, such as, to name a few, Social Transformation (Riddell, 2013), Education (Combs, 2009), Healthcare (Shea et al., 2019), Ecology (Esbjörn-Hargens & Zimmerman, 2009), Gender Studies (Poole, 2014), Business Management (Landrum & Gardner, 2012) and Professional Development (Klein, 2012).

The theoretical paradigm for this research is grounded in Integral Theory. Integral Theory contextualises the research by providing a framework for a holistic approach while informing the methodology that should be employed to reach the objectives set for the research (Esbjörn-Hargens, 2009). Integral Theory suits the complicated and interconnectedness of a teaching and learning environment that forms the focus of this research. A teaching and learning environment cannot be assessed with a view to develop a strategy for improvement within the constraints of one methodology or through only one worldview. To achieve this, various perspectives/lenses on spatial thinking will have to be adopted and integrated in this research, for which Integral Theory provides a suitable framework. Although Ken Wilbur initially developed Integral Theory, a number of articles and books have also been authored by Esbjörn-Hargens (Esbjörn-Hargens, 2005; Esbjörn-Hargens, 2007, 2010a, 2010b; Esbjörn-Hargens &

Wilber, 2008) The development of Integral Theory for this research is based on these publications.

This chapter explains the relevance of Integral Theory, and elaborates on the AQAL model (all quadrants, all levels, all lines, all states and all types) in detail. The reasons for choosing this model as a methodological framework are discussed and its application within this research context is described and illustrated. As informed by Integral Theory, each methodology used in the data collection and analytical processes for this research is explained in detail.

3.2 Theoretical framework: Integral Theory

Integral Theory is often referred to as the AQAL model (pronounced as ah-qwal) (Rentschler, 2006). AQAL refers to 'all quadrants and all levels of the model' (Esbjörn-Hargens, 2010a). Quadrants and levels are two of the five elements that inform Integral Theory. The other three elements include lines, states and types (Ibid). These five basic elements provide a contextually-free framework within which to conduct research and to ensure that all essential components of the research topic are covered and can be used to explore reality (Ibid). Integral Theory can organise and honour all the existing approaches to research while allowing the researcher to select the most applicable methodology relevant to a specific research field (Ibid). In the subsections that follow, each of the five elements comprising the AQAL model is explained, while the application of these elements in the context of this research is covered in Section 3.4 of this chapter.

3.2.1 The four quadrants of the AQAL model

At the most basic level, Integral Theory is informed by the "All Quadrants" (AQ) model (Esbjörn-Hargens, 2007). According to Integral Theory, there are four perspectives, namely, subjective, inter-subjective, objective and inter-objective, that should be considered in order to fully understand any issue at hand (Esbjörn-Hargens, 2010a). The quadrants further recognise that realism can be viewed from two perspectives, namely, an interior and exterior perspective and a singular and plural perspective, both representing aspects of reality that are always present at any moment (Ibid). All individuals have a subjective perspective or an experience of the real world (interior), as well as an objective perspective of the behaviour of others, observed from the exterior (Esbjörn-Hargens, 2010a). Individuals usually function as part of a larger group or collective (Ibid). The interior perspectives of these groups are known as inter-subjective perspectives, while the exterior perspectives are known as inter-objective perspectives (Ibid). The four quadrants and perspectives of the AQAL model are illustrated in Figure 3.1.

The four pronouns, namely, 'I', 'We', 'It' and 'Its' represent the four dimensions of the AQAL model (Esbjörn-Hargens, 2006b). The Upper Left (UL) quadrant represents the 'I', while the Upper Right (UR) quadrant represents the 'It' (Esbjörn-Hargens, 2010a). As such, the UL and UR quadrants represent a singular or individual perspective (Wilber, 2003). The Lower Left (LL) quadrant represents 'We', while the Lower Right (LR) quadrant represents 'Its'. As such, the LL and LR quadrants represent the plural perspective of the AQAL model (Ibid). In addition, each of the quadrants represents an inside and an outside view (Ibid). The inside view draws on the views and experiences of the individuals and groups, forming part of the phenomena under investigation. In contrast, the outside view is observed by individuals and groups not constituting part of the phenomena under investigation (Esbjörn-Hargens, 2010a). The interior and exterior perspectives and the singular and plural perspectives should be seen as the 'layers' of the AQAL model (Wilber, 2003).

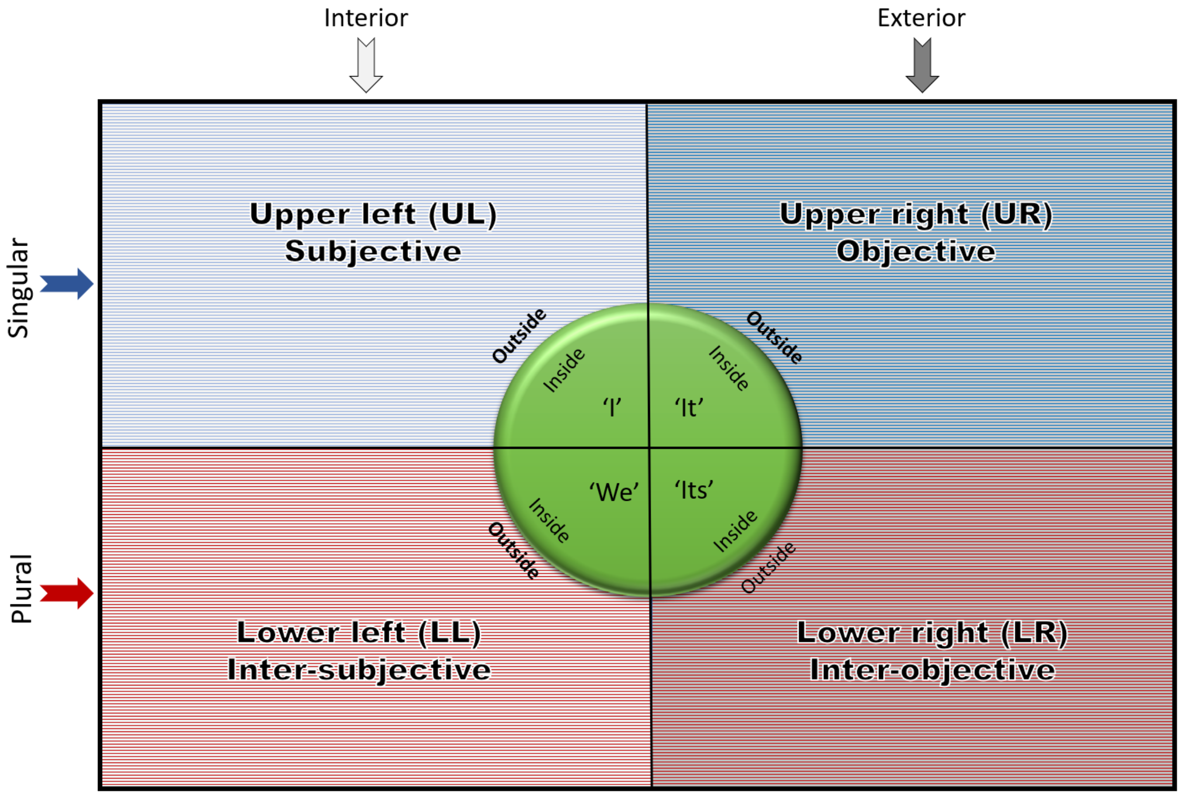


Figure 3.1: The four quadrants of the AQAL model.

(Adapted from Esbjorn-Hargens (2009) and Wilber (2003))

The interior and exterior perspectives and/or singular and plural perspectives should not be interpreted as clear-cut lines, but rather as different ways of seeing and interpreting reality, thus giving rise to different ways of observing reality (Davis, 2019a). Since the UR and LR quadrants are characterised by objectivity and the UL and LL quadrants are characterised by subjectivity, the four quadrants are also referred to as the three value spheres (Esbjörn-Hargens, 2010a). The three value spheres are called the spheres of subjectivity (UL) inter-subjectivity (LL) and objectivity (UR and LR) (Ibid). Figure 3.2 illustrates the three value spheres and their related characteristics, namely aesthetics and consciousness (UL), morals and culture ((LL), and nature and science (UR and LR).

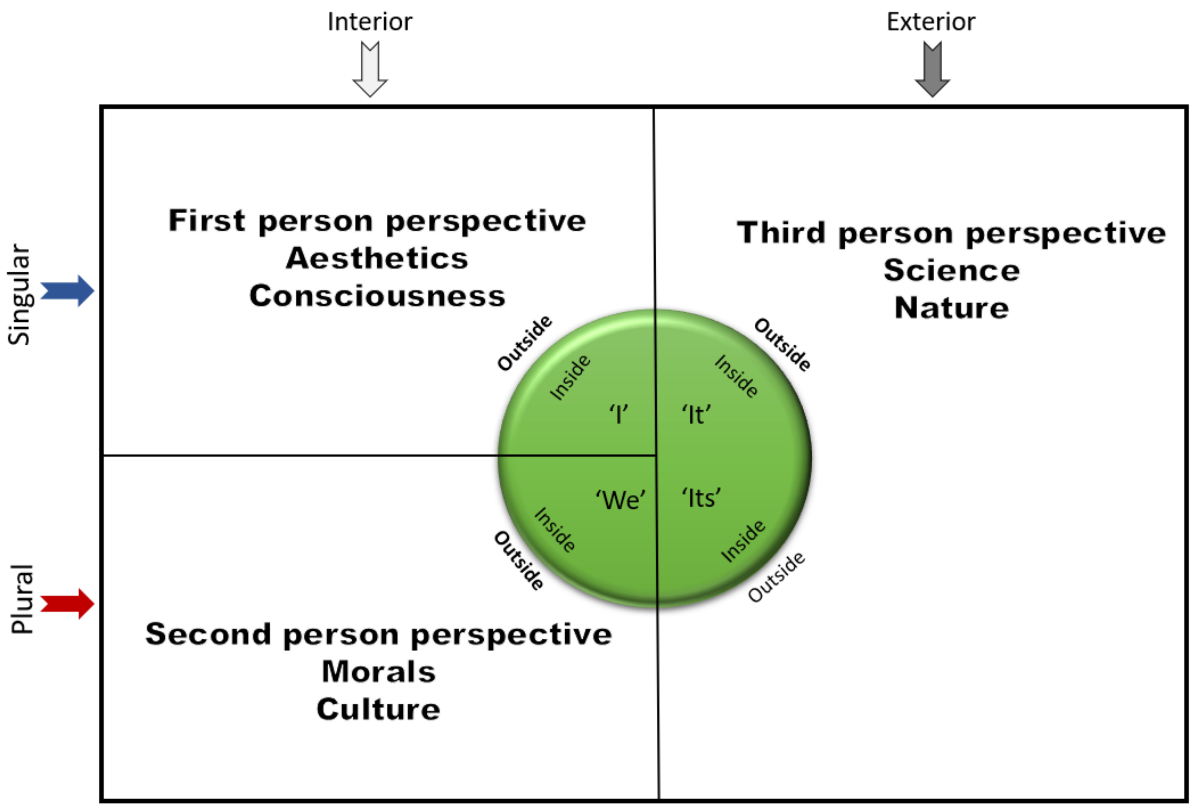


Figure 3.2: The three value spheres of the AQAL model.

(Adapted from: (Esbjörn-Hargens, 2010a)

According to Integral Theory, a specific reality (e.g. an objective reality) cannot be understood through the lens of any of the other realities (e.g. a subjective reality) (Esbjörn-Hargens, 2010a). It is important to realise that observing reality through an incorrect lens will lead to distorted results (Ibid). It is therefore necessary to consider the interior-exterior and individual-collective (singular-plural) perspectives together with the three value spheres, which create a matrix for drawing together perspectives and conclusions based on the various methodological approaches (Davis, 2019a)

This UL quadrant allows for data on the researcher's subjective view or the experience of the person participating in the research to be captured through a singular interior perspective (Esbjörn-Hargens, 2010a). (Refer to Figure 3.3) Data from this quadrant may be based on the researcher's expertise (inside view) or may be collected, for example through individual interviews (from an outside perspective) (Ibid). The LL quadrant represents an inter-subjective approach and implies a cultural or an agreed-upon way of carrying out tasks (Ibid). This quadrant represents a plural interior perspective. Data for this quadrant are often collected through focus group interviews conducted by the researcher (from an outside perspective) or through a known or an agreed-upon way of doing things (from an inside perspective) (Ibid). The UR quadrant suggests that data measured objectively using a known measurement instrument are associated with a singular, exterior perspective (Ibid). The data required to support this quadrant could be qualitative or quantitative and are usually collected through known and tested instruments (Ibid). The LR quadrant indicates a systems analysis approach. This quadrant incorporates a plural view with an exterior perspective (Ibid). Data in this quadrant are usually obtained through a systematic approach, as in the case of an ecosystem or economic system analysis.

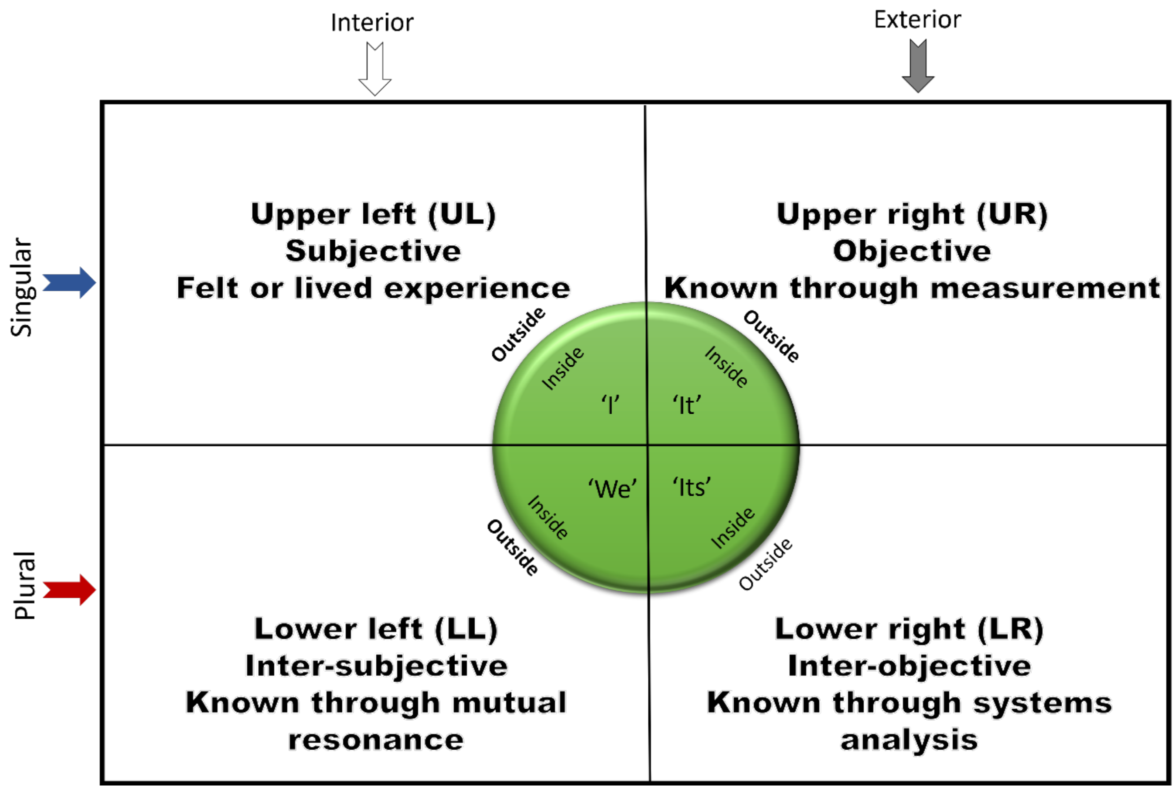


Figure 3.3: The four quadrants informing the methodology for the research.

Adapted from: (Esbjörn-Hargens, 2010a)

3.2.2 Quadrants and Quadrivia

The AQAL model can be applied in at least two ways, namely, in terms of dimensions or perspectives. If using the AQAL model in terms of dimensions, an individual is positioned where the quadrants coalesce at the centre. This is also referred to as the quadratic approach (Esbjörn-Hargens, 2010a). The researcher perceives the four quadrants through his/her experience, measurable methods, agreed-upon knowledge, or systems analysis (Ibid).

If using the AQAL model is in terms of perspectives, also referred to as the quadrivia approach, different perspectives are associated with each quadrant and directed at reality, which is placed at the centre of the quadrants (Esbjörn-Hargens, 2010a). In this way, the focus is placed on methodologies to investigate the realities that form part of the research (Ibid). The quadrivia and quadrants are intertwined and allow researchers to address complex challenges in a complex world (Ibid).

3.2.3 The levels, lines, states and types of the AQAL model

The AQAL model is further expanded by four additional elements: levels, lines, states and types (Esbjörn-Hargens, 2010a). This expanded model is referred to as the all-quadrant, all-level, all-line, all-state and all-type (AQAL) model (Ibid). The application of the expanded AQAL model ensures that research will attain the required level of profundity and be inclusive of all relevant perspectives (Esbjörn-Hargens, 2007).

Each quadrant has levels of development (Esbjörn-Hargens, 2010a). The interior left quadrants involve levels of profundity, and the exterior right-hand quadrants involve levels of complexity (Ibid). The levels represent the dynamic characteristics of reality and how respective realities perform under different circumstances (Ibid). The levels in the respective quadrants correlate with one another. The inclusion of levels is valuable and recognises that any reality domain has potential developmental layers (Ibid). The levels also demonstrate holarchy, meaning that each of the new levels of complexity surpasses the previous level's limits while including that level's essential characteristics (Ibid). The levels of the AQAL model recognise the layers of development within any domain of reality (Ibid). They are often illustrated as the 'contour lines' in a research project (Esbjörn-Hargens, 2010a). Lines could, for example, be represented by school years, such as grade 1, grade 2, grade 3, up to grade 12. Progressing through the various grades represents a level of profundity and a grade at a higher level that encompasses the previous level's limits and includes the essential characteristics of that level.

The lines of the AQAL model demonstrate different levels of depth or complexity (Esbjörn-Hargens, 2009). Furthermore, the lines illustrate how Integral Theory accommodates the contributions of many application fields and organises them in a useful way (Ibid). Lines also identify distinct aspects of each quadrant that demonstrate development and indicate sequential development (Ibid). This sequentially of development distinguishes lines from states or types (Esbjörn-Hargens, 2010a). A line has an identifiable series of stages that unfold in a particular order that cannot be skipped (Ibid). Lines are used as a diagnostic tool to ensure that aspects of phenomena are acknowledged and addressed (Ibid). Lines are illustrated as the 'path' one would follow through the contours (levels) (Esbjörn-Hargens, 2010a). Lines within the AQAL model could be represented by, for example, the methodological sequence to learn how to do Mathematics. After some basic knowledge is taught, a learner would learn how to summarise, subtract, multiply and divide numbers. The sequence of learning how to do Maths would represent the 'path' a learner would follow to move to a next grade or level (contour) to do more advanced Mathematics.

States are temporary occurrences of an aspect of reality (Esbjörn-Hargens, 2010c). States are incompatible with one another, meaning that only one state can be true at any one time. States are realities that may change at any given time (Ibid). Within the given example of Mathematics, a state could be represented by the ability of a student to give a correct answer. The answer (within the example of Mathematics) could only be correct or incorrect. Still, the ability of a student to do Mathematics may improve to provide correct answers that may have previously been incorrect.

The types included in the AQAL model represent various consistent styles in various application fields (Esbjörn-Hargens, 2010a). Types occur irrespective of the developmental levels. Types can overlap or they can be conflicting, but they generally remain stable and resilient (Ibid). Researchers should be aware of the types and the potential role these may play in the research (Ibid). Within the example of Mathematics at school level, types may be the teaching style of the educator. The educator's teaching style is, to a certain extent, independent of the grade/level or the combination of different teaching styles but may remain stable throughout a teaching year.

The use of levels, lines, states and types contributes to the researcher's understanding of the issue at hand and to the development of explanations for the relationships existing between the phenomena under investigation. (Clarke, 2019).

3.3 Integral Theory and related research

An integral approach to education is needed to encompass the totality of all aspects of the human experience (Combs, 2009). This notion can be extended to Geography as a holistic science that should be taught from different perspectives to incorporate socioeconomic circumstances, cultural and traditional backgrounds and belief systems (Pretorius, 2017). In addition, Geographers use maps to understand the world's interconnectedness (Haigh, 2013). Integral Theory provides an alternative mapping technique that offers a new perspective in understanding viewpoints and worldviews (Ibid). Therefore, Integral Theory has been successfully implemented as a methodological framework in various research studies in an educational context in Geography and related fields of study such as Ecology (Davis, 2019b; Esbjörn-Hargens, 2006a; Murray, 2009), and will be briefly discussed in this section.

Integral Theory is based on the notion that everything contains an element of truth (Esbjörn-Hargens, 2010a). This encompassing approach makes a constructive contribution to the development of mixed methods research by introducing a multi-method approach referred to as Integral Methodological Pluralism (IMP) (Esbjörn-Hargens, 2006b). IMP should not be confused or used interchangeably when referring to mixed methods research (Davis, 2019b). While mixed methods research focuses on qualitative and quantitative ways of collecting data, it is often executed from an outside ("It" or "Its") perspective. IMP, as implemented in Integral Theory, may include a mixed methods approach but could also be performed from the 'inside' ("I" and "We") perspective. IMP is therefore not only about qualitative and quantitative methods but also about perspectives and views from an inside (e.g. experiences of the researcher and participants) or an outside (observed or measured phenomena) perspective.

Davis (2019b) applied Integral Theory to survey the range of research attitudes and methodologies emanating from educational research. This research by Davis (2019b) demonstrates the different ways research foci are perceived and the methodological distinctions necessary for addressing different research attitudes . It also focuses on educational research at a graduate level (Ibid).

Murray (2009) discusses Integral Theory as a model, method, community and developmental stage in his research on Integral education. He elaborates on the developmental levels as consisting of awareness levels, including contract awareness, ego awareness, relational awareness and systemic awareness, which are essential to the educational process (Murray, 2009). Murray (2009) proves that a teacher with an integral perspective on human development is a stronger proponent of progressive pedagogies and proposes new ways of offering lectures in a classroom and approaching the educational process.

Esbjorn-Hargens (2006) demonstrates that educators could apply Integral Theory to develop their educational practices to the benefit of their students. This refers to the case where integral Theory was used to rethink and redevelop a graduate programme curriculum in psychology (Esbjörn-Hargens, 2006a).

Integral Ecology was developed from Integral Theory to express, represent and understand the world from various perspectives (Esbjörn-Hargens, 2005). Various approaches to ecological and environmental problem solving, such as philosophical, spiritual, religious, social and political, exist. While each of the approaches highlights essential components within the respective study fields, it does not cover all the available perspectives emanating from Integral Theory. Integral Ecology was therefore developed to provide a way to encompass all the different approaches into one framework and allows for a comprehensive understanding to address different perspectives as an essential component in solving ecological and environmental problems (Esbjörn-Hargens, 2005)

Students should learn how to think and perceive the world differently and from various perspectives (Esbjörn-Hargens, 2007). Integral Theory provides an effective template to design pedagogy, classroom activities, evaluations, courses and curricula by incorporating the five elements of the quadrants, levels, lines, states and types of the AQAL Integral Teacher, Integral Student and Integral Classroom, with the development of all being based on Integral Theory. By implementing these models, an instructor will include all essential aspects of an educational space. Integral Education has also been developed on the basis of Integral Theory. Educators can use Integral Education to assess themselves, their students and their courses. Integral Education creates a multidimensional learning environment that brings students and educators into a fuller engagement with the major aspects of reality.

Integral Geography is a way of addressing the geographical questions of "when?" and "where?". Adding Integral Theory to maps may present an interesting alternative way of communicating different perspectives when examining issues of globalisation, sustainable development, geopolitics and diversity (Eddy, 2005). Geographers can apply Integral Theory to examine phenomena on various scales and from different perspectives. Integral Geography explores awareness and realisation from a geospatial perspective to examine how space and place can affect an individual. Eddy (2005) illustrates this with the example of a GIS model that was used to construct Integral Places from anthroposophic, biospheric and cosmospheric information. Integral Geography therefore adds to Integral Theory by suggesting that consideration be given to the 'locational' dimension of AQAL for many of its applications (Ibid).

Integral Theory lends itself to studies in an educational environment where research results are influenced by a spectrum of observations, experiences and perspectives. For challenges such as globalisation, ecology and environments, security and foreign policy, to name but a few, Integral Theory provides different approaches for educators to understanding themselves in relation to the world, and which they can incorporate into their teaching. (Eddy 2005)

3.4 Methodological framework: Positioning this research in the AQAL model of Integral Theory

Integral Theory is particularly suitable for dealing with the complexity of this research, which involves multiple perspectives and views from students, lecturers and the researcher. It provides a suitable methodology for the balanced inclusion of qualitative and quantitative data, the systematic consideration of both subjective and objective experiences and inside and outside perspectives, to attain the aim of this research. The methodology used in this research varies from an analysis of the perspectives of Geography lecturers to the outcomes of quantitative tests (such as the taxonomy of spatial thinking and the STAT) completed by the students and the perceptions of the researcher, who has extensive experience in the field of GST in higher education.

The methodology used for data collection in this research flows from the AQAL model, which is at the centre of Integral Theory. For this section, each research objective was considered against the requirements of the four quadrants to determine the best possible fit and the associated choice of the data collection instruments to be used. Figure 3.4 summarises how the AQAL model informs the methodology to be used for data collection in this research.

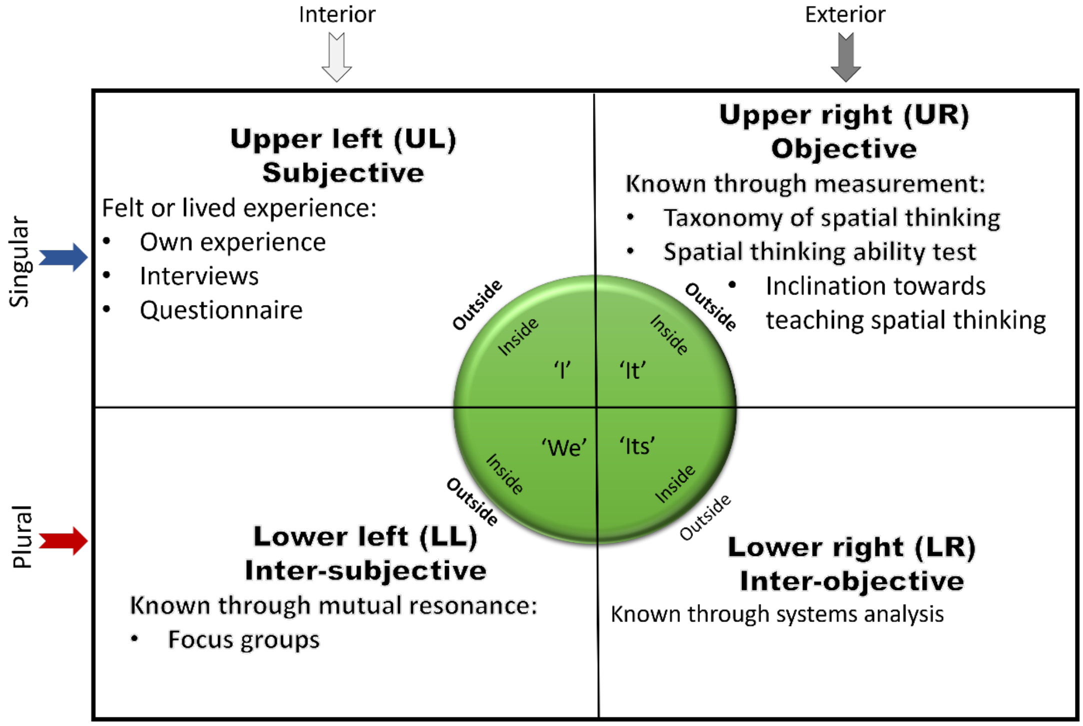


Figure 3.4: Methodologies informing the research.

The methods used for this research are in the UL, UR and LL quadrants of the AQAL model. The three quadrants used for this research (UL, LL and UR) satisfy the requirements for the application of the AQAL model and provide for an adequate representation of reality from the first, second and third perspective (Esbjörn-Hargens, 2010a). The LR quadrant, representing an inter-objective perspective that is usually measured through systems analysis, does not form part of the research methodology. The lower LR quadrant implies a phenomenon to be investigated through an exterior, plural perspective. This quadrant requires the researcher or participants to view the object/phenomenon from an exterior perspective, which is difficult to achieve in teaching and learning. Every person participating in the teaching and learning experience would also have an interior subjective view of the issue. The following subsections explain the different perspectives and methods for data collection informed by the AQAL model for this research. To ensure that the research reaches the required level of profundity, and all required aspects and views are incorporated into the model, the four quadrants are further informed as set out in the following paragraphs by levels, lines, states and types.

Levels: In this research, the National Qualifications Framework (NQF) levels 5, 6 and 7 represent the levels of development of the AQAL model. The NQF levels are suitable for representing levels of development since they represent the levels of profundity and complexity that are required by the AQAL model. These levels intensify as a student proceeds to a higher NQF level, thus indicating a correlation between the respective NQF levels and the level of complexity in the AQAL model. The NQF levels also demonstrate holarchy as the work covered by the higher NQF levels and include the work already covered by the lower NQF levels. The NQF levels represent the 'contour' map for this research.

Lines: In this research, the taxonomy of spatial thinking is applied in terms of the lines of the AQAL model. The taxonomy of spatial thinking demonstrates levels of complexity (in this specific instance – spatiality). The taxonomy of spatial thinking is a diagnostic tool that measures the level of development (inclusion of spatial thinking) in the modules offered on subsequent NQF levels. The taxonomy of spatial thinking represents the complexity level of spatial thinking for each NQF level and the 'path' that should be followed when progressing through the NQF levels (the contour map).

States: In this research, the states of the AQAL model are represented by a lecturer's disposition towards the teaching of spatial thinking. Only one state can be true at a time: a lecturer has either a positive or a negative disposition towards teaching spatial thinking; however, this disposition may change at any given time. The disposition towards spatial thinking influences the inclusion of spatial thinking by a lecturer in his/her course material (the lines of the AQAL model).

Types: In this research, the consistent styles of the AQAL model are represented by the different application fields of the modules. The application fields include Human Geography, Physical Geography and Geospatial Applications. An integrated approach may consist of aspects of Human Geography and Physical Geography and may include components of Geospatial Applications. The application fields occur irrespective of the NQF level and are, therefore, independent of the developmental levels. The application field offers a stable pattern within the presentation of the module. A lecturer's approach to teaching the different application fields is an important consideration if spatial thinking is to be included in the module in question. An approach common to Human or Physical

Geography may be offered with more focus on a specific topic. It may or may not include tools, such as GIS, remote sensing techniques and other GSTs, that may potentially be used to teach spatial thinking. In an integrated approach, it might be more likely for the tools to be incorporated into the course material as opposed to a disciplinary approach.

3.4.1 Methodology to achieve Objective 1

To achieve Objective 1, namely, to determine the extent and nature of the incorporation of spatial thinking into the syllabi of undergraduate Geography modules, all universities in South Africa that offer undergraduate Geography modules first had to be identified. Secondly, the description of each Geography module had to be scrutinised to identify the modules and departments that might potentially contribute to this research. These specific Geography departments were contacted and invited to participate in this research and were requested to provide the researcher with the outcomes of their respective identified modules. Thirdly, the spatiality of the module outcomes had to be determined using the taxonomy of spatial thinking. The modules presenting with the highest level of spatiality for their outcomes were then chosen to form part of the research. The focus of this research was specifically on modules offered on NQF levels 5, 6 and 7 and anticipated to include spatial thinking, based on the high level of spatiality for their outcomes. The methodology to collect the data required to achieve this objective was positioned in the UL and UR quadrants of the AQAL model, thus allowing for a singular view with an interior and exterior perspective. (Compare against Figure 3.2.)

Data collection and analysis

To address the first part of this objective, the researcher investigated the websites of all universities in South Africa to determine whether they offer Geography modules. The list of universities in South Africa was obtained from the website of the Department of Higher Education and Training (DHET, 2020) and UniRank (*UniRank*, 2020). The name of the university, the name of the department offering Geography, and all the Geography modules offered on NQF levels 5, 6 and 7 were recorded in a spreadsheet. The focus field within which these modules are offered was also recorded.

The methodology used for this initial identification of the universities offering Geography was in the UR quadrant of the AQAL model since the offering (or not) of Geography is an objective perspective that can be measured. This assessment was conducted by the researcher from an outside ('It') perspective.

The second part of this objective was addressed through the researcher's subjective assessment of each module description by comparing it against phrases from the literature that would be indicative of the inclusion of spatial thinking. The evaluation of the module descriptions to determine whether spatial thinking would potentially be included in the module in question was, therefore, located in the UL quadrant of the AQAL model with an outside ('I') perspective.

Purposeful sampling was undertaken by scrutinizing the course description of each module to identify those modules per department from NQF levels 5, 6 and 7 that might potentially include spatial thinking as part of the teaching and learning process. Modules with descriptions directly or indirectly indicative of spatial thinking, were selected. The module descriptions might also include phrases such as 'on different scales', 'using maps or images', or might refer to an applied component of spatiality (Lee & Bednarz, 2012; Bearman et al., 2016; Collins, 2018b). Keywords indicating that spatial thinking might be incorporated in syllabi included references to the ability to solve problems in an unfamiliar context, to identify information required to address challenges, and with specific mention of or reference to the use of technology and the ability to work in a team (Bednarz, 2019; Jo & Bednarz, 2011).

Some of the modules listed their outcomes as part of the module description. If the study outcomes were available on the internet, one module per NQF level was identified to constitute part of this research. If the module outcomes were not available online, two modules per NQF level that might include spatial thinking were identified for further investigation. The heads of each identified department were contacted and invited to participate in this research. The departmental heads or lecturers were requested to provide the researcher with the study guides containing the module outcomes.

As a final step, an evaluation of the module outcomes against the taxonomy of spatial thinking was conducted to select a module per NQF level for each identified department that could best contribute to this research. Although the taxonomy of spatial thinking is a known and tested instrument, the interpretation of spatiality was partially based on the researcher's subjective view. The evaluation of the module outcomes against the taxonomy of spatial thinking was, therefore, located in both the UL and UR quadrants of the AQAL model and presented a singular interior perspective from an outside view, in other words 'I' while the UR quadrant presented a singular exterior perspective from an outside view ('It') (Compare against Figure 3.2.).

3.4.2 Methodology to achieve Objective 2

This objective aimed to critically assess, firstly, the methods used by lecturers to convey the content of modules to foster the spatial thinking abilities of students and, secondly, the disposition of the lecturers to include spatial thinking in their teaching of Geography content. To achieve the first part of the objective a further in-depth study of the Geography modules identified in Objective 1 was conducted through interviews with the lecturers. The information collected during the interviews was assessed against the taxonomy of spatial thinking, as developed by Jo and Bednarz (2009). To achieve the second part of this objective a questionnaire was completed by the interviewed lecturers to determine their disposition towards teaching spatial thinking. Since the data were collected through interviews, the methodology used to address this part of the objective is positioned in the UL quadrant of the AQAL model. Furthermore, because the taxonomy of spatial thinking and the questionnaire used to gauge the disposition of lecturers towards spatial thinking are existing tested tools, this part of the objective is located in the UR quadrant of the AQAL model. The assessment of how the module content is conveyed against the taxonomy of spatial thinking was also partially based on the researcher's experience, thus implying a positioning in the UL quadrant (Compare against Figure 3.2).

Data collection and analysis

The first part of this objective aimed to obtain insight into the methods and support material used by lecturers to convey the course content to students to determine the effectiveness of implementing spatial thinking in a Geography syllabus/module. The research required in attaining this objective involved a qualitative study in the form of interviews with the selected lecturers on NQF levels 5, 6 and 7. An understanding of the content of the modules and how the content is conveyed to the students would indicate whether students would have the opportunity to effectively acquire spatial thinking capabilities (instead of merely being exposed to Geography and GST, and other tools of representation).

Each lecturer responsible for the modules identified in Objective 1 was invited to an online interview. The purpose of the interviews was to critically assess the extent to which spatial thinking is included in how the module content is conveyed by the lecturers in the identified undergraduate Geography modules and whether it is incremental and in line with the respective NQF levels. The interview questions were based on the underlying theory of what spatial thinking is and whether the lecturer incorporates the basic concepts of spatial thinking (the concepts of space, the tools of representation and reasoning processes) into his/her lectures. The purpose of the interview was to firstly determine indirectly whether, either consciously or subconsciously, a lecturer includes spatial thinking in his/her method of teaching and then to move on to more direct questions. The questions posed during the interview were open-ended and gauged the experience of the lecturer, and, in an indirect way, the inclusion of spatial thinking in the course material. (Refer to Annexure B for the questions posed during the interviews.) During each of these online interviews, the study guide, assignments and examination papers for the modules under discussion were requested from the lecturers.

Secondly, the lecturers also completed a questionnaire developed by Jo and Bednarz (2014) to determine their disposition more particularly towards teaching spatial thinking but also to allow for comparative studies. According to Jo (2016), this questionnaire is the only tool currently available to determine a person's disposition towards teaching spatial thinking. It consisted of 40 questions that were subdivided into five categories to determine an individual's disposition toward the teaching of thinking skills (Questions 1-7), of spatial thinking skills (Questions 8-14), and of spatial thinking in Geography (Questions 15-20). Furthermore, it also investigated the explicit teaching of spatial concepts (Questions 21-31) and the adoption of spatial representations and GSTs to convey content to students (Questions 32-40) (Jo & Bednarz, 2014). The answers were indicated on a Likert scale ranging from 1 to 5 (1 = strongly disagree, 2 = disagree, 3 = neutral or do not know, 4 = agree, 5 = strongly agree). The questionnaire also included five counter statements, namely, Questions 4, 11, 15, 16 and 34. These counter statements ensured that participants would pay attention when completing the questionnaire and would filter their contradictions into responses (Ibid). (Annexure C contains the questionnaire completed by the lecturers.)

The interviews conducted with the lecturers were grounded in the subjective view of the lecturers and are thus located in the UL quadrant of the AQAL model. The lecturers responded to the interview questions based on their experiences and preferences when teaching Geography modules. The interview responses were analysed and interpreted, also in terms of the researcher's experience, which therefore added a subjective element to them. As such, this methodology was found to present a singular, interior perspective with a view from both the inside ('I') - by lecturers - as well as the outside ('I') - by the researcher (Compare against Figure 3.2.). The assessment of the interviews against the taxonomy of spatial thinking is partially located in the UR quadrant - because a tested instrument was used - and partially in the UL quadrant – because the assessment was also based on the researcher's experience. Because the questionnaire completed by the lecturers to determine their disposition towards spatial thinking is in fact a tested tool that is in the UR quadrant of the AQAL model, this method provided a singular exterior perspective as viewed by the researcher from the outside (It).

3.4.3 Methodology to achieve Objective 3

Objective 3 critically reflects on the spatiality of the questions posed in formative and summative assessments and the spatial thinking capabilities of undergraduate Geography students at a selection of South African universities. To achieve Objective 3, the spatiality of the questions posed in formative and summative assessments had to be determined, and the spatial thinking skills of students at the selected South African Universities had to be gauged.

The research to address this objective is positioned in the UR and UL quadrants of the AQAL model. Since a known instrument was being used, the evaluation of the formative and summative assessments against the taxonomy of spatial thinking implies positioning in the UR quadrant. The interpretation of the questions and the measurement of the spatiality of the questions was also partially based on the researcher's experience, implying positioning of this part of the research to achieve the objective ed in the UL quadrant . Because the spatial thinking skills of students were assessed with the STAT, which is a quantitative instrument, the research for this part of the objective is positioned within the UR quadrant of the AQAL model. Given these research approaches, Objective 3 provided for both an exterior and an interior singular perspective. (Compare against Figure 3.2.)

Data collection and analysis

Questions asked in the formative and summative assessments were compared against the elements of the taxonomy of spatial thinking, namely the concepts of space, the processes of reasoning and the tools of representation. Only the assessments from 2019 to 2021 were considered in this research. The results of the evaluation of the assessment questions against the taxonomy of spatial thinking were captured in a spreadsheet. The words or phrases indicating the concepts of space and the processes of reasoning for every question were recorded in the spreadsheet. Should representation tools, such as a map, graph, GST, or diagram, have been used in posing a question, or a student have been asked to do an illustration or diagram, this would also have been noted. The gathered data on the concepts of space, the processes of reasoning and the tools of representation were then used to assign a unique value to each question to indicate its spatiality. The marks allocated to each question counting towards the final mark of the assessment were also captured to calculate a weighted contribution for each question. The type of question asked was also noted in the spreadsheet. These include straight forward MCQs (multiple-choice questions), MCQs based on scenarios, and scenario-based questions but which are not MCQs. Straight forward MCQ questions include all questions where students had to choose the correct answer from a list of predefined answers.

According to the taxonomy of spatial thinking, the values allocated to each question were nominal (descriptive), representing the difficulty and complexity of the questions in the assessments. Since spatiality is a nominal value, the statistical methods that could be applied to determine patterns or trends in the data set were, therefore, limited. Since nominal values are generally used to determine the frequency of the values recorded through the taxonomy of spatial thinking and to indicate the level of complexity of the module outcomes and assessments, the results showed the following: the number of spatial questions identified, the increasing complexity per NQF level, the use or non-use of the tools of representation, and whether the three concepts of spatial thinking were sufficiently integrated into the questions to contribute towards the development of the student's spatial thinking skills. The results were also compared against the spatiality of the module outcomes to determine whether the assessment questions aligned with the spatiality of the module outcomes.

The taxonomy of spatial thinking is a known and tested instrument and is, as such, located in the UR quadrant of the AQAL model. However, the evaluation of the questions against the taxonomy of spatial thinking is also partially subjective and based on the researcher's experience. The assessment of the questions against the taxonomy of spatial thinking is, therefore, located in the UL and UR quadrants of the AQAL model, thus presenting with an outside ("I") and ("It") perspective (Compare against Figure 3.2).

The STAT, as developed by Lee and Bednarz (2012), was used to gauge the spatial thinking capabilities of NQF levels 5, 6 and 7 students, who had completed or were in the process of completing the identified undergraduate Geography modules. The STAT was adjusted to reflect South African scenarios and examples (Example questions of the adjusted STAT is included in Annexure D.). Permission was obtained from the developers to reproduce and adjust the STAT. (Refer to Annexure E.)

The lecturers of the modules constituting part of this research were requested to provide their students with a link to an online version of the STAT. Once the students had completed the STAT, the online responses were returned to the researcher. This method ensured that the researcher had no contact with the participants. Although the name of the university and the NQF level of the student were recorded, the completed STAT returned to the researcher were anonymous.

The responses to the STAT were evaluated and the results were differentiated into maximums, minimums and average scores per NQF level, gender and other GST modules possibly completed by the students. SPSS was used to perform several t-tests to determine whether there were significant differences between the results per NQF level, gender and students who had completed GST modules as opposed to students who had not completed GST modules. Although only students who had studied the identified modules on NQF levels 5, 6 and 7 were invited to complete the online STAT, the results of the STAT might also have been influenced in some way by other modules that the students had completed in other departments. The influence that other completed modules might have had on the results of the STAT could not be ignored but neither could they be controlled. Should the results of the STAT have indicated, for example, that the students do in fact have high level of spatial thinking capabilities and that the concept of spatial thinking is incorporated into the Geography modules, the deduction would then be that the students could have learned to think spatially in the identified Geography module or in any other module that they had completed at university.

However, should the results of the STAT have indicated that the students generally present with limited spatial thinking capabilities, this might have been an indication that the Geography module has not effectively developed their spatial thinking skills or that the students have not made use of the opportunities emanating from the teaching material and presented during lectures and/or practicals to develop their spatial thinking capabilities.

Since the STAT is a known and tested instrument, this methodology is positioned in the UR quadrant. This objective view of the research results is associated with an outside ('I') perspective (Compare against Figure 3.2.).

3.4.4 Methodology to achieve Objective 4

The development of the strategy for improving spatial thinking in undergraduate Geography modules was based on the findings obtained through the achievement of Objectives 1, 2 and 3. What these findings provided was an indication as to whether the current students are sufficiently capable of thinking spatially and whether spatial thinking has been effectively included in the syllabi and offered in an incremental way and according to the NQF levels. The detailed study and interviews with the lecturers provided an indication as to how spatial thinking is taught on the various NQF levels and point towards good practices and the current limitations that need to be addressed. The envisaged strategy, built upon and integrated into the findings of this research, provides pointers towards improved spatial thinking and a structure within which this can be achieved in undergraduate Geography modules and their syllabi in South Africa.

Once the initial strategy for improving spatial thinking in undergraduate Geography modules had been developed, a feedback session in the form of focus groups was conducted with the lecturers from the departments which had participated in the research. (Refer to Annexure F for an outline of the feedback sessions.) The feedback from the lecturers was included in the final strategy for the improvement of spatial thinking in undergraduate Geography in South Africa. Since the focus groups presented with an inter-subjective perspective, they are in the LL quadrant of the AQAL model and are thus associated with a plural interior perspective. Because the discussions in the focus groups between the researcher and the lecturers were conducted to reach mutual consensus for devising a strategy to improve the spatial thinking of undergraduate Geography students, both an inside and an outside perspective were at stake ('We') (Compare against Figure 3.2.).

3.5 Summary

Integral Theory is one of a few theoretical frameworks that does not shy away from the complexities of real-world challenges. By applying the AQAL model, it was possible to achieve a holistic view of a teaching and learning environment that cannot be assessed with one methodology or one worldview only.

The AQAL model was applied to inform the methods used to collect the data required for this research. These methods included interviews and the application of existing well-developed instruments, such as the taxonomy of spatial thinking, the STAT and a tool for measuring the disposition of lecturers towards their teaching of spatial thinking. Focus groups were also conducted to incorporate feedback and the views of the lecturers to ensure that an appropriate strategy to improve the inclusion of spatial thinking in undergraduate Geography modules could be developed.

The inclusion of all five of the elements of the AQAL model, namely, quadrants, levels, lines, states and types, ensured that the research reached the required level of profundity and that it would be inclusive of all relevant perspectives on the phenomena under investigation. The three NQF levels were used as the respective levels of development, and the taxonomy of spatial thinking represented the lines of complexity within the levels of the AQAL model. The disposition of the lecturers was used to represent the different states, while the application fields of Geography were used as the different types within the AQAL model.

Chapters 4, 5 and 6 discuss the application of the methods which have been identified in this chapter to determine how spatial thinking is included in Geography syllabi, the way in which module content is conveyed to the students, the disposition of lecturers towards teaching spatial thinking and the spatial thinking abilities of students.

The next chapter, Chapter 4, focuses on Objective 1 namely to determine the extent and nature of the incorporation of spatial thinking into current undergraduate Geography teaching at the selected South African universities.

Chapter 4: Exploring the nature of undergraduate Geography in South Africa

4.1 Introduction

More than a century ago, the first Geography department in South Africa was established at the University of Stellenbosch (Visser et al., 2016). Since then, Geography has grown into a strong discipline in South Africa and is currently offered at 18 South African universities. These departments developed along more-or-less the same historical lines which shaped the discipline's development to its current status. The latest development that has significantly influenced the higher education landscape is the call for the transformation, decolonisation and Africanisation of modules and syllabi globally and locally (Knight, 2018; Esson, 2020; Fritzsche, 2021; Moorman et al., 2021). This call has undoubtedly had a major influence on changes made to Geography modules and syllabi in South Africa (Knight, 2018; Dianne Long et al., 2019). In addition, there are also calls for Geography education to focus more on sustainability (Meadows, 2020; Pretorius, 2017) and Environmental Science (Sandham & Retief, 2016).

Various research projects highlight the challenges, opportunities and gaps within the curricula offered by Geography departments in South Africa (CMoloi et al., 2017; Golightly & Muniz, 2013; Malatji & Singh, 2018; Moolman & Donaldson, 2016). One critical gap identified is the lack of research regarding the integration of spatial thinking into the Geography curriculum (Pretorius, 2018). Although the challenges facing South African universities are comparable to those facing international universities, more research on spatial thinking has been conducted internationally than in South Africa.

This chapter commences by providing a general background to clarify the contexts within which Geography departments function in the South African higher education system. The focus then shifts to the nature of the current offering of undergraduate Geography modules at South African universities. The outcomes of Geography modules offered by universities on NQF levels 5, 6 and 7 were obtained and scrutinised in a preliminary way to determine whether it can be expected that spatial thinking is integrated into these modules. The modules thus identified pointed towards Geography departments that could contribute to this research, and which could then be invited to participate. The outcomes of the selected modules for these departments were evaluated against the taxonomy of spatial thinking, and the results of this evaluation are presented, analysed and discussed in this chapter.

In terms of the methodological framework for this research, the process which was followed to identify modules that might include spatial thinking and to evaluate the module outcomes against the taxonomy of spatial thinking is positioned in respectively the UL and UR quadrants of the AQAL model and these modules are assessed from both an interior ("I") and an exterior ("It") perspective.

4.2 Background: South African universities and qualifications

The South African university system plays an essential role as the frame of reference in developing higher education governance, policies and policy instruments in many sub-Saharan countries (Andreadakis & Maassen, 2016). South African universities also demonstrate a strong commitment to serve communities effectively and fittingly - from the local to the global (Ibid). When discussing the governance of higher education in South Africa, the influence of the Apartheid (segregation) era cannot be ignored (Andreadakis & Maassen, 2016). After the dawn of democracy in 1994, the government published a White Paper in 1997 to overcome implied inequalities and inefficiencies, which are believed to be the legacies of Apartheid (Ibid).

South Africa hosts 26 higher education institutions (DHET, 2020; *UniRank*, 2020), 25 of which are residential higher education institutions, and one of which is an open distance learning institution. In addition, South Africa hosts several Technical and Vocational Education and Training (TVET) colleges and private universities (DHET, 2020). The Department of Higher Education and Training (DHET) manages and coordinates funding, policies and the regulatory framework for public universities in South Africa (DHET, 2020).

All modules and qualifications offered by public or private higher education institutions in South Africa must be registered with the South African Qualifications Authority (SAQA) (SAQA, 2020). SAQA is, amongst others, responsible for implementing the National Qualifications Framework (NQF) (Ibid). All programmes leading to formal qualifications that are registered on the NQF are quality-assured by the Higher Education Quality Council (HEQC) (SAQA Glossary, 2017). The NQF is a system consisting of three coordinated Qualifications Sub-frameworks, namely, General and Further Education and Training, Higher Education, and Trades and Occupations (Ibid). The Higher Education Qualification Sub-framework comprises NQF levels 5, 6, 7, 8, 9 and 10 and relates to different exit levels that can be obtained at tertiary institutions. The NQF levels and the type of qualification that can be obtained at each level when studying at a tertiary institution in South Africa are summarised in Table 4.1.

NQF Level 5 represents the first year of study at a tertiary institution, NQF Level 6, the second year, and NQF Level 7, the third year of study. After successfully completing a qualification on NQF Level 7, a student will obtain a Bachelor's degree (NQF levels, 2017). Credits are assigned to each module when a module is registered on the NQF. One credit is awarded ten notional hours. The number of notional hours is the estimated time it will take a student to achieve the specified module outcomes. The number of notional hours is not a precise measurement of how long it will take to complete a module but rather an indication of the commitment expected from the student to complete the module successfully. A bachelor's degree on NQF Level 7 comprises at least 360 credits (3 600 notional hours).

This research focuses specifically on undergraduate Geography modules on NQF levels 5, 6 and 7, as presented by the 26 public universities in South Africa. The section that follows provides a brief description of the growth and development of the Departments of Geography at some of the 26 public universities in South Africa.

Table 4.1: Summary of Higher Education Qualifications Sub-framework.

(Based on NQF Levels (2017))

Qualification Sub-framework	NQF Level	Qualification Type	
Higher Education Qualifications Sub-framework	5	Higher Certificate	Focus of this research
	6	Diploma Advanced Certificate	Focus of this research
	7	Bachelor's Degree Advanced Diploma	Focus of this research
	8	Bachelor's/Honours Degree Postgraduate Degree	
	9	Master's Degree	
	10	Doctoral Degree	

4.3 The historical development of undergraduate Geography in South Africa

Since the DHET manages the public universities in South Africa (DHET, 2020), the Geography departments at these universities have all developed along more-or-less the same historical lines. The changes in the curricula of the various Geography departments have also been influenced by more-or-less the same historical events (Visser et al., 2016). Figure 4.1 illustrates the historical timeline from when the Geography departments were established at the respective universities and the factors that impacted their development.

According to Visser, Donaldson and Seethal (2016), four main factors impacted the establishment and historical development of the Geography departments. These factors are the political environment from the early 1900 to the late 1970s, the era of political unrest (1980 to the mid-1990s), the establishment of GIS and Environmental Science in these departments (1990s to 2000s), followed by a period of growth in student numbers and research outputs, and the development of new curricula (the 2000's to currently). The factors influencing the historical development of the respective departments changed over the successive time periods and caused them to develop at different rates.

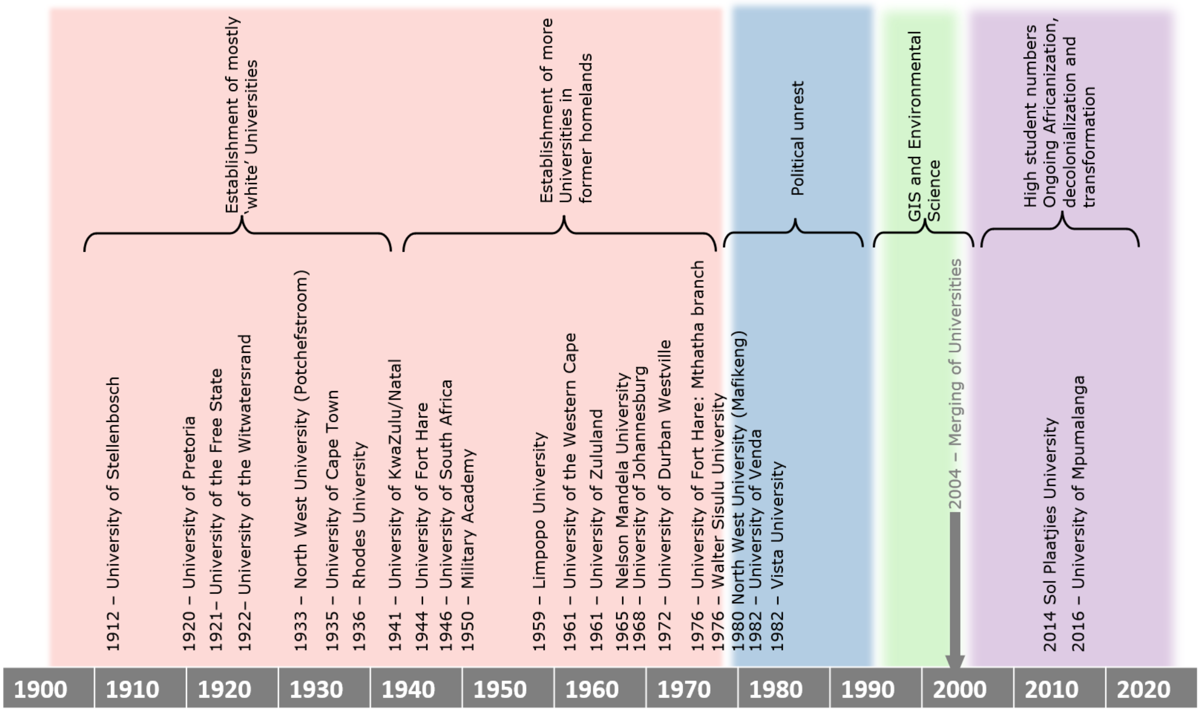


Figure 4.1: Historical development of Geography departments from 1900 to 2020. (Based on Visser, Donaldson and Seethal (2016).)

4.3.1 Overview of the establishment of Geography departments

During the period 1900 to 1970, the establishment of Geography departments was influenced by the nature of the political environment, which initially led to the development of Geography departments at mostly the former 'white' universities (Visser et al., 2016).

The first Geography department was established at Stellenbosch University in 1912 (Van der Merwe et al., 2016). In 1920, the groundwork for the development of a Geography department at the University of Pretoria commenced (Fairhurst et al., 2016), followed by Geography modules offered at the University of the Free State in 1921 (Visser & Barker,

2016) and at the University of the Witwatersrand in 1922 (Pirie & Mather, 2016). The Geography department at the University of South Africa (UNISA) was established in 1946 and acted as an incubator from which other university departments emanated. Most Geography departments founded up to 1950 mainly aimed to serve the former so-called 'white population' (Visser et al., 2016). In 1950, the Department of Military Geography, with its unique offering of Geography applications in a military environment, was established at the Military Academy at Saldanha (Smit & Donaldson, 2016).

From the 1940s to the 1970s, several Geography departments were established in or close to the former "homeland" areas, such as the University of Limpopo (Tait et al., 2016), the University of Transkei (Mrara & Pakama, 2016) and the University of Venda (Musyoki & Nethengwe, 2016). The former homeland areas were created under the Apartheid (Segregation) Acts of South Africa. Ten homelands were established to cater for the different ethnic groups and included QwaQwa, Lebowa, KwaZulu, KwaNdebele, KaNgwane, Transkei, Bophuthatswana, Ciskei, Venda and Gazankulu. The universities located in the former homeland areas were all established under various Apartheid (Segregation) Acts to provide education to black Africans, Coloured people and Indians (Visser et al., 2016). The Geography departments at these universities faced, and to some extent still face unique challenges. The biggest challenge is that most of them have remote locations and are far from any major urban centres. As such, they find it challenging to retain their staff (Visser et al., 2016). Another challenge is the high throughput in staff for these departments which leads to instability in the teaching, learning and research processes (Ibid).

4.3.2 Geography during the era of political unrest

The 1980s to mid-1990s marked an era of political unrest in South Africa. The political unrest spilt over to the universities, especially to those established in the former homelands, such as Venda, Bophuthatswana and Lebowa (Visser et al., 2016). Students demanded equal opportunities for studies in line with those offered by the former 'white' universities (Ibid). The unrest led to many riots on campuses, which disrupted classes and created an uncertain environment which was not conducive to teaching and learning (Ibid). When the late former President Nelson Mandela was released from prison in 1990, the political unrest in the country was eased to a great extent (Mngadi & Tibane, 2019). Democracy was established in the country for the first time, with promises of equality in all facets of life (Ibid). The transition from Apartheid to a democratic society also marked a change in Geography teaching in South Africa (Mather, 2007). Research now shifted towards the applied challenges associated with the reconstruction of a post-Apartheid South Africa (Ibid).

From the 1980s, Geography departments in South Africa started transforming and decolonizing their curricula (Visser et al., 2016). This transformation also involved appointing more Black African, Coloured and Indian staff members to teach Geography. Together with the transformation of the staff component, some curricula were revised to place a unique focus on the local and African context (Ibid). The departments that continued ignoring the impact of Apartheid on social and spatial patterns became isolated from the more liberal Geography departments (Van der Merwe et al., 2016). Universities such as the University of the Witwatersrand and the University of Limpopo have been sensitive to the impact of Apartheid on communities (Pirie & Mather, 2016; Tait et al., 2016). As a result, the curricula of these universities focused from the onset on the local and national environment (Ibid).

4.3.3 The era of growth, technological advancement and transformation

During the era of growth, technological advancement and transformation (from the early 2000s to currently), it was reported that Geography in South Africa was increasingly recognised as an integrative Applied Science, offering insights into various application fields in both the public and private employment sectors (Fairhurst et al., 2003)**.** While the curricula of most of the Geography departments in South Africa initially focused on teacher education, they became more industry-focused in the 1990s (Visser et al., 2016). The second half of the 1990s saw internal and external changes at most universities in South Africa. As such, curricula were adapted to reflect the political changes and transformation in the country (Fairhurst et al., 2016; Tait et al., 2016; Visser & Barker, 2016). Geography departments responded by turning their focus to become industry-focused by increasingly offering Environmental Science, GIS and Remote Sensing (Fairhurst et al., 2016; Fox, 2016; Sandham & Van Brakel, 2016; Tait et al., 2016; Van der Merwe et al., 2016). The University of Johannesburg (formerly known as the Rand Afrikaans University) was one of the first universities to introduce GIS and Remote Sensing into its Geography curriculum (Kelso & Kotze, 2016). Following this initiative, most Geography departments started offering GIS in the late 1990s to early 2000s (Visser et al., 2016). For example, the University of Stellenbosch introduced GIS as a postgraduate course in 1990, and at the undergraduate level in 1997 (Van der Merwe et al., 2016). The University of the Western Cape introduced GIS as a course in its Geography department in 1993 (Gilfellan et al., 2016), and was followed in 1999 by the University of the Free State (Visser & Barker, 2016). During this period, Environmental Science was also incorporated into many Geography departments, thus leading to name changes or alternatively, the establishment of separate Environmental Science departments (Visser et al., 2016).

In line with the introduction of GIS into Geography departments, cartographic units transformed to align with the latest technologies used in GIS (Visser et al., 2016). As reported by the University of Stellenbosch (Van der Merwe et al., 2016) and North-West University (Sandham & Van Brakel, 2016), the incorporation of GIS into these departments led to many of their cartographic units developing into dedicated research units. The growth in cartographic units significantly contributed to an increase in research outputs in these departments (Visser et al., 2016).

Universities that aligned their teaching and research with the impact of Apartheid on the country enjoyed a smooth transition to the new era of transformation and continue to grow in terms of education and research (Fox, 2016; Pirie & Mather, 2016). Geography departments at these universities reported on the introduction and growth of 'cutting edge syllabi in the study fields of Climatology and Geomorphology and Human Geography' (Pirie & Mather, 2016). The acknowledgement of the impact of Apartheid on society and the environment in South Africa made it easy for these universities to react to the challenges of reconstructing their curricula and aligning them with the needs of industry (Pirie & Mather, 2016).

Since the 1990s, Geography departments have faced an ever-growing increase in student numbers (Visser et al., 2016), with many of the newly admitted students unprepared for tertiary education (Visser & Barker, 2016). The increase in the number of Geography education students and the focus on Environmental Management, Environmental Science, GIS and Tourism has also contributed to growing student numbers in Geography departments (Visser et al., 2016). Another contributing factor to the increase in student numbers has been the offering of government funding schemes to make tertiary education accessible to a larger cohort of students (Pirie & Mather, 2016; Visser & Barker, 2016). As a result, some Geography departments, such as at the University of Limpopo, reported increased student numbers from the late 1990s (Tait et al., 2016), while the Geography departments at the University of the Free State and the University of Cape Town have reported increased student numbers since the early 2000s (Meadows & Richard, 2016; Visser & Barker, 2016).

This growth in student numbers posed many challenges to Geography departments. Previously, some departments reported participation by their lecturing staff and students in a variety of successful field trips (Musyoki & Nethengwe, 2016; Sandham & Van Brakel, 2016). However, owing to the increase in student numbers, some universities can no longer offer these. The growth in student numbers has also led to increasing workloads and has resulted in fewer research outputs in some departments (Fox, 2016; Smit & Donaldson, 2016).

To address the inequality caused by the Apartheid policies and the large number of universities in South Africa, several universities (including their Geography departments) were merged in 2004 into larger single entities (Goldman, 2011). The mergers reduced the number of Geography departments in South Africa (e.g., Vista University was dissolved and certain of its departments respectively merged with the University of South Africa, the University of the Free State, the University of Pretoria and the Vaal University of Technology (Mouton et al., 2013)). The University of North–West (Mafikeng) merged with the Potchefstroom University of Christian Higher Education to become the North-West University and incorporated the Sebokeng campus of Vista University (Ibid). The Rand Afrikaans University joined with the Technikon Witwatersrand and partially with Vista University to become the University of Johannesburg (Ibid).

Most recently, Geography departments were established at the University of Mpumalanga in 2016 (Parker, 2021) and at Sol Plaatje University in 2014 (Sol Plaatje University, 2021). The School of Biology and Environmental Science at the University of Mpumalanga offers qualifications focusing on Environmental Science but also includes some Geography modules. This school also offers an honour's degree in Geography (Parker, 2021). The Geography modules offered at Sol Plaatje University focus on teacher education, while some Geography modules are also offered by the Department of Physical and Earth Sciences. (Education Overview - Sol Plaatje University, 2021)

4.4 Current trends in the offering of Geography at South African universities

Although slow in some departments, the processes of transformation, decolonisation and Africanisation currently continue in all Geography departments in South Africa (Knight, 2018; Long et al., 2019). However, the staff profile in Geography departments is still mainly white males, with a few black male geographers and very few black African female geographers (Breetzke et al., 2020). In addition, most white male geographers are employed at the historically white universities, while most black males are employed at the historically black universities (Ibid).

4.4.1 Current research and application domains of Geography in South Africa

In line with the call for transformation in Geography curricula, there is also a call for Geography education with a specific focus on sustainability goals (Meadows, 2020). The focus on sustainability goals will put curricula in line with the needs of communities on different scales – from the local to the global (Ibid). However, despite the importance of integrating Geography with education for sustainability, the integration has not gained much support in South Africa (Pretorius, 2018). Nevertheless, the potential link between sustainability and Geography and the processes of decolonisation and Africanisation has put Geography departments in a strong position, allowing them to be relevant and influential within the South African context (Knight, 2018; Pretorius, 2018; Meadows, 2020).

Research by Sandham and Retief (2016) indicates that Geography curricula also significantly contribute to environmental assessment practices. In fact, because of the holistic thinking processes embedded in the discipline, Geography modules in the South African context will continue to provide a basis for environmental assessment training and research (Sandham & Retief, 2016). Geographers in South Africa have an essential role in addressing challenges related to food security, water management, biodiversity, conservation and ecotourism (Oldfield and Patel, 2016; Sandham & Retief, 2016). These challenges emphasise the importance of engaging an involved and relational Geography in line with societal needs (Oldfield and Patel, 2016). Such a brand of Geography raises the question as to how knowledge is generated, the type of knowledge that is considered essential and how the knowledge is conveyed to students to enable them to address societal challenges in a local and global context (Oldfield and Patel, 2016).

Although each Geography department has its own unique take on teaching Geography modules, the Military Academy at the University of Stellenbosch deserves special mention. It offers Geography to support the development of officers within a military-academic and high-tech environment (Smit & Donaldson, 2016). The Geography topics may be similar to those offered at other Geography departments, but the focus is on unique applications within the military environment (e.g. terrain analysis focusing specifically on troop manoeuvres in areas, tactical operations in relation to specific terrain forms and avenues of approach in a conflict situation (Smit & Donaldson, 2016). Furthermore, the Department of Geography at the Military Academy is one of the few that specifically refers to the importance of spatial thinking within its application domain (Ibid). The Department of Geography at Unisa also deserves special mention. Unisa is described as a mega institution and is one of the largest open distance and e-learning institution in the world (Unisa, 2023). Unisa has more than 370000 registered students from across Africa, South Africa and other parts of the world (Unisa, 2023) and caters for people who cannot afford to attend residential universities, are employed or can for some reason not physically attend a university (THE, 2023). Therefore, teaching at the Department of Geography at Unisa reaches students based in cities to those in the most remote rural areas in various countries (Nicolau & Pretorius, 2016).

4.4.2 Challenges, opportunities and gaps within curricula

The #Feesmustfall campaign and the call to Africanise and decolonise curricula of modules (Ndelu et al., 2017) (including Geography) has provided all universities in South

Africa with the opportunity, but has also challenged them, to transform the content of their curricula (CMoloi et al., 2017). Furthermore, it has been suggested that Geography curricula should develop subject-specific skills such as spatial reasoning, spatial thinking, the representation of spatial data, the design of sample data and an understanding of the different theoretical perspectives of Physical and Human Geography (Whalley et al., 2011). In fact, for universities to remain current, CMoloi, Makgoba and Miruka (2017) maintain that curricula offered at South African universities should be ethically responsive to evolving complexities in an ever-changing world.

The results of research conducted by Golightly and Muniz (2013) indicate that problem-based learning should form part of the formal education system in South Africa. Although this research (Ibid) was conducted by using a Geography module offered to student teachers as a case study, the results can be applied to all Geography modules. Problem-based learning places the responsibility of learning on the shoulders of students and develops not only their problem-solving skills, but also, to name but a few, their communication skills, teamwork skills and the identification of their own personal strengths and weaknesses (Golightly & Muniz, 2013). The afore-mentioned research (Ibid) indicates that respondents expect lecturers to play a pivotal role in their learning process in such areas as explaining the module content, identifying learning material and grading assessments. After understanding the benefits of problem-based learning, the students in this research study (Ibid) agreed that problem-based learning could assist them in becoming independent lifelong learners.

Research conducted by Moolman and Donaldson (2016) among South African geographers indicates that they work in various positions in industry. Most respondents work as GIS specialists, followed by those in research-orientated jobs and those with internships at GIS and environmental companies. The respondents indicated that a geographer's most essential capability is understanding human and environmental interactions, possessing GIS skills, adopting a multidisciplinary approach to tasks and adapting to the workplace environment (Moolman & Donaldson, 2016). A holistic and diverse view, general qualities and spatial thinking were rated as the most critical characteristics of geographers in the workplace, while the lack of adequate fieldwork training was highlighted as an area for concern (Ibid).

The gap between secondary school education and university education still exists to a large extent in Geography (Malatji & Singh, 2018). The lack of alignment in some parts of the Geography curriculum, when students enter tertiary education, affects their learning and developmental path. Furthermore, certain sections of the curriculum, such as GIS, are not well taught at secondary school level (Ibid).

As transformation is ongoing in the country, increasing numbers of students are gaining access to study opportunities at university. Owing to the inferior primary and secondary school education that they have been subjected to, they are often unprepared for tertiary level studies (Webb, 2007), thus leading to the necessity for various bridging courses to prepare them for the challenges of tertiary education (Fox, 2016). This trend of under-prepared students entering universities seems to be ongoing, with many of those entering first-year Geography classes not having studied Geography at school (De Waal & Williams, 2020). The under-prepared students experience tasks, such as drawing inferences from subject matter, constructing meaning from the content given them, retrieving knowledge from texts and processing knowledge, as serious challenges (Webb, 2007). One skill that can be taught to address many of these challenges that students are experiencing is spatial thinking (Bednarz, 2019). Despite the benefits of including spatial thinking as part of the formal Geography curriculum, a search on the internet indicated that spatial thinking is not an actively researched topic in South Africa.

4.5 Geography at universities: touching on the international scene

Geography teaching in higher education could be described as "alive and well". A search on the internet using the phrase "Geography teaching higher education", returned 23 800 articles in 0.04 sec. This is encouraging as it indicates that research in Geography education in general is vibrant and attracting ample interest.

Currently, as in South Africa, there is also a call to decolonise Geography curricula in countries such as Britain, the United States of America (USA), Canada and Fiji (Esson, 2020; Fritzsche, 2021; Moorman et al., 2021). In Britain, the focus is on addressing racism in higher education Geography curricula and decolonizing them (Esson, 2020). In Canada and Fiji, it is suggested that the curricula be decolonised through indigenisation – a culturally sensitive approach that adds indigenous knowledge, concepts and practices to curricula (Moorman et al., 2021). In the USA, research focuses on including teaching material on anti-oppression issues in decolonised curricula (Fritzsche, 2021).

During the early 2000s, various countries, such as the USA , Austria, Hong Kong and Taiwan, also experienced a period of massification, leading to increasing student numbers at educational institutions (Neubauer et al., 2018). Although research has indicated that fieldwork plays a crucial role in developing geographers, the international experience suggests that many Geography departments have had to terminate their fieldwork trips on account of increasing student numbers (France & Haigh, 2018; Thomas & Munge, 2017). The experiences of international universities in this regard are the same as those of South African Universities, where the increase in student numbers, started in the 1990s (Visser et al., 2016), and also led to the termination of fieldwork trips (Musyoki & Nethengwe, 2016).

The vital role of Geography in education for sustainability and in the realisation of the SDGs is recognised internationally. Research conducted by Yli-Panula, Jeronen and Lemmetty (2019) involving 17 journal articles from various countries focuses on learning methods in Geography to promote sustainability, including fieldwork and problem-based learning. In contrast to the situation in South Africa (Pretorius, 2017), research conducted in Germany indicates that, although there is room for improvement, sustainability concepts constitute part of Geography curricula at most universities (Sprenger & Nienaber, 2017).

In terms of employability, research in Turkey confirms the importance of having GIS skills to improve the employability of Geography students and to modernise the image of Geography as a discipline (Şeremet & Chalkley, 2016). The findings of this study are comparable to those of Moolman and Donaldson (2016), who list GIS as an important technical skill for employment in South Africa.

In bridging the gap between school Geography and tertiary Geography, students in the United Kingdom face challenges similar to those of South African students (Ferreira, 2018). The respondents in the latter research (Ibid) indicated that Geography as a university subject is much broader and more compartmentalised than Geography at the school level. Furthermore, they could not understand how study topics included in curricula fit in with or complement one another (Ferreira, 2018).

In contrast to the South African situation, spatial thinking has been included in various international research projects at the primary, secondary and tertiary levels. In these projects, the taxonomy of spatial thinking has been utilised for the evaluation of questions posed in Geography textbooks, for example, in Rwanda (Tomaszewski et al., 2015), Brazil (Duarte, 2018), and Indonesia (Ridha et al., 2019a). Furthermore, Scholz et al. (2014) also evaluated questions posed in popular World Geography textbooks against the taxonomy of spatial thinking. Other research projects have included the effect of various pedagogies on the development of spatial thinking skills. They include the use of the Eartcomm learning model (Aliman et al., 2019), geospatial technologies (Ishikawa, 2013; Lee & Bednarz, 2009; Madsen & Rump, 2012; Manson et al., 2014) and augmented reality (Carrera & Asensio, 2017)). This list of research projects is by no means complete. In fact, these examples (and many more) are discussed in the following chapters of this thesis.

4.6 Mind the gap: Geography and spatial thinking

Including spatial thinking in the Geography curriculum can address many challenges experienced by local and international students studying at universities. Any person of any age, gender or background can learn to think spatially (National Research Council, 2006; Newcombe and Stieff, 2012). Research has indicated that spatial thinking can address challenges such as gender inequalities (Newcombe & Stieff, 2012) and differences in educational background (Bednarz, 2019), and can close achievement gaps in STEM subjects (Bednarz, 2019; Uttal & Cohen, 2012). Reducing addressing these types of challenges may contribute to giving students a fair chance to complete their studies successfully and to perform better in the workplace (Bednarz, 2019). Spatial thinking is an essential tool that should be included in the Geography curriculum to improve academic performance in Geography and other subjects and to lead to better work opportunities and prospects for successful careers (Goodchild & Janelle, 2010; Wright et al., 2008).

Bednarz (2019) emphasises that, as Alderman (2018) proposes, the inclusion of spatial thinking in Geography curricula will bring the curriculum content closer to a radical Geography curriculum. The inclusion of spatial thinking in a Geography curriculum does not mean that the foundational knowledge of Geography and other finer details should be neglected. However, this basic knowledge and finer details, will serve only a limited purpose within a Geography curriculum as long as students are incapable of applying it to examine, critique and challenge issues in the real world (Alderman, 2018;

Bednarz, 2019). Bednarz (2019) proposes that the Geography curriculum should be spatialised to improve the quality and magnitude of spatial learning.

Research conducted in 2007 (Mather, 2007) indicated that Geography curricula at South African universities had become increasingly localised and tended to focus on developmental challenges in the region in question. However, it was also reported later that Geography modules should focus on both challenges and opportunities in the real world and should not be influenced by political views (Alderman, 2018). Research by Bearman et al. (2016) found that there are only a limited number of modules exposing students to the entire problem-solving process in the context of spatial thinking. The problem-solving process includes the processes of data identification, data acquisition and management, data analysis and output through communication media, such as maps or graphs (Ibid).

An overview of the Geography modules and descriptions of curricula, as collated by Pretorius (2017), indicates that most Geography departments at South African universities follow a sub-disciplinary approach or a combination of a sub-disciplinary and an integrated approach. Higher-order thinking skills should be developed through active pedagogies such as problem-based learning and project and inquiry-based learning (Pretorius, 2018). An initial investigation by the researcher and Pretorius (2017) indicated that spatial thinking is not sufficiently incorporated into the curricula of undergraduate Geography modules at South African universities. As such, these observations form the basis for the research results presented in this thesis.

4.7 Identification of Geography departments and modules for this research

4.7.1 Positioning within the AQAL model

The positioning of the process to identify Geography departments and modules for this research within the AQAL model is set out diagrammatically in Figure 4.2. The first step comprises the identification of universities in South Africa offering Geography. This step is located in the UL quadrant of the AQAL model, since all the Geography departments and the modules that are offered were identified objectively by the researcher from an outside ("It") perspective. The second step, a subjective process, is based on the researcher's experience in teaching at three higher education institutions over 20 years and comprises an evaluation of module descriptions on the websites of universities against phrases from the literature to identify whether spatial thinking might constitute part of a module. The evaluation of the module descriptions against the phrases in the literature was conducted from an outside ("I") perspective. Although the taxonomy of spatial thinking is a known and tested instrument and, therefore, located in the UR quadrant, the final step to determine the spatiality of the module outcomes was based on the researcher's experience in higher education teaching and is, therefore, also partially located in the UL quadrant. This is justifiable since some of the module outcomes are defined in an encompassing manner and are therefore, more implied than specific. The process of evaluating the spatiality of the module outcomes is therefore carried out from an outside (both "I" and "It") perspective.

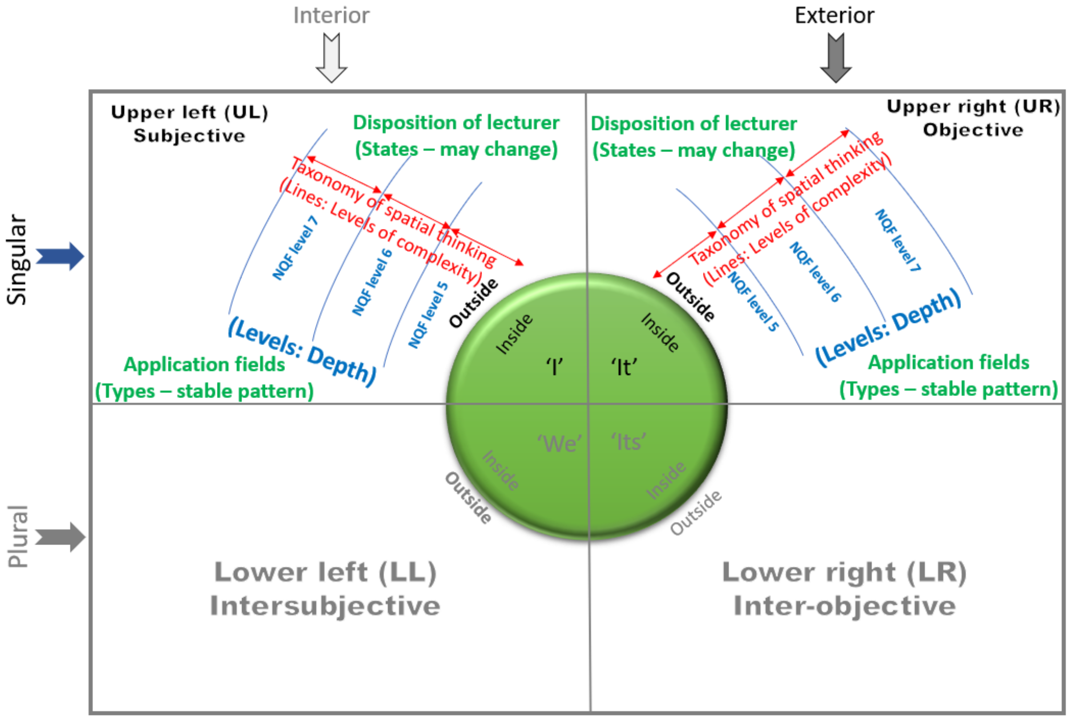


Figure 4.2: Identifying departments – positioning within the AQAL model.

The NQF levels at which the modules are offered were recorded and represent the different levels of the AQAL model. The cell values (1 to 24) of the taxonomy of spatial thinking represent the lines in the AQAL model. The application fields of each of the modules were also recorded. The application fields constitute the types in the AQAL model. The NQF levels represent levels of development through the three-year study period, while the taxonomy of spatial thinking represents the lines and, therefore, the levels of complexity. Each module is expected to reach a certain level of spatiality (or complexity), with the spatiality increasing from NQF levels 5 to 7. The application field is a stable entity and occurs irrespective of the NQF levels (e.g., any application field, such as Human Geography, may be offered regardless of the NQF level).

4.7.2 Process to identify the departments and modules

This research focuses specifically on Geography modules offered on NQF levels 5, 6 and 7 at the 26 public universities in South Africa. The results from a desktop study indicated that 16 universities in South Africa offer students the opportunity to study towards an undergraduate qualification with Geography as a major, or they offer Geography as a loose module or modules. Only departments that clearly identified themselves as a Geography department (and not only an Environmental Science department) were considered for this research. Some of the departments considered for this research have an overlap between Geography and Environmental Science in terms of their content knowledge. As such, the two disciplines may be offered in an integrated way and were considered to form part of this research. Geography modules offered as part of an education study programme were not considered for this research since, generally, only students studying towards a qualification in education are allowed to register for these modules, which are usually not available to all students on campus. The newly established University of Mpumalanga was not included since, at the time of the research, it might not have had a sufficient throughput of students to justify participation in the in-depth study that constituted part of this research.

One module per NQF level for each identified department was included to form part of this research. The modules offered by Geography departments that were not considered to form part of this research were those focusing on Environmental Science (without incorporating or overlapping with Geography). These modules were omitted since the specific focus of this research demanded the inclusion of spatial thinking in Geography modules. Table 4.2 provides a list of South African universities that offer Geography modules and that were considered to potentially form part of this research.

The review of the websites indicated that the 16 Geography Departments offer 190 Geography modules at undergraduate level. Of these modules, 43 are offered on NQF

Level 5, 62 on NQF Level 6 and 85 on NQF Level 7. The modules excluded from this research included those with short descriptions referring only to focus topics and broad subject topics that would be covered in the module, and which did not reveal any further inclusion of spatial thinking. Furthermore, the course descriptions of some modules were not written in full sentences and did not refer to any of the phrases that could typically be expected from a module that might include spatial thinking in its syllabus. These modules were therefore also excluded.

Table 4.2: List of South African universities that offer Geography modules.

Name of University	Name of University
Nelson Mandela University	University of Limpopo
North-West University	University of Pretoria
Rhodes University	University of South Africa
Stellenbosch University	University of the Free State
University of Cape Town	University of the Western Cape
University of Fort Hare	University of the Witwatersrand
University of Johannesburg	University of Venda
University of KwaZulu-Natal	University of Zululand

4.7.3 Indicators of spatial thinking

The Geography module descriptions and outcomes available on the websites of 16 South African universities were scrutinised to identify phrases indicative that spatial thinking might be included in the modules in question. After scrutinizing the module descriptions and outcomes on the websites, eight Geography departments were invited to participate in the research. The heads of the identified departments were contacted to confirm that they would be able to participate in this research and were requested to provide the researcher with the outcomes of the selected modules if these were not available on the university websites. Two of the invited departments declined to participate in this research. Since purposive sampling was used to identify and include only modules that could potentially contribute to this research, the researcher did not invite additional Geography departments to participate as their modules would not have significantly contributed to this research. Apart from the identified modules, the six participating universities were keen to participate in the research. They suggested additional modules to include in the research since they were interested in the results. This brought the total number of modules that were identified to potentially include in this research to 21.

Table 4.3: List of anonymous Geography departments, module codes, application fields and spatial thinking keywords/phrases.

Anonymous name	Module code	Application fields	Key words/phrases
Department A	A.5	Human Geography	Solve problems in a new context; analysis, synthesis and evaluation; geographic actions on various scales; spatial data interpretation and representation.
	A.6	Human Geography	Interpretation of aerial photographs; identify and analyse information appropriately; communicate and present complex information; work in teams
	A.7	Geospatial Applications	Evaluate the effectiveness of spatial data, apply knowledge to solve spatial problems
University B	B.5	Physical Geography	Interrelationships between systems
	B.6(1)	Human Geography	Problem-solving
	B.6(2)	Human Geography	Problem-solving
	B.7	Geospatial Applications	Fieldwork component
Department E	E.5	Human Geography	Solve problems; interpret visual material; work in a team
	E.6	Human Geography	Apply knowledge; interrelationships; distribution; densities; work in a team
	E.7(1)	Human Geography	Case studies; different scales; analyse patterns
	E.7(2)	Geospatial Applications	Spatial analysis; solve real-world problems
Department F	F.5	Human and Physical Geography	Problem-solving; interrelationships
	F.6	Human Geography	Complex real-world problems; applications
	F.7	Human Geography	Interpret patterns; provide solutions; different scales
Department H	H.5	Physical Geography	Patterns, problem-solving
	H.6	Human Geography	A complex and ever-changing world
	H.7	Physical Geography	Various scales; processes; applications
Department J	J.5	Physical Geography	Interpretation; application
	J.6(1)	Human and Physical Geography	Interpretation; real-world situations; interrelationships
	J.6(2)	Physical Geography	Apply knowledge; develop thought processes
	J.7	Geospatial Applications	Spatial data; applications

Interestingly, most (48%) of the identified modules were found to focus on Human Geography, followed by modules in Physical Geography (24%), Geospatial Applications (19%) and those with an integrated approach to Human and Physical Geography (9%). The reason why most of the identified modules focused on Human Geography may be grounded in the way that the module descriptions were written (e.g. modules in Human

Geography often refer to facing challenges on a global and local scale and on solving problems using a team approach; in contrast, Physical Geography modules often focus on processes on a local scale, such as rock weathering or erosion). (Refer to Chapter 3,Section 3.4.1.) Very few Geography modules at South African universities follow an integrated approach (Pretorius, 2017), and the percentage of these modules forming part of this research would, therefore, be low.

Although purposive sampling was carried out objectively to determine which departments and modules should contribute to this research, it was, in most cases, easy to identify the specific modules. Several of the identified modules were well described, and provided a clear indication that spatial thinking could potentially be included. It was also found that some of them specifically referred to the task of developing students' spatial, geographic, or critical thinking skills. Figure 4.3 summarises the keywords used in the identified modules. The generated word cloud indicates that keywords such as "interpretations", "solve problems", "scales", "complex" and "apply" were the words most frequently used in the module descriptions.

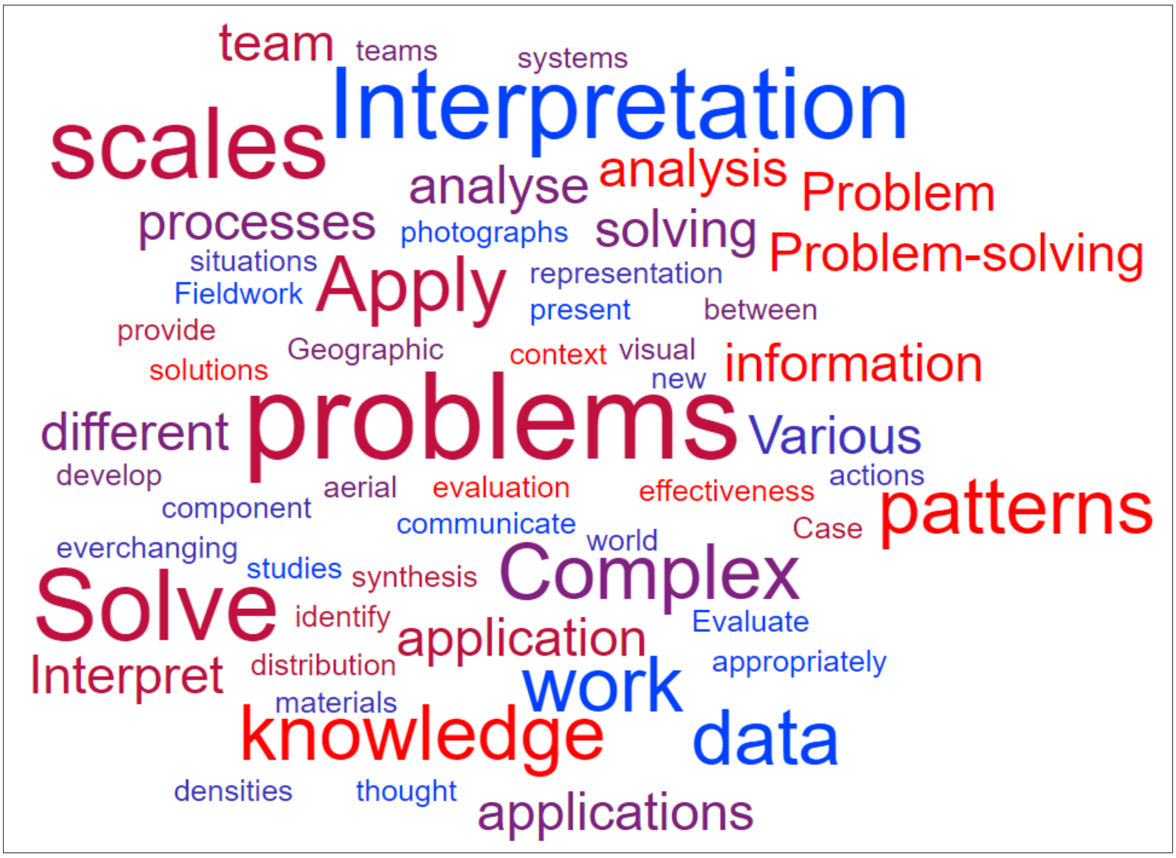


Figure 4.3: Word cloud of spatial thinking keywords.

(Generated using worditout.com)

4.8 Evaluation of module outcomes against the components of spatial thinking

The module outcomes were evaluated against the taxonomy of spatial thinking as developed by Jo and Bednarz (2009). The same process as that explained in Chapter 2, Section 2.3.2, was followed to evaluate the spatiality of the module outcomes.

The researcher interpreted the outcomes through her own experience of more than 20 years of teaching GIS at private and public institutions and developing various new modules over these years. In instances where the module outcome was not clearly defined, the implied outcome was measured against the taxonomy of spatial thinking. Should any doubt arise, the solution would be to allocate the outcomes being evaluated at a higher cell value on the taxonomy of spatial thinking. The reason for this is that the outcomes reflect the desired level a student should attain after successfully having completed the module; as opposed to the teaching and learning processes which occur throughout the entire semester and to give the lecturer the benefit of the doubt.

A total of 107 outcomes for the six departments were evaluated against the taxonomy of spatial thinking. Table 4.4 below summarises the number of outcomes evaluated per department.

Table 4.4: Number of outcomes evaluated per department.

University	Number of outcomes
Department A	19
Department B	6
Department E	18
Department F	12
Department H	15
Department J	37
Total number of outcomes	107

In instances where there was more than one module per NQF level for a department, the module that attained the highest cell value on the taxonomy of spatial thinking would be included in this research for further analysis and discussion. This brought the final number of modules to 18. The 18 modules consisted of three modules for each department on NQF levels 5, 6 and 7.

4.8.1 Evaluation and discussion of results for the analysis according to cognitive level

The graphs in Figure 4.4 summarise and illustrate the cognitive level at which the outcomes of the 18 modules offered by the six departments are pitched and distinguish between the input, processing and output levels. (Refer to Chapter 2, Section 2.3.2, for a detailed explanation of the three cognitive levels.) One lecturer did not submit the module outcomes (B.5) and this module could, therefore, not be included in this research.

In general, the outcomes pitched at the input level vary from 0% (A.5, A.7, B.6, F.7, J.5 and J.7) to the highest percentage for Department B (NQF Level 7) - 67%. The outcomes pitched at the processing level vary from 0% (A.6, B.7 and E.5) to 100% (J.5), while the outcomes pitched at the output level vary from 0% (F.5, H.5, J.5) to 83% (A.7).

The evaluation of NQF Level 5 shows that module outcomes pitched at the input level vary from 0% (A.5 and J.5) to 40% (H.5). The module outcomes pitched at the processing level vary from 0% (E.5) to 100% (J.5), while the module outcomes pitched at the output level vary from 0% (F.5, H.5 and J.5) to 75% (E.5). The NQF Level 5 modules of Departments F, H and J present with no module outcomes pitched at the output level.

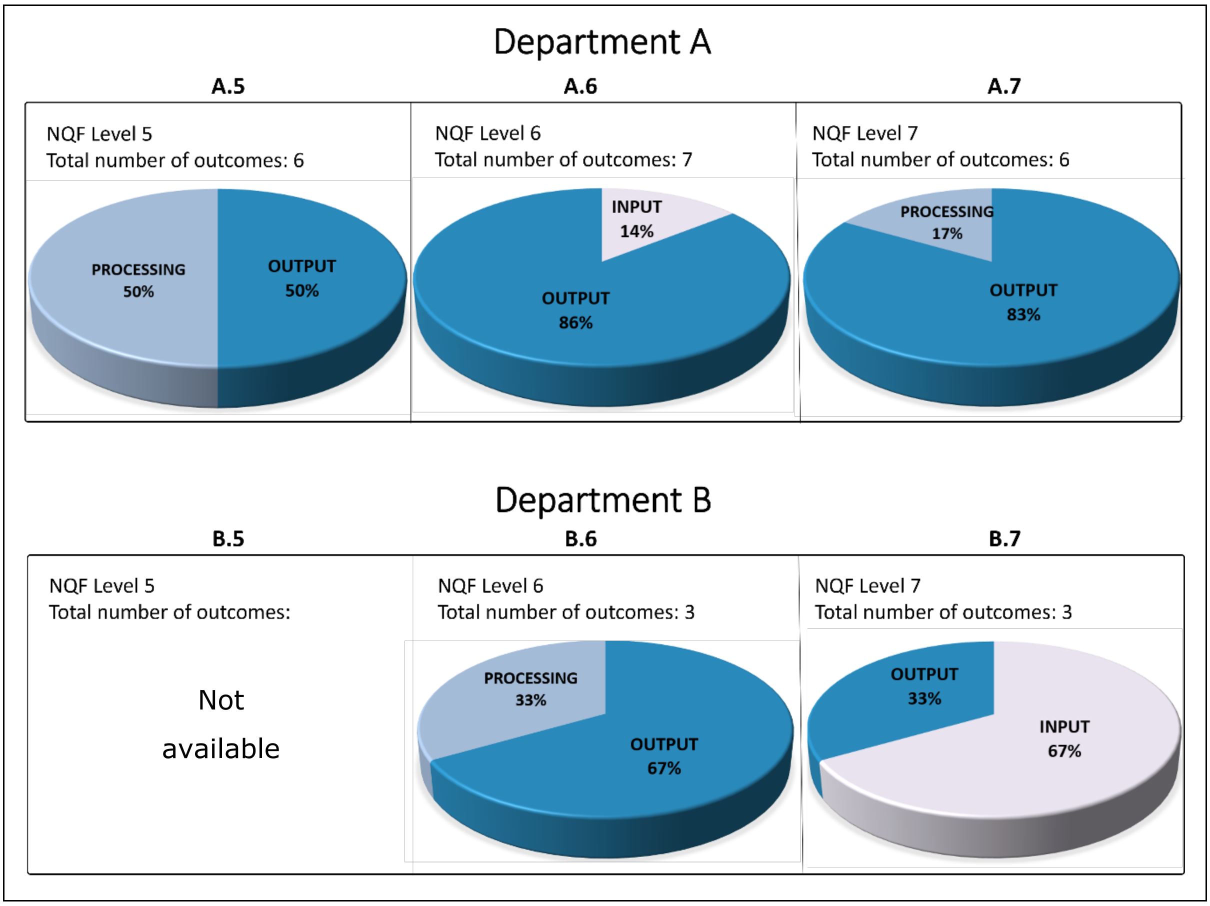
On NQF Level 6, the evaluation shows that module outcomes vary from 0% (B.6) to 50% (H.5) pitched at the input level, from 0% (A.6) to 33% (B.6 and F.6) pitched at the processing level, and from 33% (F.6 and H.6) to 86% (A.6) pitched at the output level. The NQF Level 6 module for Department A presents with no outcomes on a processing level, while the NQF Level 6 modules for Departments F and H present with most of their outcomes, respectively 34% and 50%, pitched at the input level.

The NQF Level 7 evaluation shows that module outcomes vary from 0% (A.7, F.7 and J.7) to 67% (B.7) on the input level and from 0% (B.7) to 50% (J.7) pitched at the processing level. The module outcomes pitched at the output level vary from 25% (H.7) to 83% (A.7). Departments B (67%) and H (50%) have most of their module outcomes pitched at the input level on NQF Level 7.

It could be expected that the complexity of the module outcomes should increase from NQF Level 5 to NQF Level 7. A larger percentage of the module outcomes on NQF Level 5 could be on an input level when compared to NQF levels 6 and 7. However, the input level module outcomes should constitute the smallest percentage of the outcomes on NQF Level 5 and diminish on NQF levels 6 and 7. The module outcomes pitched on an outcome level should constitute the highest percentage of the outcomes on all NQF levels (e.g., the modules as offered by Department A and F). Modules with no outcomes pitched at the output level would be at risk of not reaching the desired depth to develop the spatial thinking capabilities of the students (e.g., the module outcomes of F.5, H.5 and J.5). It could also be expected that modules offered on NQF Level 6 would include mostly outcomes on a processing and output level and that outcomes on an input level would be kept to a minimum (e.g., B.6 and J.6). The NQF Level 6 modules of

Departments E and H would be at risk of not reaching the desired level of spatiality since these modules present with a high percentage of outcomes on an input level.

For all the departments, the modules on NQF Level 7 include outcomes pitched at the output level. To fully develop the spatial thinking abilities of the students, it could be expected that the outcomes pitched at the output level on NQF Level 7 would constitute the highest percentage. The output level includes questions on a high cognitive level and might require students to predict or to hypothesise, for example, what might transpire within a scenario or to plan for a specific situation. In fact, questions on this higher cognitive level align with the applied and problem-solving nature of Geography. The NQF Level 7 modules of Departments A and F include a high percentage of outcomes pitched at the output level (respectively 83% and 80%). Departments B, E and H include outcomes at the input level on NQF Level 7 (respectively 67%, 20% and 50%). For these departments, the NQF Level 7 modules that includes module outcomes on an input level might not achieve the desired cognitive level in their outcomes. As a result, they are at risk of not adequately developing the spatial thinking capabilities of their students but to a larger extend for B.7 and H.7 than for E.7.



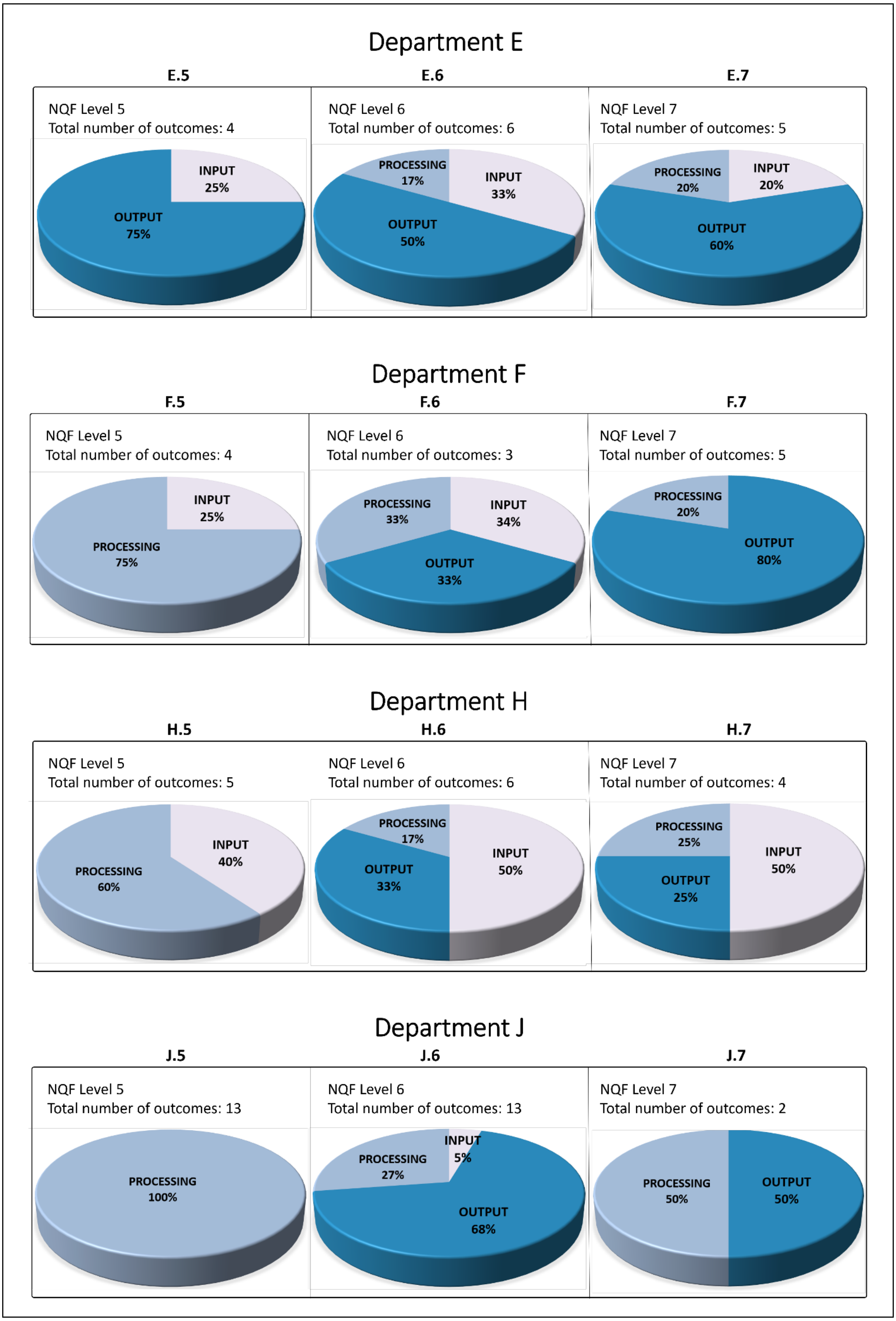


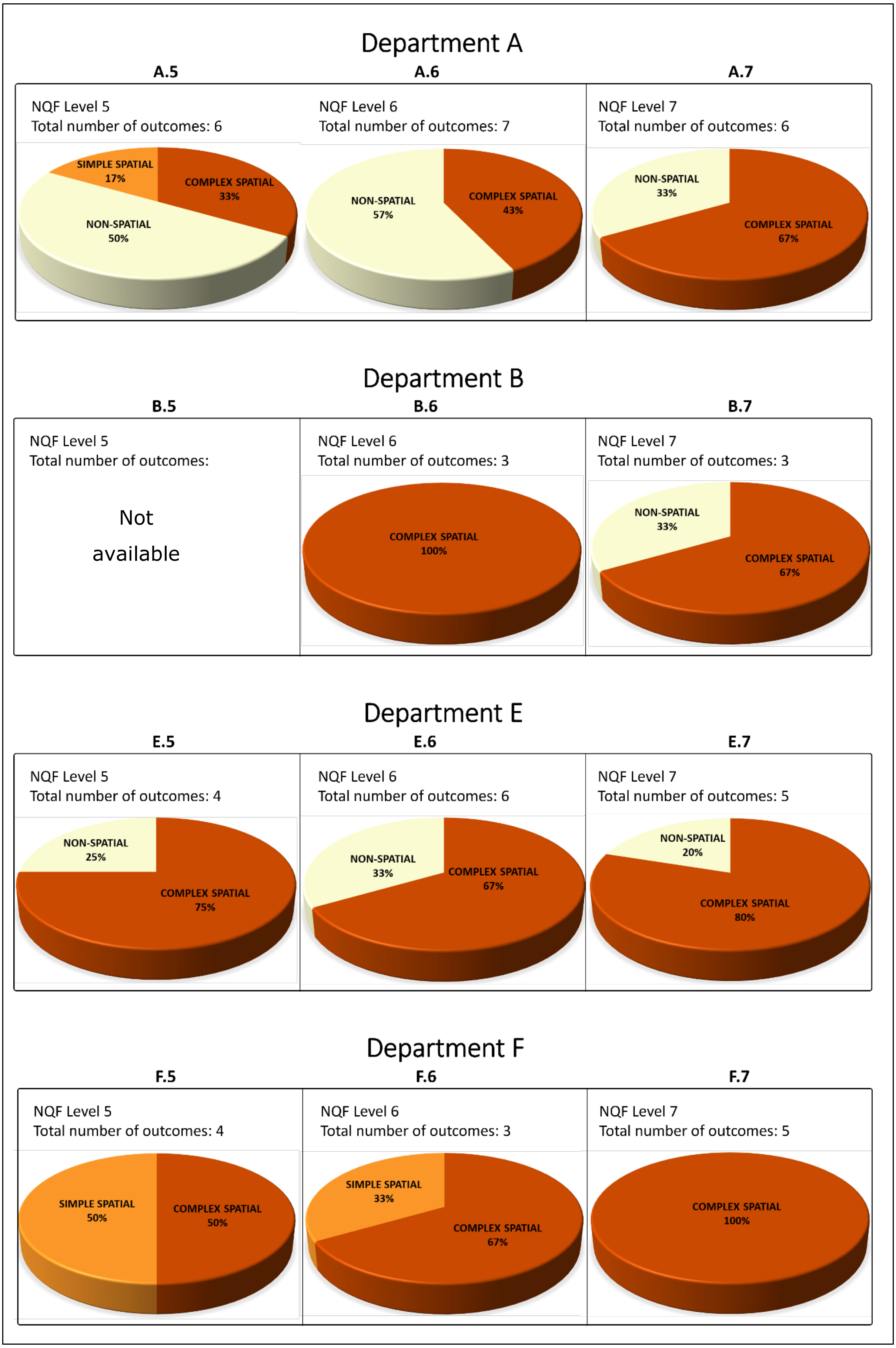
Figure 4.4: Percentage of module outcomes per cognitive level, arranged per department and per NQF level.

In terms of this analysis of module outcomes, none of the six departments provides evidence of a clear path in developing the cognitive level of students from an input, through a processing, to an output level from NQF levels 5 to 7. Although the inclusion of some outcomes on an output level for NQF Level 5 should be considered, Department F best illustrates the development of cognitive levels from NQF Level 5 to NQF Level 7.

4.8.2 Evaluation and discussion of results for the analysis according to concepts of space

Figure 4.5 demonstrates how the concepts of space are incorporated into the module outcomes of the six departments and distinguishes between non-spatial, primitive, simple and complex concepts of space. (Refer to Chapter 2, 2.3.2 for a detailed explanation of the concepts of space.) In general, the inclusion of non-spatial concepts of space in module outcomes varies from as low as 0% (B.6, F.5, F.6, F.7, J.6 and J.7) to as high as 57% (A.6). Primitive concepts of space are reflected in the outcomes of two modules, namely, J.6 (8%) and H.7 (50%), while simple spatial concepts of space are present in the outcomes of five modules (A5, F.5, F.6, H.5 and J5) and vary from 15% (J.5) to 50% (F.5). What is encouraging is that the outcomes of all the modules include complex concepts of space. The percentage of module outcomes per NQF level per department that includes complex concepts of space varies from 25% (H.7) to 100% (B.7, F.7 and J.7).

On NQF Level 5, the evaluation shows that four of the five modules include outcomes with a non-spatial concept of space. In one instance (A.5), the outcomes are mostly formulated in terms of a non-spatial concept of space (50%). Four of the departments also include outcomes with a simple spatial concept of space (A.5, F.5, H.5, J.5) which vary from 15% (J.5) to 50% (F.5). The outcomes that include a complex concept of space range from 33% (A.5) to 77% (J.5). Module F.5 finds a balance between the simple and complex concepts of space, with 50% of the outcomes based on each of these two spatial levels.


Department A
A.5
NQF Level 5
Total number of outcomes: 6
SIMPLE SPATIAL 17%
COMPLEX SPATIAL 33%
NON-SPATIAL 50%
A.6
NQF Level 6
Total number of outcomes: 7
NON-SPATIAL 57%
COMPLEX SPATIAL 43%
A.7
NQF Level 7
Total number of outcomes: 6
NON-SPATIAL 33%
COMPLEX SPATIAL 67%
Department B
B.5
NQF Level 5
Total number of outcomes:
Not available
B.6
NQF Level 6
Total number of outcomes: 3
COMPLEX SPATIAL 100%
B.7
NQF Level 7
Total number of outcomes: 3
NON-SPATIAL 33%
COMPLEX SPATIAL 67%
Department E
E.5
NQF Level 5
Total number of outcomes: 4
NON-SPATIAL 25%
COMPLEX SPATIAL 75%
E.6
NQF Level 6
Total number of outcomes: 6
NON-SPATIAL 33%
COMPLEX SPATIAL 67%
E.7
NQF Level 7
Total number of outcomes: 5
NON-SPATIAL 20%
COMPLEX SPATIAL 80%
Department F
F.5
NQF Level 5
Total number of outcomes: 4
SIMPLE SPATIAL 50%
COMPLEX SPATIAL 50%
F.6
NQF Level 6
Total number of outcomes: 3
SIMPLE SPATIAL 33%
COMPLEX SPATIAL 67%
F.7
NQF Level 7
Total number of outcomes: 5
COMPLEX SPATIAL 100%

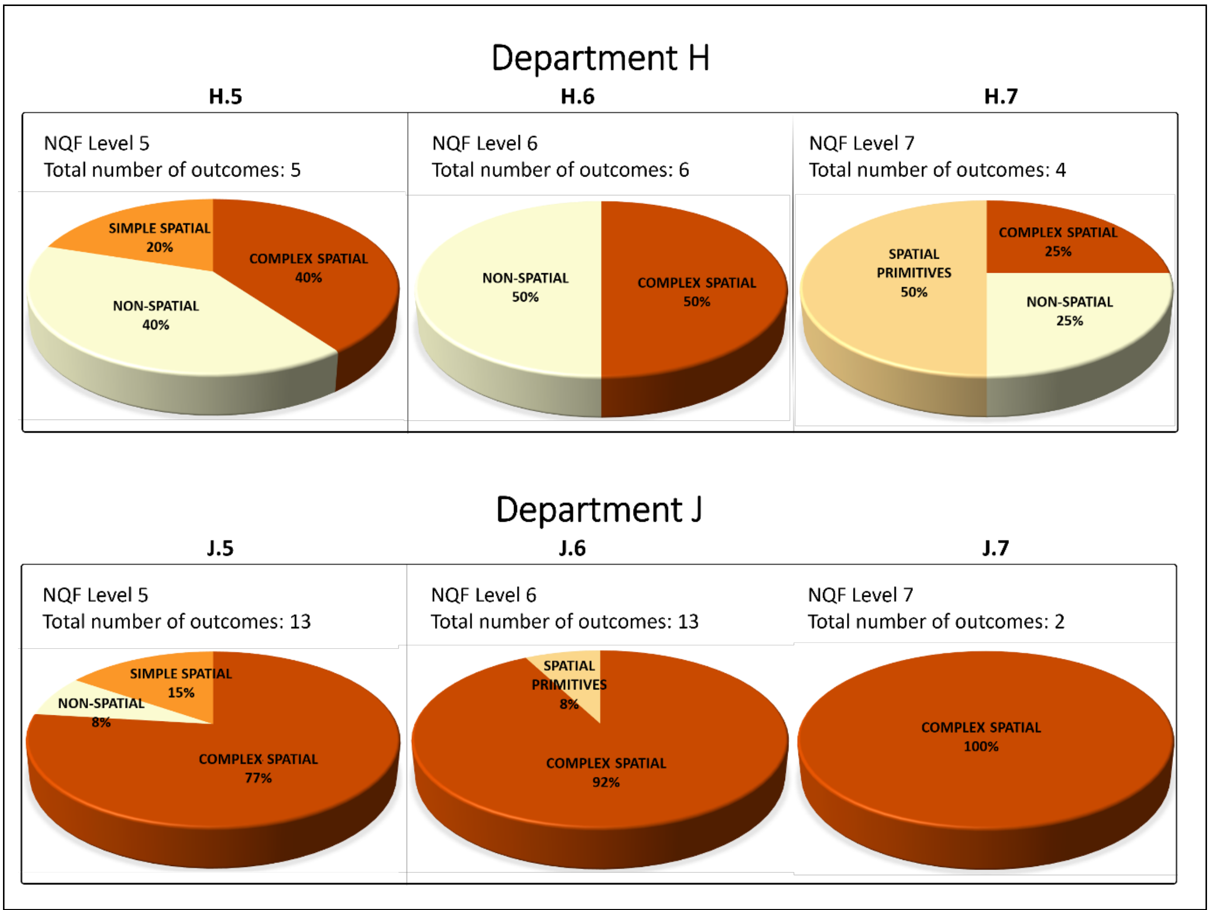


Figure 4.5: Percentage of module outcomes per concept of space, arranged per department and per NQF level.

The evaluation of NQF Level 6 shows that three of the six modules (A.6, E.6 and H.6) include outcomes with a non-spatial component. The inclusion of a non-spatial concept of space varies between 0% (B.6, F.6 and J.6) and 57% (A.6). Only one module (J.6) includes outcomes with a primitive spatial concept of space, and one (F.6) includes outcomes with a simple spatial concept of space. The inclusion of complex spatial concepts of space for this NQF level varies from 43 % (A.6), 92% (J.6) to 100% (B.6).

The NQF Level 7 evaluation shows that four of the six modules (A.7, B.7, E.7 and H.7) incorporate non-spatial concepts of space in their outcomes, varying from 25% (H.7 to 100% (F.7 and J.7). However, except for Department H, most of the module outcomes per department on this NQF level use complex concepts of space. Department H is an exception and includes 50% of the outcomes on the level of spatial primitives and 25% each on the simple and complex spatial levels. Departments F and J are at the opposite end of the scale in that 100% of their outcomes on NQF Level 7 are on a complex spatial level.

Since Geography investigates phenomena in space, it could be expected that module outcomes should reach a complex spatial level and that outcomes at the non-spatial level should be kept to a minimum. The research results indicate a high occurrence of non-spatial concepts at all NQF levels in the outcomes of the modules offered by Departments A and H. This is a matter of concern as modules with many outcomes embodying non-spatial concepts of space are at risk of not reaching the desired level of spatiality to develop the spatial thinking abilities of students. Some non-spatial outcomes could be expected from the modules on NQF Level 5, but for such concepts to develop the spatial thinking ability of students, the former would need to find applications in space. In the case of Departments A, E and H, the increase in the percentage of outcomes with non-spatial components from NQF levels 5 to 6 is therefore cause for concern.

For the modules on NQF levels 6 and 7 offered by Departments B, F and J, and focusing on Human Geography and Geospatial Applications, 100% of the outcomes are on a complex spatial level. This serves as a benchmark since Geography is a discipline investigating phenomena in space with its primary aim expected to focus on complex spatial phenomena on NQF Level 7.

As opposed to those departments with modules presenting with 100% complex spatial outcomes, the modules presented in Department F and, to a certain extent, Department J, are regarded as illustrative of a developmental path for outcomes reflecting lower level concepts of space. The module outcomes for Department F on NQF Level 5 include simple spatial concepts of space (50%) and complex spatial concepts of space (50%). On NQF Level 6, the outcomes for F.6 that include simple spatial concepts of space decline to 33%, while the outcomes with complex spatial concepts of space increase to 67%. All the module outcomes on NQF Level 7 for Department F include complex spatial concepts of space. In the case of Department J, the module outcomes on NQF Level 5 include non-spatial concepts of space (8%), simple spatial concepts of space (15%) and complex spatial concepts of space (77%). On NQF Level 6, the outcomes for J.6 with complex spatial concepts of space increase to 92%, with eight percent (8%) presenting with primitive spatial concepts of space. All the outcomes on NQF Level 7 include complex spatial concepts of space. Department J should reconsider the outcomes reflecting primitive spatial concepts of space on NQF Level 6 and replace these with outcomes on a simple spatial level.

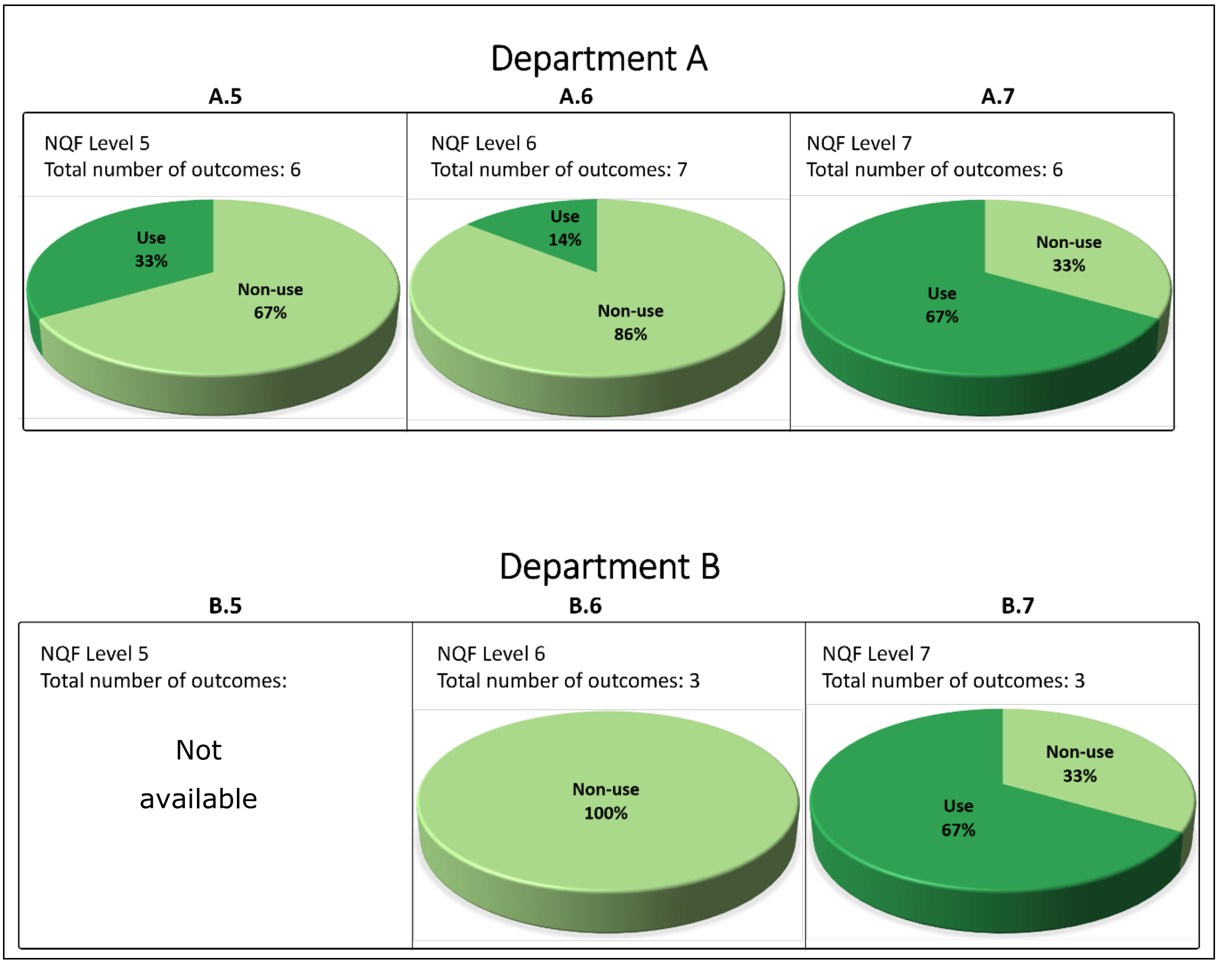
4.8.3 Evaluation and discussion of results for the analysis according to representation tools

Figure 4.6 summarises the results of the evaluation of module outcomes in terms of the inclusion or non-inclusion of a representation tool or tools. The evaluation is straightforward in that it simply distinguishes between the use and non-use of representation tools such as a graph, map, globe or GSTs.

In general, all modules on all NQF levels, except one (J.7), include outcomes excluding the use of representation tools. The non-use of representation tools varies from 0% (J.7) to 100% (B.6, E.6, H.5, H.7 and J.5.). The outcomes of five of the modules do not include the use of representation tools (B.6, E.6, H.5, H.7 and J.5). In their outcomes, the remaining modules that incorporate the use of representation tools vary from 14% (A.6) to 100% (J.7) of the outcomes.

The non-use of representation tools in module outcomes on NQF Level 5 varies from 50% (F.5) to 100% (H.5 and J.5). Two of the five modules on NQF Level 5 do not include the use of representation tools (H.5 and J.5), while two others present with more outcomes without the use of a tool than with one (A.5 and E.5). The remaining module on NQF Level 5, F.5, presents with 50% of its outcomes without the use of representation tools and 50% of its outcomes with tools.

There are more outcomes for modules on NQF Level 6 that do not incorporate the use of representation tools than for outcomes using them. In fact, representation tools are excluded from the outcomes of two of the modules (B.6 and E.6). The use of representation tools on NQF Level 6 varies from 0% (B.6 and E.6) to 33% (F.6) of the outcomes.



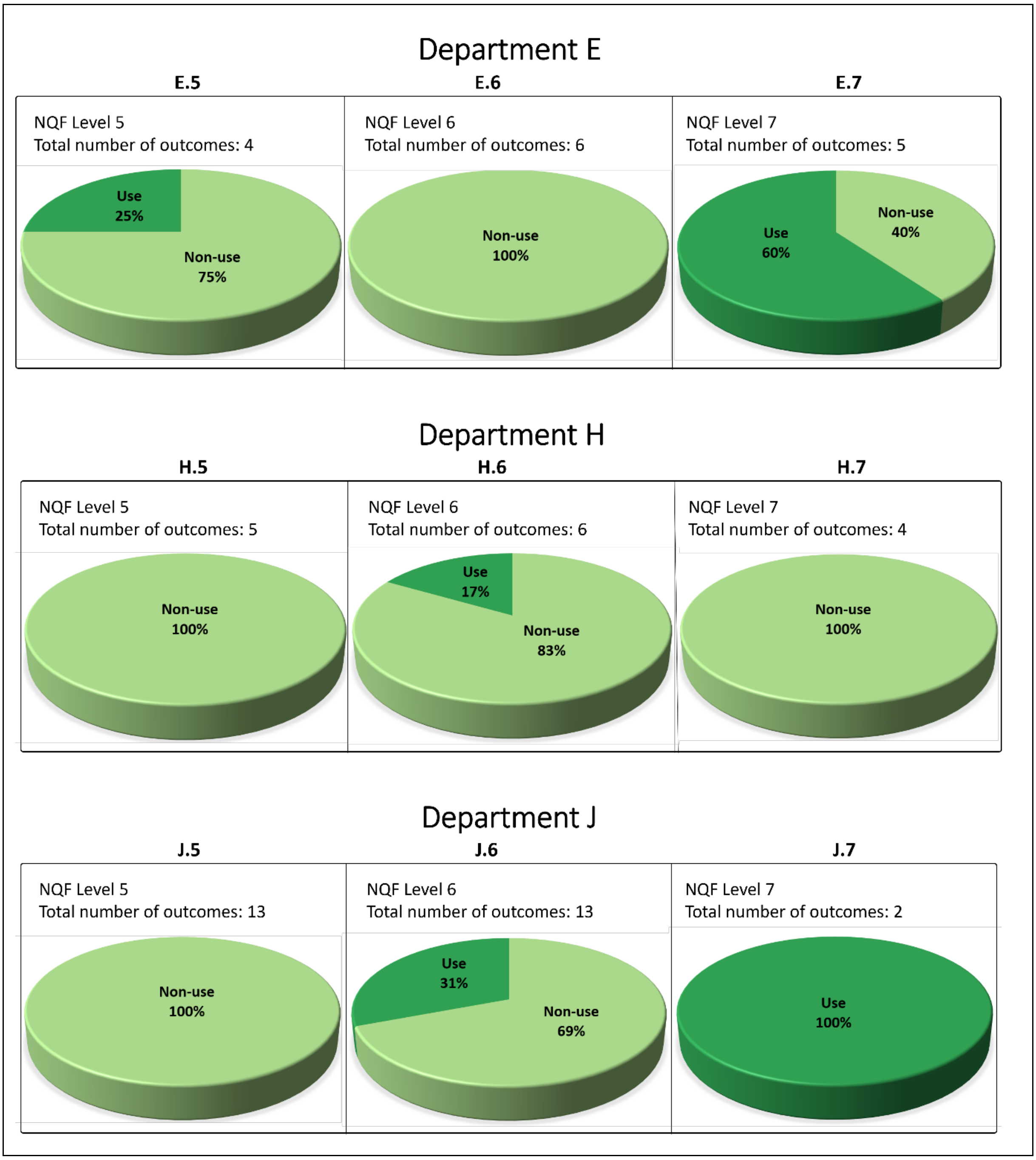


Figure 4.6: Percentage of module outcomes that include representation tools arranged per department and per NQF level.

On NQF Level 7, three of the five modules (A.7, B.7, E.7, F.7 and J.7) present with more outcomes that include representation tools than those without them. One module (H.7) includes no representation tools in its outcomes, while one module (J.5) includes 100% of its outcomes involving the use of such tools.

Since Geography is by nature a visual and creative discipline (De Jager, 2014), one would expect a high usage of visual material such as videos, graphs, charts, globes and maps in various forms. To develop the spatial thinking abilities of the students, the inclusion of a representation tool or preferably more than one tool is essential on all NQF levels.

The high prevalence of the non-use of representation tools in the module outcomes that were evaluated is a matter of concern. The use of representation tools is essential for developing the spatial thinking abilities of students and should be included from NQF levels 5 to 7. However, the only module that includes the usage of representation tools in 100% of its outcomes is on NQF Level 7, is on Geospatial Applications and is offered by Department J.

4.9 The integration of the three components of spatial thinking

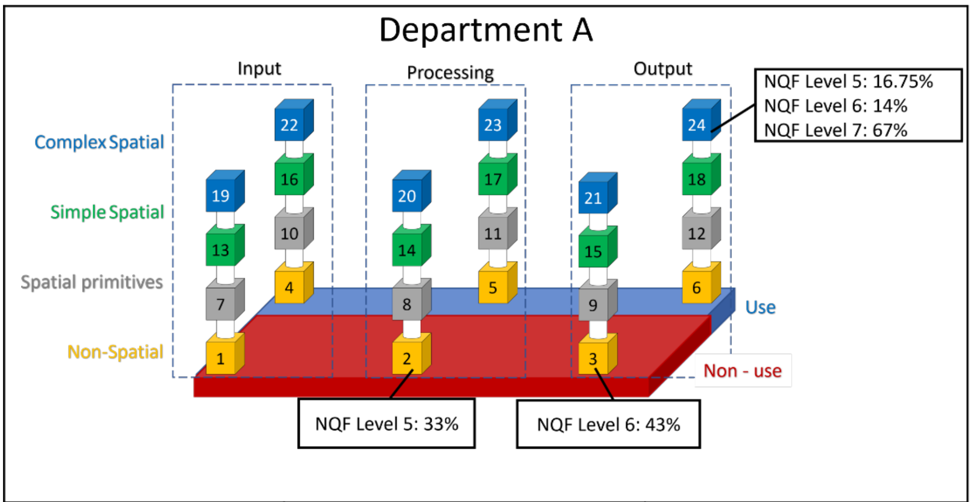
The preceding evaluation and discussion of the results of the analysis of the outcomes of the identified 18 modules at six Geography departments at universities in South Africa according to the respective cognitive levels, concepts of space and representation tools serve as indicators of the inclusion of spatial thinking in the outcomes of the selected modules (National Research Council, 2006). These indicators are combined in the taxonomy of spatial thinking (Jo & Bednarz, 2009), which was used in the next step of this research to perform a more precise evaluation of how spatial thinking is incorporated into the module outcomes. (Refer to Chapter 2, Section 2.3.2, for a detailed explanation of the taxonomy of spatial thinking.) Figure 4.7 summarises the results of the evaluation of the module outcomes against the taxonomy of spatial thinking per department. The total number of outcomes and the percentage of the modules per department and NQF level that integrate all the spatial thinking components are also indicated in Figure 4.7. Blocks with a cell value of 10, 11, 12, 16, 17, 18, 22, 23 and 24 integrate the three components of spatial thinking sufficiently to foster the development of students' spatial thinking skills.

The results of the evaluations against the taxonomy of spatial thinking should be interpreted cautiously. Firstly, the number of outcomes per module varies greatly. The module with the lowest number of outcomes, namely two, is the one from Department J on NQF Level 7. The module with the largest number of outcomes, namely 22, also from Department J, is on NQF Level 6. Secondly, this research assumes that with the teaching of the module content, an equal number of notional hours are assigned to each of the outcomes. However, in some instances, this may not be the case. Lastly, the results should not be applied to compare departments against one another but rather to determine whether and how spatial thinking is included in the curriculum of a specific department and to detect whether there is an increase in the complexity of spatiality in the module outcomes from NQF levels 5 to 7.

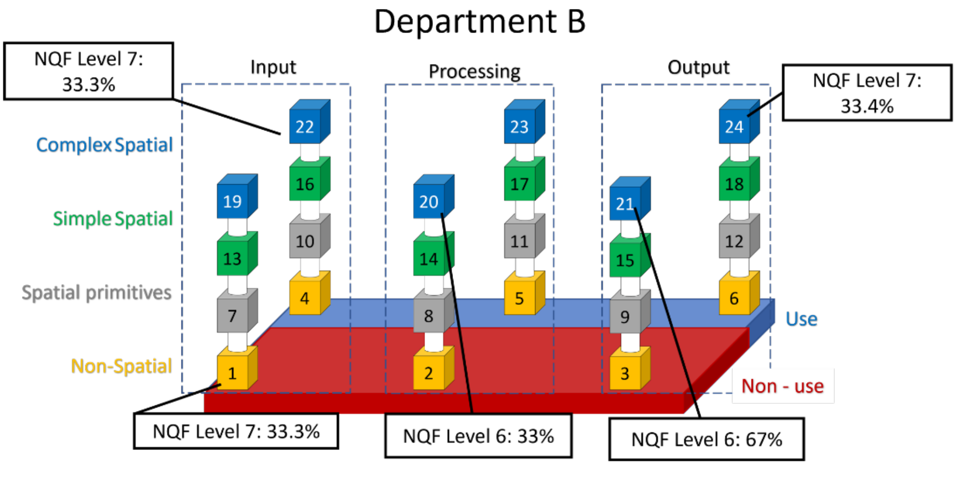
Considering all six department together, the spatiality of the 107 module outcomes (as indicated in the taxonomy of spatial thinking) varies from a cell value of 1 to 24, (e.g.

B.7, H.5 and F.6, F.7) and the integration of the three components of spatial thinking varies from 0% (B.6, E.6 H.5, H.7 and J.5) to 100% (J.5). The results indicate that only 24% of all 107 outcomes on all the NQF levels for all six the departments include all three components of spatial thinking. On both NQF levels 5 and 6, only 13% of the outcomes integrate the three components of spatial thinking, while the corresponding percentage is 56% on NQF Level 7. Although all the departments have outcomes with a cell value of 24, it is only Departments A and F that have outcomes with a cell value of 23 or 24 on all the NQF levels.

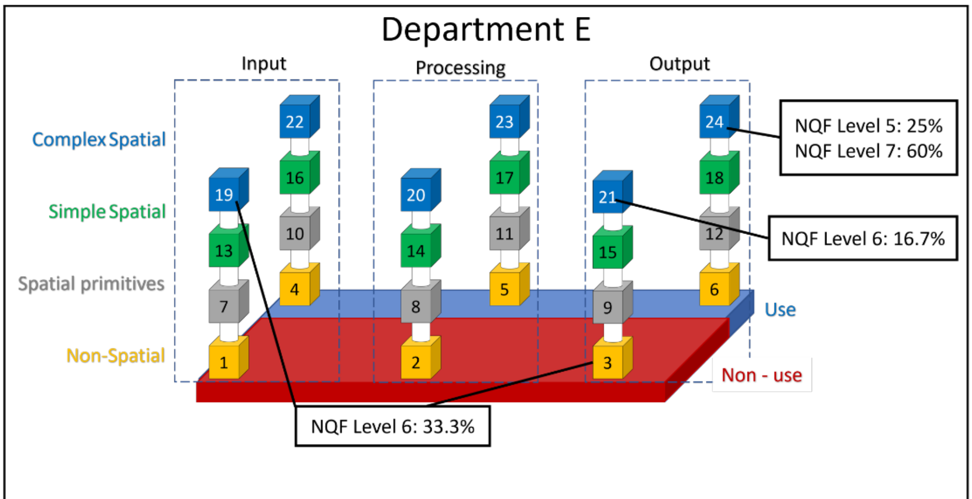
A low percentage of outcomes per department integrates all the components of spatial thinking. One NQF Level 7 module (J.7) presents with a 100% integration of the components of spatial thinking. This is a module on Geospatial applications. For other departments and modules, the integration of the three components of spatial thinking drops to 67% and lower. Only Departments A and F do not have modules with a 0% integration of the three components of spatial thinking, while the other four departments, namely, B, E, H and J, all have a module on one or more of NQF levels 5, 6 or 7 that does not integrate the three components of spatial thinking.



A.5 Integrated = 16.75% N = 6			A.6 Integrated = 14% N = 7			A.7 Integrated =67% N = 6		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
2	33%	2	1	14%	1	2	16.5%	1
3	16.75%	1	3	43%	3	3	16.5%	1
14	16.75%	1	21	29%	2	**24**	**67%**	**4**
21	16.75%	1	**24**	**14%**	**1**			
24	**16.75%**	**1**						

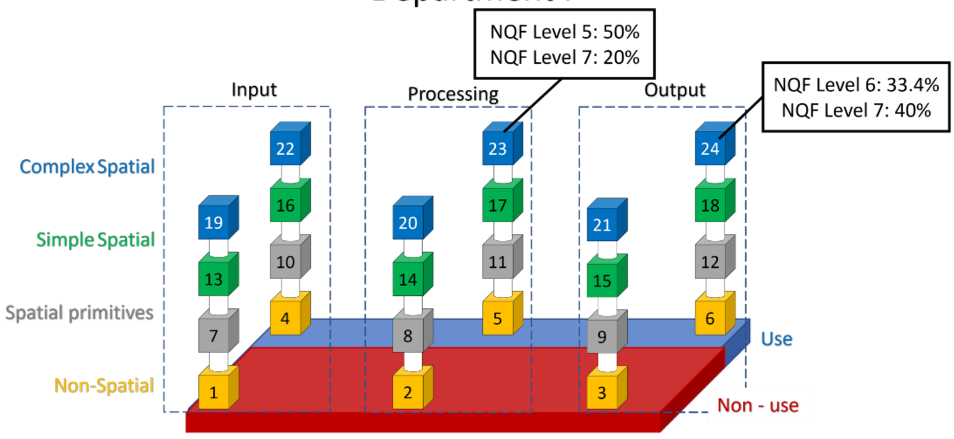


B.5			B.6			B.7		
Integrated = N =			Integrated = 0% N = 3			Integrated =67% N = 3		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
Not available			20	33%	1	1	33.3%	1
			21	67%	2	**22**	**33.3%**	**1**
						24	**33.4%**	**1**



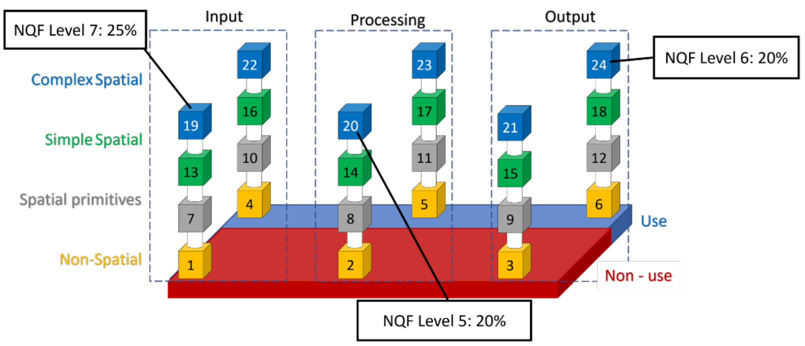
E.5			E.6			E.7		
Integrated = 25% N = 4			Integrated = 0% N = 6			Integrated =60% N = 5		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
3	25%	1	3	33.3%	2	1	20%	1
19	25%	1	19	33.3%	2	20	20%	1
21	25%	1	20	16.7%	1	**24**	**60%**	**3**
24	**25%**	**1**	21	16.7%	1			

Department F

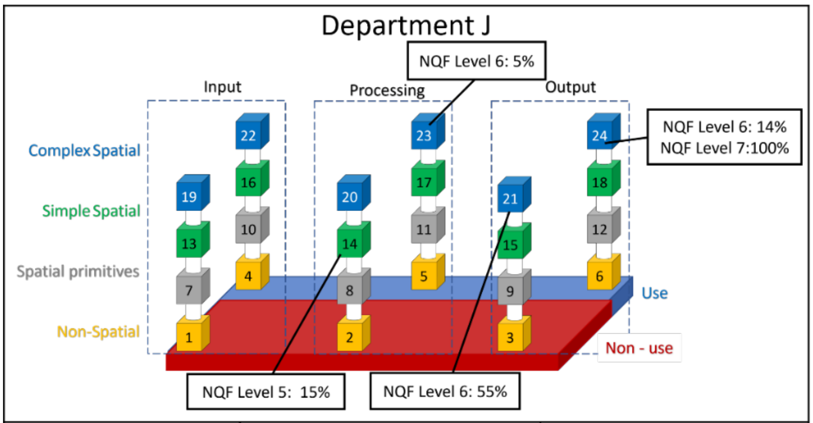


F.5 Integrated = 50% N = 4			F.6 Integrated = 33.4% N = 3			F.7 Integrated =60% N = 5		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
13	25%	1	14	33.3%	1	21	40%	2
14	25%	1	19	33.3%	1	**23**	**20%**	**1**
23	**50%**	**2**	**24**	**33.4%**	**1**	**24**	**40%**	**2**

Department H



H.5 Integrated = 0% N = 5			H.6 Integrated = 20% N = 6			H.7 Integrated =0% N = 4		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
1	20%	1	1	20%	1	1	25%	1
2	20%	1	2	20%	1	8	25%	1
14	20%	1	3	20%	1	9	25%	1
19	20%	1	19	40%	2	19	25%	1
20	20%	1	**24**	**20%**	**1**			



J.5 Integrated = 0% N = 13			J.6 Integrated = 19% N = 22			J.7 Integrated =100% N = 2		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
2	8%	1	2	5%	1	**23**	**50%**	**1**
14	15%	2	7	5%	1	**24**	**50%**	**1**
20	10%	10	14	5%	1			
			20	14%	3			
			21	55%	12			
			23	**5%**	**1**			
			24	**14%**	**3**			

Figure 4. 7: Evaluation of the module outcomes against the taxonomy of spatial thinking. (For clarity, only the cell values with the most prominent spatiality are indicated on the graph. Spatiality in bold text refers to the integration of all the components of spatial thinking.)

There is no clear indication that the departments have implemented a strategy to develop the spatial thinking abilities of their students from NQF Level 5 through to NQF Level 7. Cell values such as one (1), two (2) and three (3) on the taxonomy of spatial thinking indicate that no spatial thinking is included in the outcomes. Such low cell values are not preferred for outcomes for Geography modules offered at the undergraduate level. In addition, the generally low level of integration of the three components of spatial thinking in the 18 modules which have been considered in this research indicates that based on the spatiality of the outcomes, the students' spatial thinking abilities will not be developed adequately.

Two factors that need to be kept in mind when assessing the inclusion of spatial thinking in module outcomes are that the outcomes demonstrate the preferred exit level a student should reach after completion of the module and that spatial thinking can be learnt at any age (National Research Council, 2006; Newcombe & Stieff, 2012). In addition, Geography is involved with teaching spatiality, spatial decision-making and spatial problem-solving. Regardless of the NQF level, it could be expected that each module will reach a high spatial level (e.g., cell values of 24, 23 or 18) on the taxonomy of spatial thinking.

4.10 Synthesis of the spatiality of module outcomes

The course descriptions in faculty brochures form an integral part of any module and they might be the first connection that a prospective student has with a module which he/she might potentially register for. This might lead to a first impression as to whether spatial thinking could be included in the module, or not. This demonstrates the importance of a carefully considered, well-formulated module description. The various application fields in Geography could learn from the way in which module descriptions in Human Geography are formulated, with many references to or phrases included indicating that spatial thinking constitutes part of the syllabus.

Since the outcomes of the modules demonstrate the preferred exit level of students, it could be expected that Geography modules, especially those on the higher NQF levels, should include a high percentage of outcomes on an output cognitive level and incorporate complex concepts of space combined with the use of representation tools. Such outcomes would integrate the three components of spatial thinking and adequately develop students' spatial thinking skills. The results of this research indicate that of the 18 Geography modules, only one module on NQF Level 5 (Department E), four modules on NQF Level 6 (Departments A, B, E and J) and three modules on NQF Level 7 (Departments A, E and F) present with the largest number of outcomes on an output level. Modules on an output cognitive level, for example, would enable students, when given a specific scenario, to predict, hypothesise or forecast changes. Modules that do not attain this cognitive level might not reach the preferred level of spatiality to develop the spatial thinking skills of students.

The use of complex spatial concepts in some of the module outcomes is encouraging. Although only two modules on NQF Level 5 (Departments E and J) define most of their outcomes as being applicable to a complex spatial level, four modules on NQF Level 6 (Departments B, E, F and J) and five modules on NQF Level 7 (Departments A, B, E, F and J) present most of their outcomes on a complex spatial level. Two of the modules on NQF Level 7 (Departments F and J) define all their modules on a complex spatial level, which would enable students to solve real-world problems by, for example, investigating the density of phenomena, interpreting patterns, performing spatial and visual overlays and investigating issues on different scales.

There is cause for concern when it comes to the use of representation tools in the module outcomes. An outcome percentage of close to 100 % would be ideal in the case of applying representation tools. Although the use of maps is inherent in the case of Geospatial applications, one could argue that the use of representation tools should intrinsically be part of any Geography module on any NQF level. Since it is a tedious process to register changes in the outcomes of modules with SAQA, it may be that no representation tool is mentioned in several of the outcomes, but that it may in fact be used when lecturing content to the students. Therefore, it is essential to investigate exactly how the module content is communicated to the students.

The findings of this research indicate that the modules displaying the highest integration of the components of spatial thinking, namely, 67% (Departments A and B on NQF Level 7 and 100% (Department J on NQF level 7) in their outcomes are those focusing on Geospatial Applications. Most (71%) of the module outcomes do not integrate the three components of spatial thinking, with five modules presenting with an integration level of 0% (one module for each for Departments B, E and J and two modules from Department H). This research assumes that each outcome carries the same number of notional hours. However, in reality a specific number of notional hours would be allocated to each outcome, but this information is not available. It might also be that more time would be spent on the outcomes with a higher cell value on the taxonomy of spatial thinking, especially on NQF Level 7.

None of the departments demonstrates clear spatial thinking development paths and a high level of integration in respect of all the NQF levels. The results indicate that the module outcomes are developed in isolation without considering the spatiality at which other modules are offered. If the outcomes of a module attain a high cell value on NQF Level 7, there should be a clear developmental path to foster the spatial thinking abilities of the students as they proceed with their studies. The development of spatial thinking abilities should transcend module boundaries and be undertaken as a concerted effort within each department.

4.11 Reflection on the nature of undergraduate Geography in South Africa

This chapter provided a reflection on the historical development of Geography at the undergraduate level at South African universities, with focus on the inclusion of spatial thinking in modules with a spatial focus. Geography departments in South Africa have developed along similar historical lines and were influenced by the political environment from the early 1900s to the 1970s, political unrest and the establishment of GIS and Environmental Science in these departments, followed by a period of growth in student numbers, research outputs and the development of new curricula.

This chapter also touched on some local and global perspectives on teaching and learning Geography. The review of published research indicated that local universities have similar challenges and opportunities to those located in other parts of the world. Many of the challenges experienced by local and other universities, such as gender inequality (Newcombe & Stieff, 2012), differences in educational background (Bednarz, 2019) and achievement gaps in the STEM subjects (Uttal & Cohen, 2012; Bednarz, 2019) can be addressed by integrating spatial thinking in a more direct way into the Geography curriculum (Bednarz, 2019). Unlike the case of the local universities, various research projects regarding the inclusion of spatial thinking in Geography curricula at the school and university levels have been conducted internationally.

An initial desktop study indicated that spatial thinking is not sufficiently incorporated into Geography curricula at South African universities. To determine more precisely whether and how spatial thinking is integrated into the Geography curricula of South African universities, the outcomes of all undergraduate Geography modules were scrutinised, and 21 modules offered by six Geography Departments were identified as appropriate for including in the study. The outcomes of the identified 21 modules were evaluated against the taxonomy of spatial thinking, whereupon 18 modules that would make the best contribution to this research were identified. Integral theory played an essential role in achieving the objective of this chapter as it allowed for the use of a tested instrument, the taxonomy of spatial thinking, to be combined with the researcher's experience in teaching at a higher education institution. The combination of a tested instrument, combined with professional experience, allowed for an outside ('I') perspective as well as an outside ('it') perspective of the objective.

The results indicated that the module outcomes do not generally attain the preferred cognitive level and that representation tools are largely lacking in the definitions of the module outcomes. However, most of the module outcomes include reference to a complex concept of space. The results of this research indicate that the three components of spatial thinking are not significantly integrated into most of the module outcomes and that there is no clear increase in complexity from NQF levels 5 to 7 to develop the spatial thinking capabilities of students. Thus, the module outcomes appear to have been developed in isolation without consideration of the level of spatiality at which other modules in the same department are offered. A concerted effort should be made by each department to develop the spatial thinking abilities of its students in an integrated way.

While Chapter 4 focuses on what is taught in the Geography curricula and specifically on the level of spatiality included in module outcomes, Chapter 5 focuses on how the curriculum content is conveyed to the students.

Chapter 5: Teaching spatial thinking

5.1 Introduction

Geography education should offer skills, subject knowledge, generic attributes and discipline-specific capabilities contributing to a lifelong learning experience and sustainable development (Walkington et al*.*, 2018; Fu, 2020). Spatial thinking is listed as one of the discipline-specific capabilities that Geography education should offer (Ibid). In addition, the use of GST in Geography education has become widespread, and the location of phenomena in space and how Geographers think about space, matters more than ever (Metoyer & Bednarz, 2017; Zhu & Turner, 2022). To address challenges in the 21st century, Geography students should learn to think critically, analyse problems from a spatial perspective (Silviariza & Handoyo, 2021) and obtain the necessary geo capabilities to address complex problems (Walkington et al., 2018). Although spatial thinking is complex (Gersmehl & Gersmehl, 2011), it is an important skill to acquire (Metoyer & Bednarz, 2017). With the aid of, amongst others, GST, spatial thinking leads to the understanding and interpretation of natural and cultural phenomena and interactions between these phenomena (Collins, 2018b).

Geography lecturers should include spatial thinking in their teaching methods with the aim to develop students' spatial thinking skills (Verma & Estaville, 2018). Therefore, lecturers should be positively dispositioned to include spatial thinking in their teaching methods (Jo & Bednarz, 2014; Lee et al., 2018). In fact, without the inclination to include spatial thinking in the teaching of Geography, lecturers are not likely to incorporate the components of spatial thinking in their teaching strategies and processes (Lee et al., 2018).

To develop the spatial thinking abilities of students, emphasis should be placed on *what* is taught to students and *how* content is conveyed to students (Bednarz, 2019). This chapter critically evaluates *how* the content of the selected undergraduate Geography modules for this research is conveyed to students. The aim is to determine whether the way spatial thinking is included in fact supports the development of students' spatial thinking skills. To this end the lecturers of these modules were engaged with an interview and a questionnaire was specifically conducted to determine the disposition of the interviewed lecturers towards teaching students spatial thinking.

The methodology applied to obtain the necessary information on which this chapter is based is situated in the UL (the questionnaire to determine the disposition of the interviewed lecturers) and UR (the interviews with lectures) quadrants of the AQAL model. The lecturers of the sampled modules were interviewed by the researcher from an inside ("I") perspective and the interview data were interpreted qualitatively from an outside ("I") perspective. The disposition of the lecturers toward teaching spatial thinking was measured quantitatively from an outside ('It') perspective using a questionnaire developed by Jo and Bednarz (2014).

A search of peer-reviewed articles found that very little research has been conducted globally on the inclusion of spatial thinking in the teaching methods of lecturers and their disposition towards teaching spatial thinking within the higher education context. Even less (if any) research has been conducted in the South African context.

5.2 Integration of spatial thinking in teaching and in study material: contextual setting

Geography is characterised by core competencies such as interdisciplinary, holistic and spatial thinking (Sandham & Retief, 2016). Spatial thinking is situated within Geography, the only discipline in which many theories and methods has a spatial component (Lobben & Lawrence, 2015). In addition, empirical research has proven that Geography is more effective than other disciplines in teaching spatial thinking skills to students (Verma & Estaville, 2018). However, the success that will be achieved with this depends on whether the education system (i.e., teacher practices, curricula, textbooks, assessments, etc.) is geared to pro-actively support the teaching of spatial thinking (Jo & Bednarz, 2009).

The building blocks to developing the spatial thinking abilities of students demand an understanding of spatial thinking concepts such as location, distance, scale and patterns (Jo & Bednarz, 2014). In addition, the ability to read and interpret patterns and processes in visual representations such as maps is critical (Collins, 2018b). Research by Verma and Estaville (2018) suggests that undergraduate Geography courses could develop students' much-needed spatial thinking capabilities, such as the analysis of patterns, profiles, transitions, spatial associations, shapes and overlays. These concepts are all on a complex spatial level in the taxonomy of spatial thinking (Jo & Bednarz, 2009). The research by Verma and Estaville (2018) also suggests that students who have completed five or more Geography modules have higher level spatial thinking skills in comparison with students who have completed fewer Geography modules.

5.2.1 Teaching practices to develop spatial thinking

A primary focus of Geography lecturers should be on preparing graduates who can think spatially (Silviariza & Handoyo, 2021). Therefore, Geography teaching should go beyond facilitating the mere memorisation of facts and also aim to develop students' spatial thinking skills (National Research Council, 2006; Jo & Bednarz, 2011; Ishikawa, 2013).

While knowing about and understanding basic facts is important, it does not serve much purpose if this does not find application within the field of Geography (Bednarz, 2019). To achieve this, Geography teaching needs to instill applications, not only of basic knowledge, but also higher level reasoning (Ishikawa, 2013).

Teaching Geography to develop critical thinking (including spatial thinking) within the discipline of Geography should not only involve problem-based learning (PBL) but also *spatial* problem-based learning (SPBL) (Silviariza & Handoyo, 2021). Like spatial thinking skills, problem-solving skills represent a highly developed cognitive process (Charcharos et al., 2016). Therefore, undergraduate Geography modules should be regarded as opportunities to improve the spatial thinking skills of students through PBL and SPBL (Verma & Estaville, 2018).

Research by Silviariza and Handoyo (2021) suggests that conventional content-based Geography teaching leads to students becoming passive listeners in the classroom, relying on the lecturer to convey subject content. In this way, the lecturer becomes the primary source of information, and students rely on her/him to solve problems (Ibid). Furthermore, research suggests that when posed with problem-solving challenges, students are reluctant to source information and instead rely on arguments that are not necessarily factually based. Also, they are not enthusiastic about participating in group discussions (Silviariza et al., 2021). On the other hand, when applying SPBL, students were found to be more inclined to actively source information and to critically use the information to solve problems.

Lecturing and guidance directly focused on spatial thinking is needed to develop a spatial habit of mind (SHOM) and to constantly exploit spatial thinking skills when addressing problems (Bednarz & Bednarz, 2008). Furthermore, the long-term retention of information and the application of knowledge to address challenges occurs when lectures are designed to force students to perform spatial tasks (Gersmehl & Gersmehl, 2007). Therefore, students will benefit in a number of ways if spatial thinking has a prominent place in the curriculum (Ibid).

To develop students' spatial thinking skills, the study material should lead them to identify and assess the data needed to address spatial problems, identify uncertainties in spatial data and integrate spatial data in terms of spatial and temporal scales (Bearman et al., 2016). Once relevant data sets have been selected, the students should be able to, amongst other skills, identify and evaluate the appropriate methods of spatial analysis needed to solve a spatial problem on the correct scale and to understand the interconnectivity of real-world phenomena (Ibid). A spatial thinker should also move beyond the natural observable Euclidian spaces and should have the skills to model phenomenological spaces. The final step is to communicate the results of spatial analysis appropriately (Bearman et al., 2016). Spatial thinking can only be developed once a student has effectively mastered all these skills, which are also necessary for addressing and solving real-world problems (Ibid).

Lecturers need to adopt a spatial perspective when teaching Geography to empower students to become spatially intelligent (Goodchild et al., 2014). Critical spatial thinkers should have an advanced level of understanding of spatial perspectives such as location, distance and direction, neighbourhood and region, scale, spatial dependence and spatial heterogeneity. The lack of attention to spatial intelligence leaves a person unable to use a spatial perspective to address challenges, thus leading to the indiscriminate use of spatial tools (Goodchild et al., 2014). In addition, lecturers should deliberately use spatial language in precise ways to further enhance spatial learning (Newcombe & Stieff, 2012).

Research by Silviariza and Handoyo (2021) emphasises the importance of applying a relevant learning model to ensure active student participation in the Geography learning process to develop students' spatial thinking skills and develop a SHOM (Kim and Bednarz, 2013b; Nursa'Ban et al., 2020) The inclusion of a spatial perspective to develop spatial thinking should not be interpreted as an addition to the curriculum, but instead, as an essential way of interpreting the curriculum (Nursa'Ban et al., 2020)

5.2.2 Tools for teaching spatial thinking

Spatial thinking can be taught to students through various tools such as spatial or analogue maps (Collins, 2018b), globes (National Research Council, 2006) and digital globes (Collins, 2018a), GIS, graphs, models, flowcharts (National Research Council, 2006), GPS (Flynn, 2018) and even through hand gestures (National Research Council, 2006; Ormand et al., 2017).

Using photographs from the astronauts' International Space Station collection has proven the effectiveness of using tools to teach spatial thinking (Ghaffari et al., 2018). In their research project, Ghaffari et al. (2018) gave their students assignments based on photographs from the International Space Station. The spatial concepts required by the assignments to locate and analyse the images were noted and measured against the taxonomy of spatial thinking. The results indicated that the photographs from the space station are valuable tools for teaching spatial concepts and developing spatial thinking skills (Ibid).

Maps are an essential tool when teaching spatial thinking to students as they are the starting point for Geographical Science teaching (Duarte, 2018). When learning spatial thinking, representation tools , such as maps, are beneficial to all students of different ages, genders, cultures and experiences (Newcombe & Stieff, 2012). Spatial thinking skills can be improved through the use of paper or digital maps (Collins, 2018b) and even concept maps (Flynn, 2018).

Research by Liu et al. (2010) concluded that students who use PBL, but without GIS technology, showed more effective rote learning and memorisation skills at a lower cognitive level. Students who use GIS in PBL developed better analytical and evaluation skills and were able to adopt a more critical approach when comparing and evaluating factors relating to problem-solving at a high cognitive level (Liu et al., 2010). Although the use of GIS improves students' spatial thinking skills, it has not outperformed in developing spatial thinking skills in all aspects thereof (Lee & Bednarz, 2009). For example, as opposed to a web-based GIS exercise, a hands-on paper exercise has proved to be equally successful in teaching students the concept of overlays (Jo et al., 2016). While the use of GIS and digital globes requires students to engage in higher levels of spatial thinking, there is no evidence to the effect that the same high level of spatial thinking cannot be reached through the use of paper maps or other teaching methods based on lower levels of technology (Collins, 2018b).

Regardless of the tools used, the spatial thinking capabilities of students can be developed only as long as students are asked to personalise their spatial thinking, since practical reasoning and related processes are, in fact, personal capabilities (Walkington et al., 2018). Students can personalise spatial thinking when their coursework encourages them to take control of their study area, allowing them the freedom to make choices and be creative in geographical investigations (Walkington et al., 2018).

Computer technology, including the use of Geospatial tools, has an impact on the way that instruction takes place and complements traditional classroom teaching (Collins, 2018a). Although spatial thinking can be taught to students through the medium of paper maps and low-level technology methods, the inclusion of Geospatial technologies in Geography teaching improves students' attitudes, motivation and achievements (Baker, 2002). Furthermore, including Geospatial tools in teaching material and thus facilitating the acquisition of the necessary knowledge and skills through the use of these tools improves students' employability (Moolman & Donaldson, 2016). As such, Geospatial tools play a prominent role as a visual tool for teaching spatial thinking at the tertiary level at South African universities (Baker, 2002; Moolman & Donaldson, 2016; Collins, 2018a) .

5.2.3 Using Geospatial technologies to teach spatial thinking

Geospatial technologies (GSTs - that includes GIS, remote sensing, GPS and web maps) has become readily available and has been integrated into many day-to-day activities and into the lives of 21st-century students (Nielsen et al., 2011). As a result, GSTs now forms part of contemporary life and has become indispensable (Ibid). In addition, GSTs includes a crucial component of specialised applications in various career fields (Nielsen et al., 2011).

Spatial thinking has been described as one of the cornerstones of Geography, and GIS, specifically, has become the primary tool used to support the development of spatial thinking skills (Liu et al., 2010). The research of Bearman et al. *(2016)* and Kim and Bednarz 2013a) focused on GIS as a tool to teach spatial thinking. Bearman et al. (2016) proved that GIS strengthens students' spatial skills, such as their use of spatial tools and concepts, pattern recognition, spatial description and visualisation. Since Geography focuses on the interrelatedness of phenomena, this discipline, incorporating GIS, is ideally placed for developing students' spatial thinking skills (Bearman et al., 2016). In addition, students with a knowledge of GIS have a better understanding of data reliability, are able to use spatial concepts to describe, compare and analyse data and can evaluate a problem in context (Kim and Bednarz, 2013b). Students with GIS knowledge are also prepared to use other Geospatial tools to address real-world problems (Ibid). These are all essential characteristics of a spatial thinker (National Research Council, 2006). Although the sample size was relatively small, research by Kim and Bednarz (2013a) proved that GIS knowledge and skills are beneficial in developing students' spatial thinking skills (Kim & Bednarz, 2013a). GIS students also have the opportunity to evaluate spatial representations and apply spatial analysis, thus enhancing their spatial thinking skills (Ibid). They have generally acquired higher-order thinking skills than students who have not completed GIS courses (Ibid). Lee and Bednarz (2009) found no statistical difference between the spatial thinking skills of students who had completed a major in Geography as opposed to those who had completed an Engineering major. However, students from both these groups were able to improve their spatial thinking abilities after having completed a course in GIS (Lee & Bednarz, 2009).

The mere inclusion of GST in course material will not necessarily improve a student's spatial thinking abilities; however, students demonstrate more significant gains in basic Geography facts and content knowledge of a Geography module than when they do pen-and-paper exercises. (Metoyer & Bednarz, 2017). Lecturers should be careful not to develop a 'cookbook' type of approach (Pye, 2014 in Bearman et al. 2016) or *buttonology* (Fombuena, 2017) where students are only required to follow steps to run the GIS software. Although students should know which buttons to press, they should also understand the logic of the software and the implications of their decisions concerning the output (Fombuena, 2017).

The inclusion of GIS to teach Geography should initially be opaque, and the focus may be more on obtaining the necessary skills and knowledge of GIS rather than on the course content (Madsen & Rump, 2012). However, the course material should support the students in making the GIS tool transparent and to be used as a means to focus on the module content and to support them in their endeavours to become spatial thinkers (Madsen & Rump, 2012). Manuals should encourage geographic thinking by asking students to apply what they have learned at the end of each GIS exercise (Ibid). The use of GIS as a tool is not neutral in that it influences the way students observe and comprehend geographical issues (Madsen & Rump, 2012). Through the teaching process, the use of GIS should become transparent, with the focus on module content (Madsen & Rump, 2012). The use of GIS to convey course content can be extended to include any scientific instruments and, in the case of Geography, any representation tools (Ibid). For PBL to take place, the focus should be on solving the problem at hand and not only on how to use the GIS technology (Liu et al., 2010)

GIS is often taught in a broader, more integrated way in first-year modules, followed by a stand-alone module (usually an optional module) in a subsequent year. Unfortunately, the stand-alone modules often lack integration with Geography and do not demonstrate how GIS can be used to address real-world challenges (Bearman et al., 2016). Therefore, stand-alone GIS modules should rather focus on a well-developed problem/problems or a theme/themes and not only on the use of GIS technology (Liu et al., 2010).

Since the initial research on GIS as an effective tool to teach spatial thinking, research has been extended to prove the effectiveness of all GSTs to develop the spatial thinking skills of students, e.g., GPS (Flynn, 2018; Lee, 2020), remote sensing (Ghaffari et al., 2018) and web maps (Jo et al., 2016; Manson et al., 2014). The effectiveness of other GSTs, such as mobile technology, has also been proven to develop students' spatial thinking skills. The use of mobile technology in inquiry-based fieldwork has enabled students to be more aware of their environment, to improve their inquiry skills and behaviours and to effectively improve skills relevant to the 21st century (Lee, 2020). The effectiveness of GSTs to develop spatial thinking skills has also been confirmed by research conducted by Jo et al. (2016) focusing on the use of web maps. The results of their research indicate that web-based GIS effectively improves student understanding of geographic data types, map symbols and spatial thinking skills.

Research by Metoyer and Bednarz (2017), suggests that, like GIS, the inclusion of any GSTs in Geography thinking does not necessarily improve students' spatial thinking skills. The correct use of GSTs can extend a student's abilities to understand spatial concepts and to think spatially if explicit attention is paid to teaching strategies, such as geographical inquiries, that develop a student's spatial thinking skills (Metoyer & Bednarz, 2017). Although students may be able to use geospatial tools, the absence of a geographically-based inquiry process may limit their ability to apply the appropriate spatial thinking skills necessary to address real-world challenges (Verma & Estaville, 2018). Although school teachers in the USA have reported on numerous issues, such as the distraction caused by the use of this type of technology, thus leading to a lack of focus on the course content, GSTs and spatial thinking have developed into a critical part of the modern world, and therefore lecturers should equip themselves to gain confidence in using GSTs as instructional tools (Collins, 2018a)

The teaching of spatial thinking, supported by GSTs, forms the foundation of an innovative Geography curriculum (Bednarz, 2007 in Madsen & Rump, 2012). While most of the research conducted to date focused on GIS as a GST, the notions could be extended to include all GSTs. However, the successful implementation of these strategies depends on the educator's disposition to include GSTs to develop students' spatial thinking skills (Jo & Bednarz, 2014).

5.2.4 Disposition of teachers and lecturers towards teaching spatial thinking

Research regarding the disposition to include spatial thinking in Geography teaching focuses on school teachers (Newmann, 1990; Nursa'Ban et al., 2020) or pre-service teachers (Jo & Bednarz, 2014; Lee et al., 2018). The disposition to teach spatial thinking through Geography is defined as the teacher's inclination, tendency, or beliefs in respect of the necessary skills, knowledge, and tools to develop students' spatial thinking skills (Jo & Bednarz, 2014). More than 30 years ago, Newmann (1990) proposed a list of teacher dispositions that might influence the development of a student's thinking skills. These dispositions should encourage students to support statements with motivations, reflect on problems rather than to accept the views of others, explore new questions to find creative and original solutions and to be thoughtful within the classroom setting (Newmann, 1990). Possessing these dispositions does not guarantee that the teacher will necessarily include spatial thinking in the curriculum (Jo & Bednarz, 2014). However, considering the importance of spatial thinking in Geography teaching, the teacher must be prepared and willing to incorporate spatial thinking into the curriculum (Ibid). A teacher should have the necessary skills and knowledge to teach spatial thinking and have the disposition to do so (Lee et al., 2018). A teacher who frequently incorporates spatial thinking in his/her teaching material often has the disposition to do so increasingly and in a way that develops the spatial thinking skills of students (Nursa'Ban et al., 2020).

Jo and Bednarz (2014) developed an assessment tool that can be used to measure the disposition of teachers in respect of teaching spatial skills (Jo & Bednarz, 2014). This assessment tool was used by Lee et al. (2018) to determine the disposition of pre-service teachers in Korea and China towards the teaching of spatial thinking. The results of this study show that although the pre-service teachers strongly believe in the importance of spatial thinking, their knowledge of the concept was inadequate (Lee et al., 2018). In addition, while the pre-service teachers believed that GSTs could be used to teach spatial thinking, they had limited confidence in their own abilities to use GSTs in their teaching practices (Ibid). It is therefore important for student teachers to learn about and master spatial thinking at the undergraduate level (Verma & Estaville, 2018). In fact, student teachers with poor spatial thinking skills will not be able to contribute to the development of the spatial thinking skills of their school learners (Ibid).

Jo and Bednarz (2014) indicated that most research focuses on filling the gap in incorporating spatial thinking in the school curriculum, classroom activities and technologies to develop spatial thinking, while very little research in fact has a focus on the disposition of teachers towards teaching this critical skill. This lack of research on the disposition of teachers has been confirmed by Lee et al. (2018).

A search on the internet indicated that research regarding the disposition of school teachers and university lecturers towards teaching spatial thinking is still largely lacking. No research articles regarding the disposition of university lecturers towards teaching spatial thinking could be found.

5.3 Positioning the way in which module content is conveyed and the disposition of lecturers participating in this research within the AQAL model

The interviews conducted with the lecturers participating in this research are in the UL quadrant of the AQAL model, allowing for a subjective "I" perspective. (Refer to Chapter 3, Section 3.4 for more detail.) During the interviews, the lecturers shared their experiences and practices relating to their teaching of Geography to a class of students. (Refer to Annexure B for the interview guide.) These interviews were recorded and then transcribed. The tools and approaches used by the lecturers to convey the content to students were noted during the interviews. The transcribed information was then interpreted and assessed against the taxonomy of spatial thinking. To this end, the transcribed material was scrutinised to determine whether the three components of spatial thinking, namely the concepts of space, tools of representation and processes of reasoning, had been included in the teaching methodologies followed by the lecturers.

The process of assessing the transcribed material against the taxonomy of spatial thinking is based on the researcher's experience in teaching at higher education institutions. Since a tested instrument (the taxonomy) is used, the process of assessing the material against the taxonomy of spatial thinking — but based on the experience of the researcher — is partially located in the UR quadrant. Since the assessment is also based on the experience of the researcher, and therefore on her subjective view, it is also partially located in the UL quadrant. The UR and UL quadrants allow for an outside 'It' and 'I' perspective, respectively. (Refer to Chapter 3, Section 3.4, for more detail.)

The responses to the open-ended interview questions were further analysed using Atlas TI. Because Atlas TI requires the researcher to identify input parameters to detect patterns and connections within the qualitative data, this process is also partially based on the researcher's experience and is, as such, located in the UL quadrant of the AQAL model. The interviews, assessments against the taxonomy of spatial thinking and the analysis of data within Atlas TI were based on the experience of both the interviewed lecturers and the researcher and were therefore conducted from an outside (the researcher's) and inside (the interviewed lecturer's) 'I' perspective. The assessment of the results of the interviews against the taxonomy of spatial thinking was conducted from an outside ('It' and 'I') perspective.

The measurement of the disposition of the lecturers is positioned in the UR quadrant of the AQAL model since it is an existing instrument. The researcher interpreted the questionnaire results from an outside ('It') perspective.

The NQF levels within the AQAL model represent levels of development or profundity (depth) in the left-hand quadrants (UL and LL) and demonstrate holarchy because the higher NQF levels surpass the lower NQF levels in profundity. The spatiality of the taxonomy of spatial thinking is applied as lines within the AQAL model and demonstrates a sequential development of complexity levels. The disposition of lecturers to teach spatial thinking constitutes the states within the AQAL model. Only one state may be true at a time – a lecturer is well disposed or not to teaching spatial thinking. The states within an AQAL model may change at any time, meaning a lecturer who did not previously include spatial thinking in his/her teaching may become dispositioned to do so. The application fields within Geography represent the types within the AQAL model and resemble a stable pattern.

5.4 Teaching of spatial thinking in undergraduate modules at selected Geography departments in South Africa

The lecturers of the selected modules were interviewed to determine further insights into the course content and how the material is taught on the various NQF levels. The purpose of the interviews was to determine whether and how Geography lecturers incorporate spatial thinking into their lectures for undergraduate students.

Annexure B for the thesis provides a list of the questions that were discussed with the lecturers during the interviews. Questions 1 to 5 of the interview guide were posed to gain some general background knowledge regarding the teaching experience of the lecturers. Question 6 of the interview guide focused on gaining insight into the lecturers' thought processes and considerations when developing a new module. Questions 7 to 17 of the interview guide were indirect questions to determine whether lectures are presented in such a way that students can develop spatial thinking skills and whether the latest technologies used by experts in the knowledge domain have in fact been included. These questions were open-ended and based on the underlying theory of spatial thinking and sought to determine whether the lecturer had incorporated the basic concepts of spatial thinking (the concepts of space, the tools of representation and the processes of reasoning) into lectures. The last two questions were direct questions to determine whether the lecturer is familiar with spatial thinking and can provide a definition and explanation of the concept.

As discussed in the preceding literature review for this chapter (Section 5.2), various methods can be used to teach spatial thinking (e.g., the use of a globe, GSTs, the interpretation of graphs and finding constructive solutions to problems). The methods and materials used to convey content during lectures to students were noted and described during the interviews. The assessment of the way in which module content is conveyed against the taxonomy of spatial thinking indicated whether students can and do in fact develop their spatial thinking skills and whether there is an increase in the level of complexity in spatial thinking from NQF levels 5, to 6 and to 7. Furthermore, by comparing the methods used by the lecturers against the results of the evaluation of the module outcomes against the taxonomy of spatial thinking, it was possible to determine whether there is an alignment between the complexity of conveying the module content and the complexity of the module outcomes, as presented in Chapter 4.

The responses to the open-ended questions were also analysed using ATLAS TI – a qualitative research tool. All the transcribed interviews were imported into ATLAS TI to identify key concepts considered by the lecturers in the development of a new module. The key concepts were then categorised into main concepts referred to for all the interviews taken together. The interviews with the lecturers from each department were then evaluated against these main concepts to determine overlaps and the omission of the concepts that are considered when planning a module.

The lecturers were also requested to complete a questionnaire to gauge their disposition towards teaching spatial thinking (Refer to Annexure C). The same methods as those developed and applied by Jo and Bednarz (2014) were used. The scores on the Lickert scale were processed by calculating the average score for each lecturer. An average score of above four (4) indicated that lecturers were well disposed towards teaching spatial thinking. Following Jo and Bednarz (2014), scores were also analysed per category. The results per category revealed strengths and weaknesses in the teaching of spatial thinking by the lecturers. (Refer to Chapter 3, Section 3.4.2, for a detailed explanation of the assessment tool.)

The sample size (n=15) was too small for further statistical analysis. It was expected that a low score in the spatial thinking category would correlate with a low use of the tools of representation of spatial thinking in teaching and learning material and a low overall spatiality on the taxonomy of spatial thinking.

The following subsections present the findings of the interviews per department, with diagrams indicating the key concepts for module development considered by the lecturers from each department, and highlights from the interviews indicated in text boxes.

5.4.1 Background information on the lecturers who participated in the interviews

For this research, 20 lecturers from the six selected Geography departments were contacted and invited to participate in interviews to determine their experience in teaching Geography and how they convey course content to students. Nineteen (19) of the lecturers agreed to the interview, while one preferred to respond to the questions in the interview guide in his own time and to return it to the researcher.

Table 5.1 is an expanded version of Table 4.3 (Refer to Chapter 4, Subsection 4.7.3.) and indicates the modules offered by the lecturers, their general teaching experience and their experience in specifically teaching the module that constitutes part of this.

To ensure anonymity, the names of the lecturers were replaced with the departmental code, followed by the A, B, C or D to distinguish between the lectures from each department. The module codes in this table correspond with the codes used, as explained in Chapter 4, Subsection 4.7.1.

As can be observed in Table 5.1, most of the lecturers that were interviewed have extensive experience in teaching Geography at the tertiary level. Their experience varies from three to 40 years. Almost 80% of these lecturers have ten or more years of experience teaching Geography at a higher educational institution. In addition, although not part of the questionnaire, some lecturers mentioned teaching Geography at the high school level before pursuing a career in tertiary education. Most of the lecturers (79%) teach more than one Geography module, some of which are on a post-graduate level. Most lecturers (84%) also have extensive experience — more than five years — in specifically teaching the Geography modules constituting part of this research.

Table 5.1: Modules offered by the lecturers and their teaching experience.

Anonymous name	Module code	Application fields	Lecturer code	Experience (years)	Experience in teaching current module (years)
Department A	A.5	Human Geography	AC	10	10
	A.6	Human Geography	AA	21	16
			AD	13	4
	A.7	Geospatial Applications	AB	14	10
Department B	B.5	Physical Geography	BB	32	17
	B.6(1)	Human Geography	BA	9	9
	B.6(2)	Human Geography	BC	27	27
	B.7	Geospatial Applications	BB	32	17
			BC	27	27
Department E	E.5	Human Geography	EA EB	20 40	4 10
	E.6	Human Geography	EA EB	20 40	3 10
	E.7(1)	Human Geography	EC	16	6
	E.7(2)	Geospatial Applications	ED	31	29
Department F	F.5	Human and Physical Geography	FA	36	17
	F.6	Human Geography	FB	9	9
	F.7	Human Geography	FC	34	7
Department H	H.5	Physical Geography	HC	3	3
	H.6	Human Geography	HA HB	31 22	13 20
	H.7	Physical Geography	HB	22	20
Department J	J.5	Physical Geography	JA	31	17
	J.6(1)	Human and Physical Geography	JA	31	17
	J.6(2)	Physical Geography	JB	30	2
	J.7	Geospatial applications	JC	9	9

All lecturers found it challenging to share their teaching experience and methods in respect of only the modules relevant to this study. They discussed and reflected on their teaching methods in general and were asked to emphasise the influence of the NQF level of a module on their teaching methods and practices. The information and perspectives on modules shared by the lecturers could be considered as current, as they all indicated that they review and update module content annually.

5.4.2 Considerations for module development flowing from the interviews

Regarding development of modules, only three lecturers indicated that they have no experience in developing a new module. On the other hand, almost 70% of the interviewed lecturers have over the past five years developed a new module. When asked what they would consider when developing new modules, most of them elaborated enthusiastically on the processes they would follow. The key concepts considered by all lecturers in creating a new module were identified for all the interview data using ATLAS TI and categorised in terms of main concepts: a problem-solving approach, Geography themes, students, Geography-centred, Geography tools, workplace and institutional requirements. Figure 5.1 gives an overview of the main concepts considered by the interviewed lecturers when developing a new module.

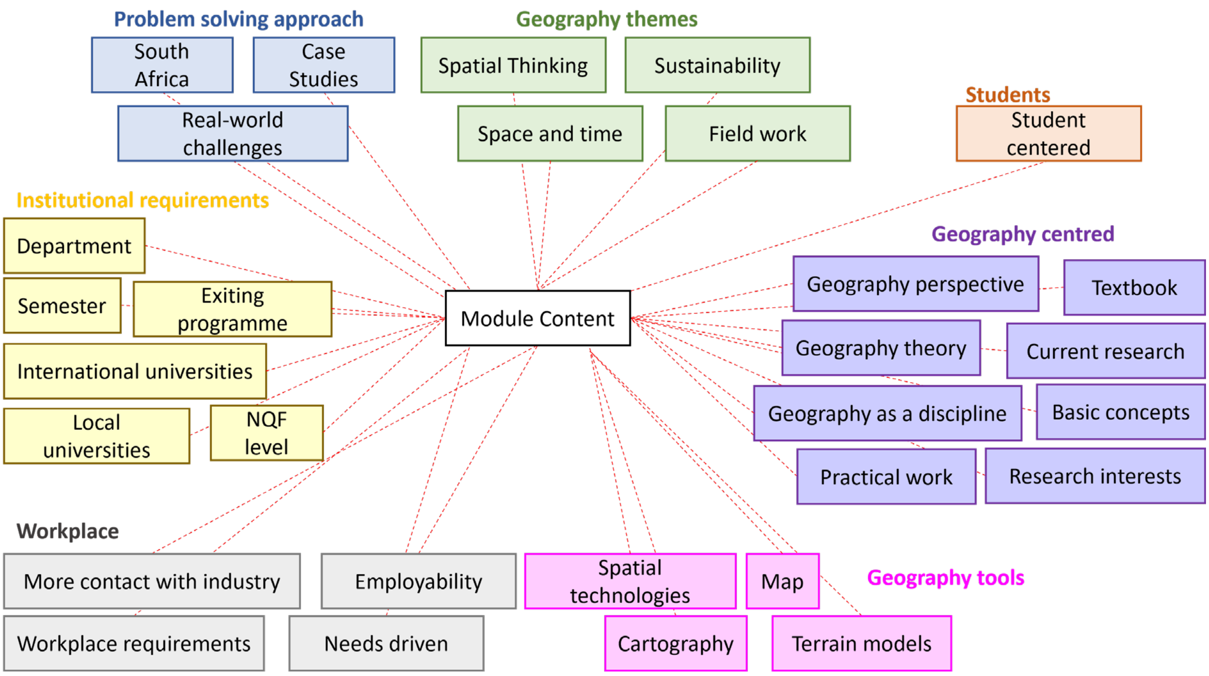


Figure 5.1: Overview of key concepts considered by the lecturers when developing a new module.

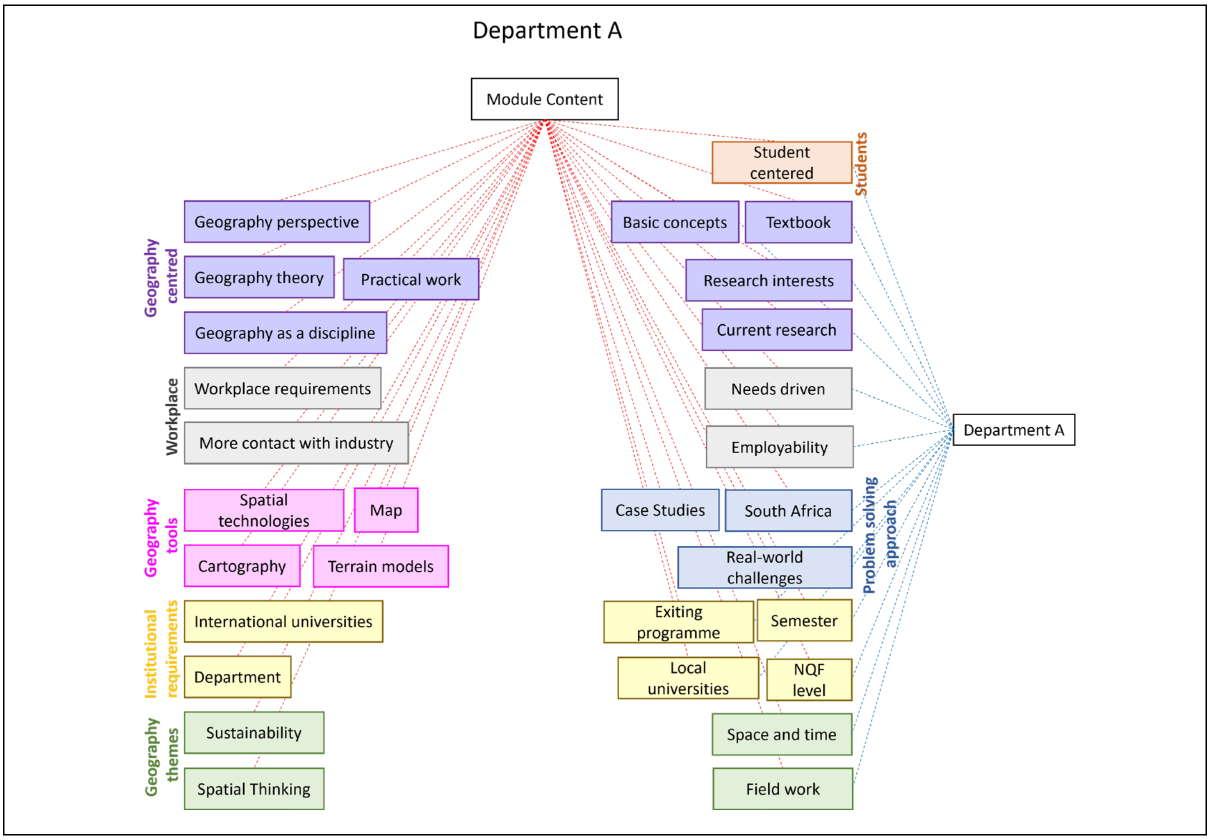
The key concept that was most frequently mentioned was "students". All lecturers indicated that they always consider the students' needs, experiences and interests, meaning that the lecturers have a student-centred approach. The second most frequently mentioned key concept was "student employability" within the South African industry.

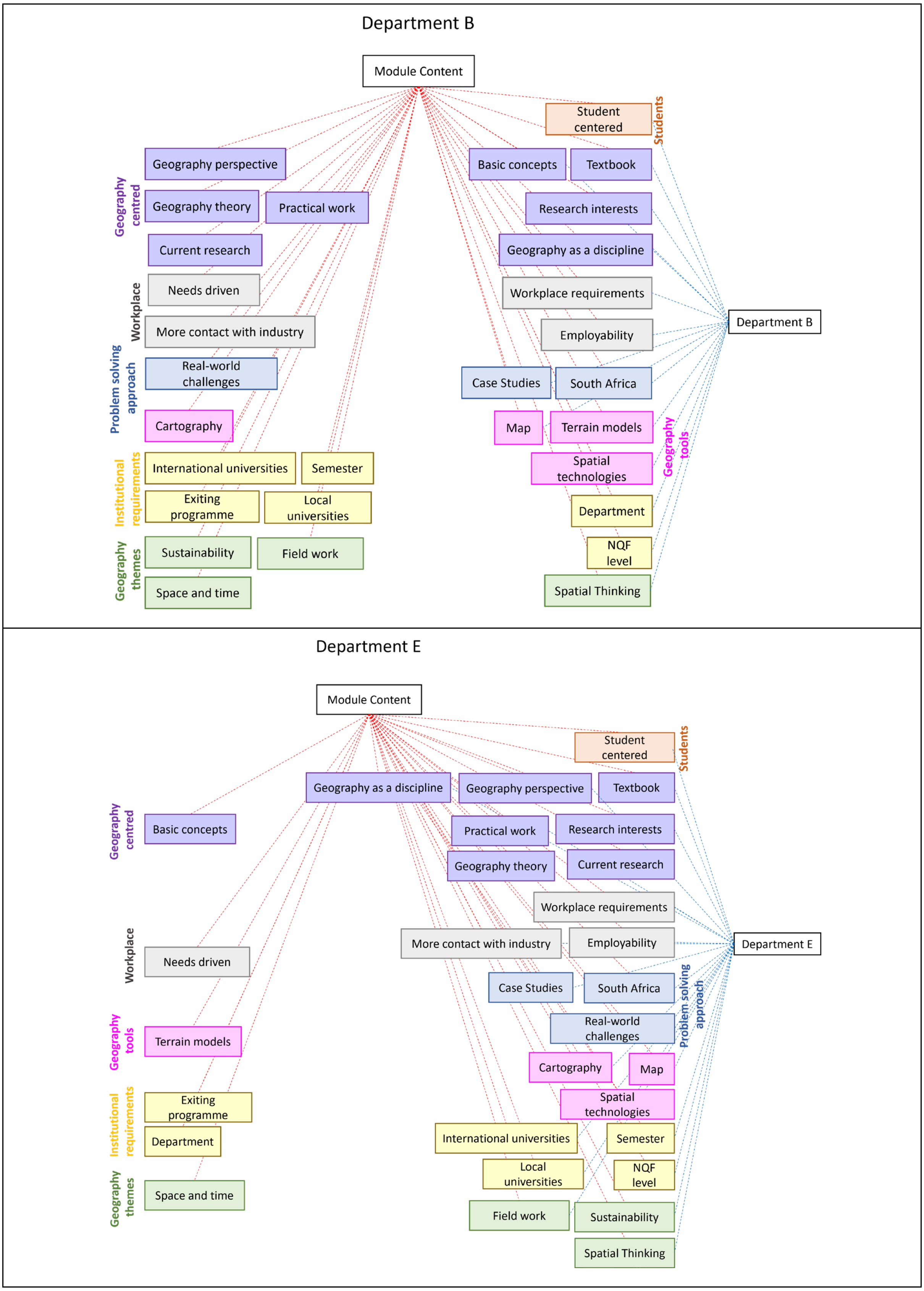
From the interviews, it was clear that in the case of developing a new module, departmental level discussions are held, but in most cases, the modules are developed by the individual lecturers. Lecturers from one department (Department F) indicated that when it comes to developing new modules, they organise a team effort on an institutional level.

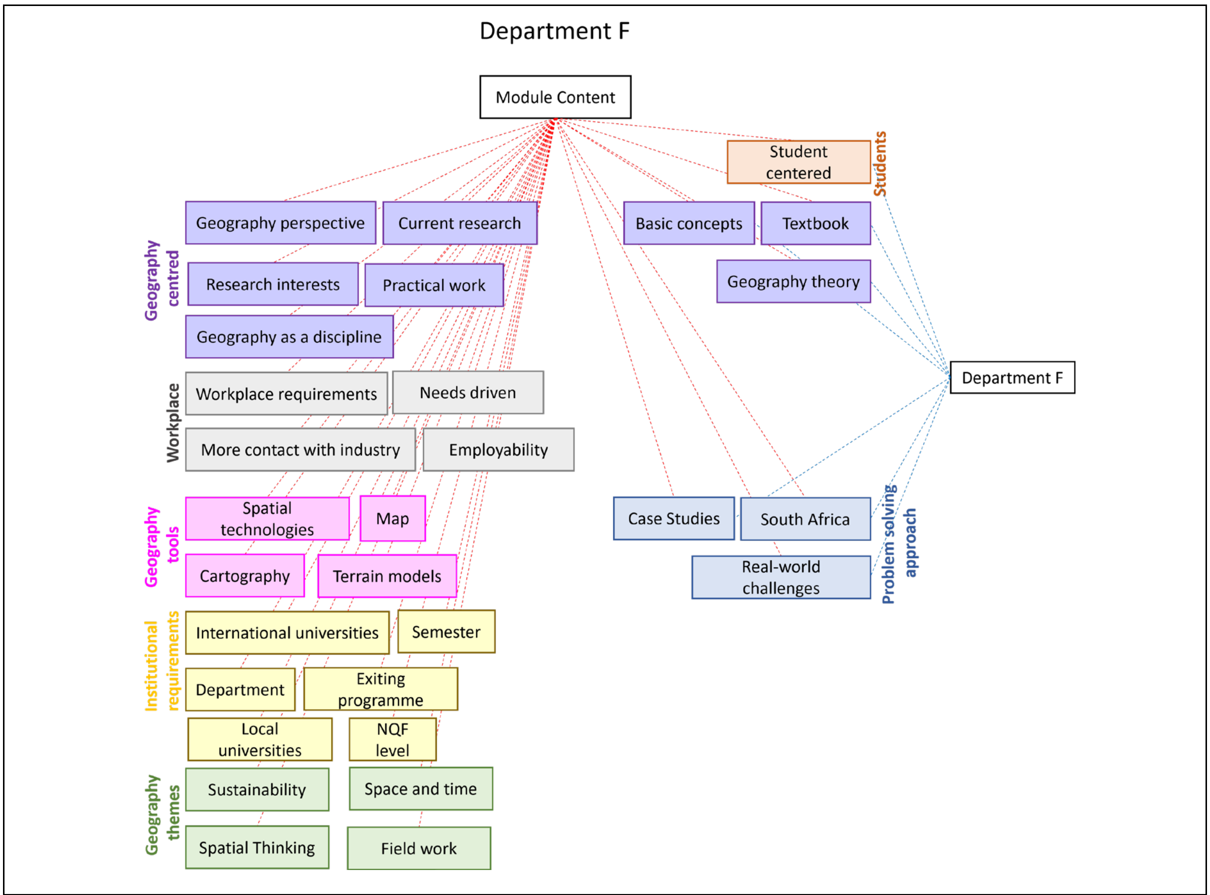
While Figure 5.1 provides an overview of the considerations of all the interviewed lecturers for module development, it is essential to understand the concepts considered by the lecturers from each department, with some differences which should be noted. Figure 5.2 summarises the key concepts considered by the interviewed lecturers when developing a new module and provides the results per department. The colours used for the different concepts in Figure 5.2 correspond with the colours of the concepts identified in Figure 5.1. The considerations for module development were not analysed per lecturer, as the lecturer responsible for offering the module in question had not necessarily developed the module and his/her input would, therefore, not contribute significantly to this research. It also became clear that the lecturers from each department have a specific approach to module development and that there are slight variations among individual lecturers.

Some observations on differences between departments are noteworthy. The interviewed lecturers from Department A included aspects of all the main concepts as identified in Figure 5.1. However, Geography tools were not considered. Interviewed lecturers from Departments B and E included aspects of all the main concepts and, most importantly, referred specifically to considering spatial thinking when developing a new module. Interviewed lecturers from Department E also referred strongly to the inclusion of a geographical tool (e.g., cartography, spatial technologies, and maps). The interviewed lecturers from Department F indicated that they have adopted a strong problem-solving approach and include aspects of Geography-centred concepts (Geography theory, textbooks, and basic concepts), and also a student-centred approach. The interviewed lecturers from Department F did not refer to Geography tools or the student's readiness for the workplace. For Department H, the interviewed lecturers included aspects of all the main concepts, except for geographical tools, and also indicated a strong student-centred approach. However, they indicated that they consider the needs of the industry (needs driven) when developing a new module. Developing a needs-driven module could also be indicative of an approach focusing on students. The interviewed lecturers from Department J considered aspects of all the main concepts except for Geography themes. During their interviews, the lecturers from this department emphasised the use of spatial technologies.

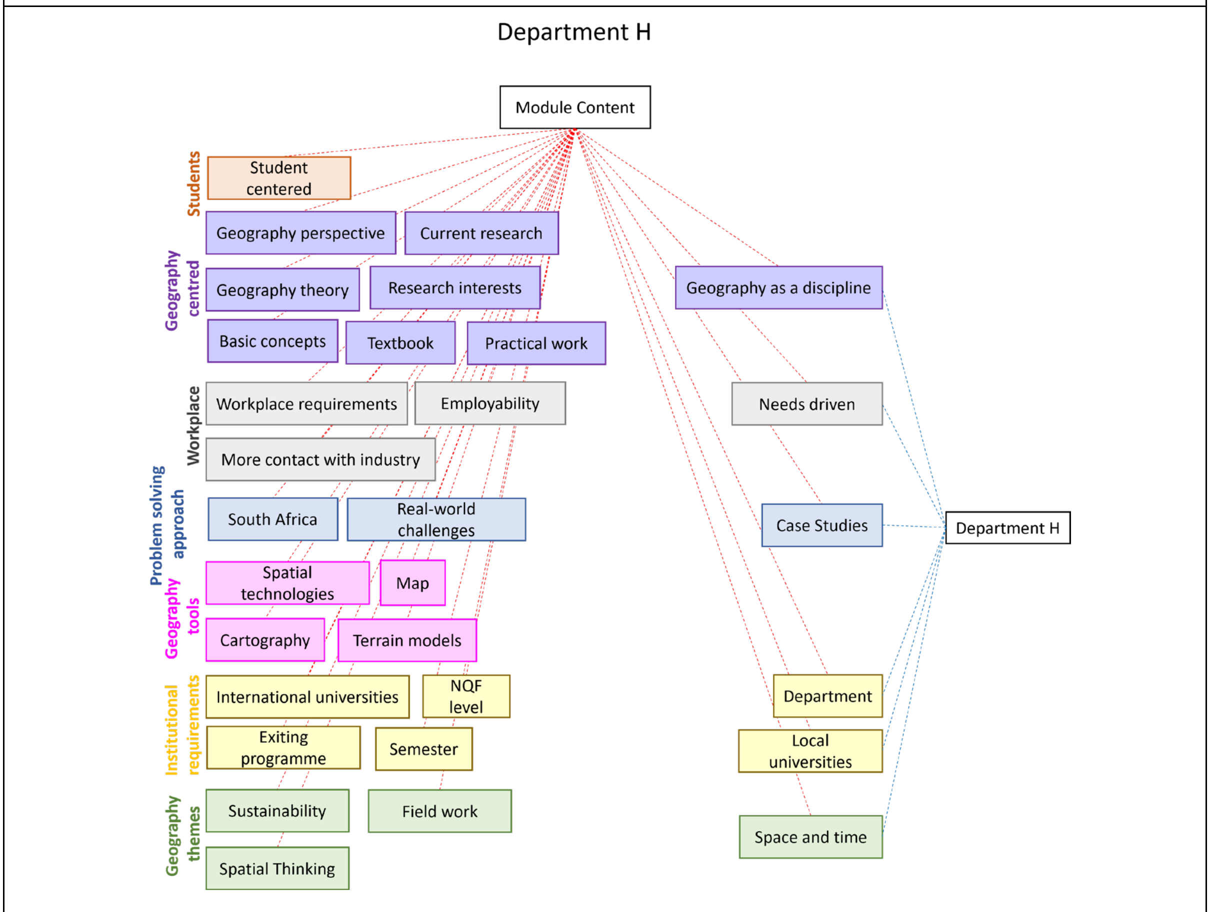
Although some overlaps emerged in the discussion of the development of new modules, each of the department's lecturers presented a unique approach. In respect of the different departments, no clear patterns of key concepts that were included or omitted by the interviewed lecturers emerged. All strongly emphasised a problem-solving approach, including real-world challenges and the local context. This might be due to the ongoing focus on the decolonisation and Africanisation of Geography curricula in South African universities.




Department B
Module Content
Students
Student centered
Geography centred
Geography perspective
Geography theory
Practical work
Current research
Basic concepts
Textbook
Research interests
Geography as a discipline
Workplace
Needs driven
More contact with industry
Workplace requirements
Employability
Department B
Problem solving approach
Real-world challenges
Case Studies
South Africa
Cartography
Map
Terrain models
Spatial technologies
Geography tools
Institutional requirements
International universities
Semester
Exiting programme
Local universities
Department
NQF level
Geography themes
Sustainability
Field work
Space and time
Spatial Thinking
Department E
Module Content
Student centered
Students
Geography centred
Basic concepts
Geography as a discipline
Geography perspective
Textbook
Practical work
Research interests
Geography theory
Current research
Workplace
Needs driven
Workplace requirements
More contact with industry
Employability
Department E
Case Studies
South Africa
Real-world challenges
Problem solving approach
Geography tools
Terrain models
Cartography
Map
Spatial technologies
Institutional requirements
Exiting programme
Department
International universities
Semester
Local universities
NQF level
Geography themes
Space and time
Field work
Sustainability
Spatial Thinking



Department F
Module Content
Student centered
Students
Geography perspective
Current research
Basic concepts
Textbook
Geography centred
Research interests
Practical work
Geography theory
Geography as a discipline
Workplace requirements
Needs driven
Department F
Workplace
More contact with industry
Employability
Spatial technologies
Map
Case Studies
South Africa
Problem solving approach
Geography tools
Cartography
Terrain models
Real-world challenges
Institutional requirements
International universities
Semester
Department
Exiting programme
Local universities
NQF level
Geography themes
Sustainability
Space and time
Spatial Thinking
Field work



Department H
Module Content
Students
Student centered
Geography perspective
Current research
Geography centred
Geography theory
Research interests
Geography as a discipline
Basic concepts
Textbook
Practical work
Workplace
Workplace requirements
Employability
Needs driven
More contact with industry
Problem solving approach
South Africa
Real-world challenges
Case Studies
Department H
Geography tools
Spatial technologies
Map
Cartography
Terrain models
Institutional requirements
International universities
NQF level
Department
Exiting programme
Semester
Local universities
Geography themes
Sustainability
Field work
Space and time
Spatial Thinking

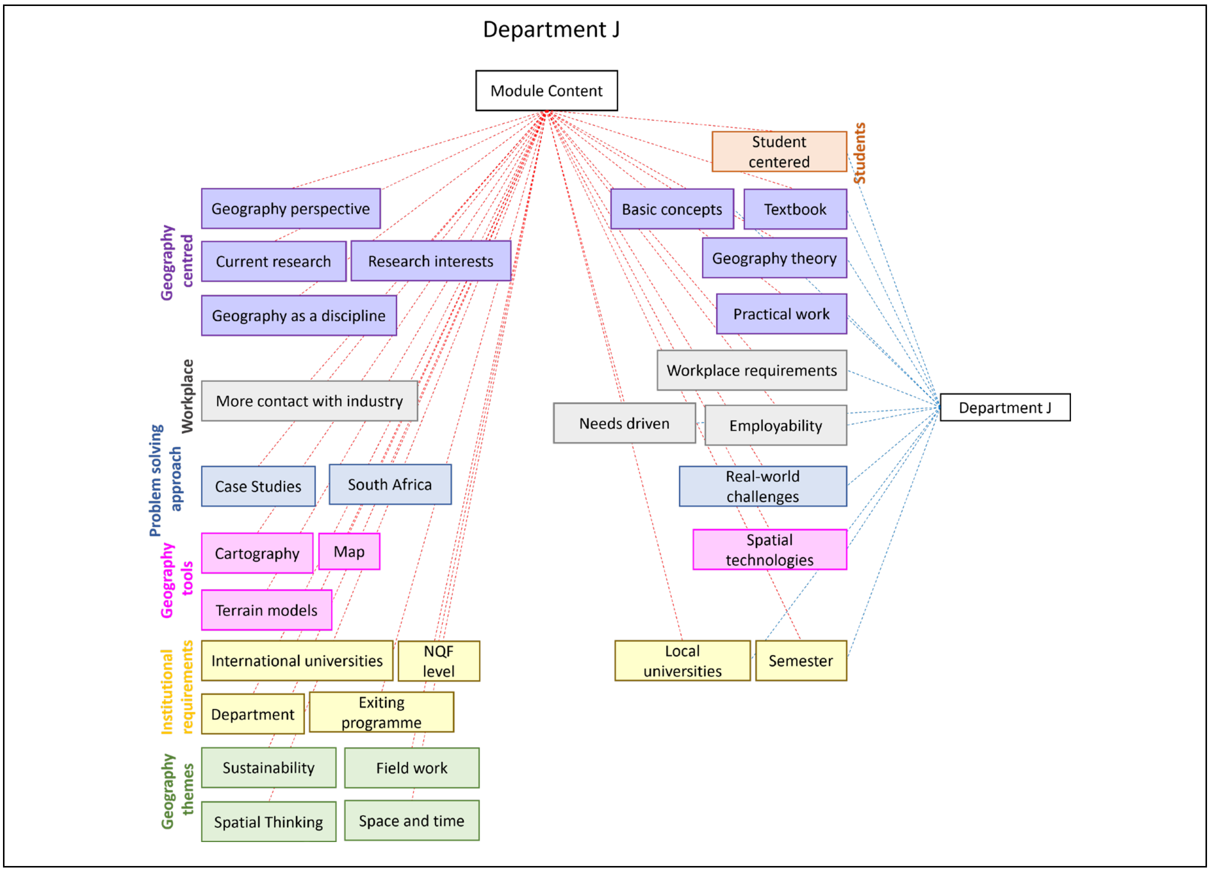


Figure 5.2: Key concepts considered by the interviewed lecturers from each department when developing a new module.

Only the interviewed lecturers from Departments B and E referred directly to the inclusion of spatial thinking when developing a new module. For Department H, the interviewed lecturers referred to space and time, which strongly indicates that spatial thinking might be considered when developing a new module. The interviewed lecturers from Departments A, B and E also frequently referred to the different NQF levels, indicating that the cognitive level of the modules was indeed a consideration. The interviewed lecturers from three departments, namely, B, E and J, mentioned the use of representation tools, while those from Departments A, F and H did not refer to any geographical tools. It is worth noting that the inclusion of Geography tools is important as such tools constitute an important component of spatial thinking.

5.5 Inclusion of spatial thinking in teaching

Based on the literature review and the researcher's experience, the way in which module content is conveyed by the interviewed lecturers were scrutinised to gauge whether the concepts of space, representation tools and higher-level reasoning processes were incorporated. The responses which were obtained to some of the questions in the interview guide and some keywords on which the analysis of the responses was based can be seen in Annexure G. The sections that follow summarise the views of the interviewed lecturers on the inclusion of spatial thinking in their teaching methods. Quoted examples of comments from the lecturers demonstrating their approach to teaching and learning are contained in the text boxes.

5.5.1 Department A: Views of the interviewed lecturers on the inclusion of spatial thinking in teaching methods

During the interviews, the lecturers of Department A emphasised spatial concepts such as the interpretation of patterns, the distribution of real-world phenomena, the use of layers to demonstrate concepts and the analysis of data and scale from a local to a global context. The use of this terminology indicates that the concepts of space are indeed represented in the modules from this department that form part of this research. The lecturers also frequently use representation tools aligned with the latest technologies to convey the module content to students.

All the lecturers of Department A indicated that they employ a spatial problem-solving approach, which requires that students follow steps to address challenges; students are also required to make predictions or use prediction models. In fact, by including models or model predictions, the reasoning process can be placed on an output level.

In some instances, however, the lecturers use outdated technologies such as paper maps or transparencies. In all these cases, the lecturers were able to justify why old-fashioned technologies are still being used. The main reason is that they believe it is to the benefit of the students. (Refer to Textbox 5.1 for an explanation by one of the lecturers.)

Text box 5.1 contains quoted examples of comments from the interviews with the lecturers demonstrating their approach to teaching and learning that could contribute to developing students' spatial skills. Analysis of the interviews conducted with the lecturers of Department A indicated that the three components of spatial thinking are included in their teaching methods. The results are summarised in Table 5.2. (Refer to Annexure G for more details.) From

> Text box 5.1: Department A
>
> *'I think that one of the major skills that geographers have is to have an analytical approach to problem-solving'.*
>
> *'I definitely think there's a time and place for having solid theories. Obviously, we still need that, but then also we try to bring it into more practical terms as well'.*
>
> ---
>
> *'So, I think I can answer this for the whole Geography course from first to third year. For instance, we still introduce the student to aerial photograph interpretation using stereoscopes, which is outdated. But we still feel, you know, that there's value in introducing them to that old technology... seeing those images jump out at them when they look at a stereoscope. We still do some of that old stuff, but then obviously we also introduce them to new technologies.*

the interviews conducted with the lecturers, it became clear that complex spatial concepts of space such as layers, projections, distributions and scale, to name a few, are included on all NQF levels when lecturing module content to students. They also use representation tools, e.g., maps and videos, to present module content and encourage students to engage on an output cognitive level in class discussions or with the module content. It is therefore clear that spatial thinking is included in the teaching methods of all the interviewed lecturers on all the NQF levels of Department A.

Table 5.2: Department A - Incorporation of the three components of spatial thinking in the teaching methods of the interviewed lecturers.

Lecturer	Module	Concept of space	Representation tools	Process of reasoning	Spatial thinking included
AA	A.6	Complex spatial	Yes	Output	Yes
AB	A.7	Complex spatial	Yes	Output	Yes
AC	A.5	Complex spatial	Yes	Output	Yes
AD	A.6	Complex spatial	Yes	Output	Yes

Table 5.3 provides a comparison between the evaluation of the spatiality of the module outcomes and the inclusion of spatial thinking in the teaching methods of the lecturers. This table provides evidence that all module outcomes reach a high level of spatiality (21 and 24 – as per the taxonomy of spatial thinking) and that the teaching methods used by the lecturers integrate all three components of spatial thinking. This provides evidence of a concerted effort by Department A to develop the spatial thinking skills of their students. This can be observed in the way the modules are presented and in the teaching methods used by the lecturers. However, the level of integration of the three components of spatial thinking in the module outcomes is low (16.75%, 14% and 67%, respectively, for NQF levels 5, 6 and 7. (Refer to Chapter 4, Figure 4.7.) Despite this constraint, the way in which the selected modules for Department A are presented, provides the students with opportunities to develop their spatial thinking skills.

Table 5.3: Department A – Spatiality of module outcomes and inclusion of spatial thinking in teaching methods of the lecturers. (Spatiality of module outcomes in bold indicates inclusion of all three components of spatial thinking.)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching
A.5	2 2 3 14 **21** **24**	AC	Yes
A.6	1 3 3 3 **21** **21** **24**	AA	Yes
		AD	Yes
A.7	2 3 **24** **24** **24**	AB	Yes

5.5.2 Department B: Views of the interviewed lecturers on the inclusion of spatial thinking in teaching methods

During the interviews with the lecturers of Department B, they referred directly to the inclusion of spatial thinking in modules and the use of GSTs in the modules they teach. Despite this, the lecturers indicated that although there is some progression from NQF levels 5 to 7, students find it challenging to apply their knowledge in an unfamiliar context. The lecturers expressed concern about the preparedness of students to study at university level. They partially attribute the seeming lack of spatial thinking skills to deficiencies in the school education system. They feel that school learners do not learn about spatial thinking at the school level and, therefore, enter the tertiary level

Text box 5.2: Department B

..but I also think that our students are coming in without the basic critical thinking skills and we are certainly finding an inability for them to just troubleshoot the problem ….like solve the problem. We're seeing that increasingly… so, the school is not preparing them for that.

And then their basic sort of spatial thinking isn't really encouraged either, I don't think, at school level. So, when we get first years in there, …. they can't actually look at a map and interpret it. You know, they can't actually see the information and convert that into an understanding or knowledge about that space.

But they're very happy to repeat things to you, but when it comes to linking ideas and especially like the spatial thinking, it can be very frustrating to get those thinking patterns in line for those students.

unprepared. Text box 5.2 contains examples of the feedback from the lecturers of Department B regarding their view of the level of preparedness of students to study at a tertiary institution.

Department B developed software training in Geospatial modules in such a manner that it does not create a barrier for students but assists them in gaining content knowledge while developing their GIS skills. From the interviews with the lecturers, it became clear that they offer the modules with reference to complex spatial concepts of space, using spatial terminologies such as networks, hierarchies, spatial relationships and distributions. GSTs are used as representation tools throughout the module offerings, and reasoning processes reach a high cognitive level, as in the case of prediction models and the application of GIS principles. Table 5.4 demonstrates that the lecturers of Department B effectively incorporate spatial thinking in their teaching methods on NQF levels 5, 6 and 7 by integrating the three components of spatial thinking. (Refer to Annexure G for more details.)

Table 5.4: Department B - Incorporation of the three components of spatial thinking in the teaching methods of the interviewed lecturers.

Lecturer	Module	Concept of space	Representation tools	Process of reasoning	Spatial thinking included
BA	B.6	Complex Spatial	Yes	Output	Yes
BB	B.5 B.7	Complex Spatial	Yes	Output	Yes
1BC	B.7	Complex Spatial	Yes	Output	Yes

The concerted effort by Department B to develop their students' technological skills should be commended. However, lecturers for modules on lower NQF levels reported that technology distracts the students from learning effectively. Outdated methods and technologies are therefore preferred for teaching the students foundational knowledge. These include the drawing of sketches and the interpretation of paper-based maps. However, students are exposed to the latest technologies later on in the NQF Level 7 modules. Geospatial technologies are taught as a separate module, as Applied Science, on NQF Level 7, and find application in other Geography modules.

The increase in the level of spatiality of module outcomes and teaching methods from NQF levels 5 to 7 is not apparent. (Refer to Table 5.5.) The module outcomes for module B.6 do not integrate the three components of spatial thinking – the integration rate is 0%. (Refer to Chapter 4, Figure 4.7.) However, module B.7 is taught in such a way that spatial thinking skills should be developed and with some of the outcomes that reach a spatiality of 22 and 24 with reference to the taxonomy of spatial thinking, although the integration of the three components of spatial thinking is low (67%).

Table 5.5: Department B – Spatiality of module outcomes and inclusion of spatial thinking in teaching methods of the interviewed lecturers. (Spatiality of module outcomes in bold indicates inclusion of all three components of spatial thinking.)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching
B.5	Not available	BB	Yes
B.6	20 21	BA	Yes
B.7	1 **22** **24**	BB BC	Yes

The integration of the three components of spatial thinking in the module outcomes is low (0% and 67% on all NQF levels (Refer to Chapter 4, Figure 4.7.), while all the modules are taught at a higher level of spatiality. Despite the constraints, as highlighted, the way in which the module content is conveyed to the students in Department B should still contribute to developing their spatial thinking skills.

5.5.3 Department E: Views of the interviewed lecturers on the inclusion of spatial thinking in teaching methods

Textbox 5.3 summarises some of the comments provided by the lecturers of Department E during the interviews. All four lecturers have a strong SPBL approach to teaching. Two of them feel that technologies such as GIS distract students from learning the module content – especially on the lower NQF levels. The students on NQF Level 5 typically lack the technical skills to successfully master computer-based modules. One of the lecturers does not have the experience to incorporate GIS successfully in his/her lectures. However, this lecturer makes up for this shortfall by integrating various visual tools such as maps, graphs, videos and even music into the teaching methods he/she uses. (Refer to Text box 5.3). One lecturer exerts considerable effort to ensure that students have gained the necessary technical skills and software knowledge by the time that they reach NQF Level 7. Mapwork and GIS are offered as stand-alone modules by Department E. However, the efforts put in by the lecturers to offer the modules in the context of various application fields and in an applied way are commendable. Department E is also one of the few Geography Departments that still does fieldwork with students.

Textbox 5.3: Department E

…you are teaching them to be managers who can solve problems in the real world.

…this is the theory; this is the example. So, it moves from the one into the other always, because there's no point explaining the theory if you don't explain the practice. And there's no point in doing practice if there's no theory…. So, I'm constantly sort of relating these things to each other.

Everything has to answer the questions, Where? and Why? I discuss that with every group of students at the beginning of the year, every year, this is what differentiates us. And to me, it's what is happening - where and why.

And then… loads of maps, documentaries, YouTube videos, and I have that too now … even to playing music that fits into Cultural Geography, and where it comes from, and to impress them, of course!

Technology can't take over from the basics… it absolutely can't!" Yes, I absolutely love teaching… teaching topo. maps and stuff; and I know you could get them in layers and

An analysis of the interviews indicates that three of the lecturers from Department E (EA, EB, and EC) include the components of spatial thinking in their teaching methods. Table 5.6 summarises the information collected through the interviews. Three lecturers include complex spatial terminologies such as scale, time and space in their teaching methods. In addition, representation tools constitute part of their teaching methods, which include reasoning processes such as the application of principles, which is on a high cognitive level. (Refer to Annexure G for more details.)

Table 5.6: Department E – Incorporation of the three components of spatial thinking in the teaching methods of the interviewed lecturers.

Lecturer	Module	Concept of space	Tools of representation	Process of reasoning	Spatial thinking included
EA	F.5	Complex Spatial	Yes	Output	Yes
EB	F.6	Complex Spatial	Yes	Output	Yes
EC	F.7(1)	Complex Spatial	Yes	Output	Yes
ED	F.7(2)	Unclear	Yes – to a certain extent	Output	Unclear

Although Lecturer ED applies an interesting teaching method, it is not clear whether the three components of spatial thinking are sufficiently incorporated into this method of teaching. The lecturer only uses images and has strong views against the use of technology during lectures. Table 5.7 summarises the measurement of the level of spatiality of the module outcomes and the inclusion of spatial thinking in the teaching methods of the lecturers. (Refer to Annexure G for more details.)

Although there is no evidence of a concerted effort by Department E to develop the spatial thinking skills of students, there is evidence that the lecturers who chose to be part of this research indeed incorporate the components of spatial thinking when conveying the module content to their students. The integration rate of the three components of spatial thinking in the module outcomes is low, with 25% for module E.5, 0% for module E.6 and 60% for module E.7. (Refer to Chapter 4, Figure 4.7.) Ideally, the module outcomes should be pitched at a higher level of spatiality and display a higher integration rate to align with the teaching methods of the lecturers.

Table 5.7: Department E – Spatiality of module outcomes and inclusion of spatial thinking in the teaching methods of the lecturers. (Spatiality of module outcomes in bold indicates inclusion of all three components of spatial thinking.)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching
E.5	3 19 **21** **24**	EA EB	Yes
E.6	3 19 20 21	EA EB	Yes
E.7	3 **21** **24**	EC	Yes

5.5.4 Department F: Views of the interviewed lecturers on the inclusion of spatial thinking in teaching methods

The lecturers of Department F flagged the number of students as the biggest challenge in teaching their students. They feel that the high student numbers per module hinder participation by students in discussions and make it difficult for them to keep track of the development of the students. Examples of the feedback obtained from the lecturers during the interviews are provided in Text box 5.4.

There is some evidence that rote learning is encouraged by the lecturers. It is also related to the way in which the learning material is structured. (Refer to Text box 5.4.) This could be because the modules in this department do not have pre-requisites. Therefore, each module starts on an introductory level and needs to reach the appropriate NQF level within one teaching semester. Lecturer FC summarised this situation as follows: *'Without foundation modules, it's difficult to just jump in at the third-year level* (NQF Level 7) *with a very specific and specialised topic that somebody who didn't even have Geography at school level does... And that in 12 credits (120 notional hours)'*.

Although the lecturers in this department use teaching methods that will improve the spatial thinking abilities of the students, the lecturers feel that students struggle to apply the foundational knowledge within the context of space. Even though the modules are updated annually and are in line with the latest theoretical developments, Geospatial tools are not incorporated into the teaching methods. Although no evidence could be found of a concerted effort by Department F to develop the spatial thinking skills of their students, all three lecturers include spatial thinking in their teaching methods. (Refer to Table 5.8.) They include the concepts of space on a complex level, such as adjacency, connections and linkages. Representation tools (such as satellite images and videos) are significantly incorporated, although no Geospatial software is used. The process of reasoning is required in the application of principles, comparisons and interpretations and is at a high cognitive level. (Refer to Annexure G for more details.)

Text box 5.4: Department F

So, we've literally given them the entire structural guide for Assignment 2. We've uploaded it on additional resources and we've told students: "If you just follow that structural guide, you will be fine". It's about 16 pages long. It's in depth. It even tells you how to answer those questions and how to think spatially.

…simply because I think our students have got a very poor understanding of spatial thinking and spatial variation.

I know that students can take rote knowledge and they can understand it, sometimes very well, but very few students - and there are wonderful students - can actually apply that to their own personal environment or a real-world environment.

That's the problem with my field - you need a picture in your head. With no picture or visual picture in your head, you can't understand and apply this type of stuff.

Table 5.8: Department F – Incorporation of the three components of spatial thinking in the teaching methods of the interviewed lecturers.

Lecturer	Module	Concept of space	Tools of representation	Process of reasoning	Spatial thinking included
FA	F.5	Complex Spatial	Yes	Output	Yes
FB	F.6	Complex Spatial	Yes	Output	Yes
FC	F.7	Complex Spatial	Yes	Output	Yes

Table 5.9 summarises the spatiality of the module outcomes and the inclusion of spatial thinking in the teaching methods of the lecturers. Although the module outcomes reach a high spatiality (23 and 24), the integration of the three components of spatial thinking on NQF levels 5 to 7 remains low (50%, 33.4% and 60%, respectively. (Refer to Chapter 4, Figure 4.7.) More of the module outcomes should be pitched at a higher level to align with the high level of spatiality of the teaching methods. Since the modules of Department F do not have pre-requisites, this may explain why some of the module outcomes have a lower level of spatiality – to ensure that the foundational knowledge is instilled before moving on to a higher level of spatiality.

Table 5.9: Department F – Spatiality of module outcomes and inclusion of spatial thinking in teaching methods of the lecturers. (Spatiality of module outcomes in bold indicates inclusion of all three components of spatial thinking.)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching
F.5	13 14 **24**	FA	Yes
F.6	14 19 **24**	FB	Yes
F.7	**23** **24**	FC	Yes

5.5.5 Department H: Views of the interviewed lecturers on the inclusion of spatial thinking in teaching methods

One important aspect that was mentioned by all the lecturers from Department H during their interviews is that the GIS module being used is not offered by Geography but by another department. This module is prescribed for all Geography students, but the lecturers apply GIS cautiously in their own modules so as not to overlap with the content of the GIS module offered by the other department. During the interviews, the offering of GIS by another department was under discussion, with the lecturers indicating that they were working towards offering more GIS content within the Geography Department.

The teaching methods employed by one of the lecturers stood out. Before the outbreak of the Covid-19 pandemic in 2020, this lecturer of a NQF Level 7 module would do fieldwork with students with great success. According to the lecturer, the aim is to continue with this practice again soon. Unfortunately, however, owing to the increasing student numbers, fieldwork on NQF Level 6 had to be terminated.

Although the NQF Level 6 lecturer is energetic and enthusiastic about doing fieldwork with the students, it appears that the rest of the department is drawing on this energy instead of joining the initiative. Generally, the lecturers in this department referred to the successes and benefits of fieldwork to students but are not including fieldwork in their modules. Another noteworthy observation is that while two of the lecturers reported that students are not participating in class discussions, Lecturer HC applies role-playing as a method to engage students in conversations with great success. The feedback provided by the lecturers and the role-playing approach to teaching are summarised in Text box 5.5.

Text box 5.5: Department H

Because teaching is not just about giving and giving. Sometimes you want to tap into their creative juices…

So, I would feel guilty if my students graduated and they had never done any fieldwork on their own. I would feel bad.

…I would give them a case of mining at [place name]: to mine or not to mine in [place name]. And then we'd have a DMR; we'd have an official from Environmental Affairs; we'd have the local communities of [place name]; we'd have the mineral resources company - the Australian mining company. And so, all of them, you know, would take on different roles. And then I would give them a week and say: "OK, go and prepare and then next week you will tell me whether we mine or whether we don't mine, and …. they'd go and do their research.

What is always very interesting is when I choose a topic like <u>Poverty in South Africa</u> and then I'll say: "OK, let's talk about poverty in South Africa", and then I put them in the boxes of the political organisations. Someone who is ANC must be in the DA box. That one always cracks! ...I always think that you know it challenges them to think outside their own politically constricted boxes and be able to appreciate the views

The interviews with the lecturers of Department H indicate that they all include spatial thinking in their teaching methods. However, the teaching methods used by Lecturer HC reveal that a lower level of spatiality is at stake. The highest cognitive level at which the module is taught appears to be at a processing level, although references to a higher cognitive level were made. Lecturers HA and HB include complex spatial concepts of space, such as distributions, correlations and hotspot relations, when teaching module content. They also incorporate a higher level of cognitive reasoning in their teaching methods. All three lecturers include representation tools when conveying module content to students. The results of the assessment of the teaching methods used by the three lecturers against the taxonomy of spatial thinking are summarised in Table 5.10. (Refer to Annexure G for more details.)

Table 5.10: Department H – Incorporation of the three components of spatial thinking in the teaching methods of the interviewed lecturers.

Lecturer	Module	Concept of space	Representation tools	Process of reasoning	Spatial thinking included
HA	H.6	Complex Spatial	Yes	Output	Yes
HB	H.7	Complex Spatial	Yes	Output	Yes
HC	H.5	Complex Spatial /Spatial primitives	Yes	Output/Processing	Yes

Table 5.11: Department H – Spatiality of module outcomes and inclusion of spatial thinking in the teaching methods of the lecturers. (Spatiality of module outcomes in bold indicates inclusion of all three components of spatial thinking.)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching
H.5	1 2 19 20	HC	Yes
H.6	1 2 3 19 **24**	HA	Yes
H.7	8 9 19	HB	Yes

Although Lecturer HC emphasised reasoning processes at the processing level, he/she also referred to a few processes on an output level. This lower spatiality in the teaching methods of Lecturer HC may be acceptable as the module is offered on NQF Level 5.

There is no evidence of the effect of a concerted effort by Department H to develop the spatial thinking abilities of students. Only one module (H.6) includes outcomes with a high spatiality (24), while the integration of the three components of spatial thinking in the module outcomes is low on all NQF levels (0%, 20% and 0%, respectively, for NQF levels 5, 6 and 7. (Refer to Chapter 4, Table 4.7.) Despite this limitation, all three lecturers offer their modules at a higher spatiality than specified by the module outcomes and in such a way that the students do indeed develop their spatial thinking skills (Refer to Table 5.11).

5.5.6 Department J: Views of the interviewed lectures on the inclusion of spatial thinking in teaching methods

Department J has an applied approach to Geography teaching. All the students in this department have a more-or-less similar background, and this makes the teaching of Geography in this department very focused. It is also easy for the lecturers to involve the students in class discussions as the classes are small.

What distinguishes Department J from other departments is that the lecturers emphasise the applicability of the modules they offer. They focus on putting the basics of the module content in place before moving on to addressing problems and applying the knowledge thus acquired. The views and feedback from the lecturers are reflected in the quotes from the interviews provided in Text box 5.6.

> Text box 5.6
>
> *To teach geography in a meaningful way, lecturers must have a sound knowledge of the various theoretical concepts or models. Personal research (case studies) gives another dimension to the teaching process.*
>
> ---
>
> *Every day is a real-life session. It is important that my students must understand their environment, and what the spatial integration and spatial inequalities in socio-economic activities are.*
>
> ---
>
> *I really do think that... like from walking into class, not knowing what GIS is, to leaving the classroom and understanding exactly what GIS is... there's a shift in their way of spatial thinking.*
>
> ---
>
> *I think it is not a matter of revising the model, but rather how I give further meaning (relevance) to the module and how my students can tap into the theoretical base and how they can relate it to the practical (geographical) world.*

One of the modules offered by Department J accumulates 200 notional hours. Although the students enter the module with no foundational knowledge, the high number of notional hours allows enough time for the lecturer to first focus on the foundational knowledge and then to assess this knowledge. The focus then shifts to the practical and applied processes and ends with a scenario-based project, constructed and presented by the students, and based on GIS. The lecturer of this module indicated that the spatial thinking skills of the students completing the module had developed significantly. Another lecturer indicated some improvement in the students' problem-solving skills as they progressed through the semester. The one lecturer who indicated no significant improvement in students' development of problem-solving skills, also admitted to much less experience in teaching students on a tertiary level.

From the results summarised in Table 5.12, all three lecturers include spatial thinking in their teaching methods. Spatial concepts included in their teaching include spatial integration, terrain analysis and projections. Sufficient representation tools are incorporated into their teaching methods, and the reasoning process is at a high cognitive (output) level. (Refer to Annexure G for more details.)

Table 5.12: Department J – Incorporation of the three components of spatial thinking in the teaching methods of the interviewed lecturers.

Lecturer	Module	Concept of space	Tools of representation	Process of reasoning	Spatial thinking included
JA	H.5	Complex Spatial	Yes	Output	Yes
JB	H.6	Complex Spatial	Yes	Output	Yes
JC	H.7	Complex Spatial /Spatial primitives	Yes	Output	Yes

Table 5.13: Department J – Spatiality of module outcomes and inclusion of spatial thinking in the teaching methods of the lecturers. (Spatiality of module outcomes in bold indicates inclusion of all three components of spatial thinking.)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching
J.5	2 14 20	JA	Yes
J.6	21 **23** **24**	JB	Yes
J.7	**23** **24**	JC	Yes

The spatiality of the module outcomes and the inclusion of spatial thinking in the teaching methods of the lecturers from this department are summarised in Table 5.13.

(Refer to Annexure G for more details.) There is no evidence of a concerted effort by Department J to develop their students' spatial thinking skills. The lectures at NQF Level 5 are offered at a higher level of spatiality compared to the spatiality of the module outcomes. The integration of the three components of spatial thinking in the module outcomes on NQF levels 5 and 6 are low (respectively 0% and 19%) but the modules are taught on a high spatiality. The module outcomes on NQF Level 7 show a 100% integration of the three components of spatial thinking, and the module is taught at a high level of spatiality. Although the three lecturers report on varying degrees of success, the modules are offered in such a way that the students can develop their spatial thinking skills.

5.5.7 Familiarity of the interviewed lecturers with spatial thinking

Considering all the departments together, most of the interviewed lecturers demonstrated that they have knowledge of what spatial thinking is. Only two lecturers, EA and HC,are not familiar with spatial thinking and could not provide a definition or explanation of what they think spatial thinking is. Lecturer HC has only three years of experience in teaching Geography, and it was found that this lecturer included spatial thinking in his/her teaching at a slightly lower level of spatiality than the other lecturers. Spatial thinking indeed forms part of the teaching methods of lecturer EA, who is, however, not familiar with what the concept, spatial thinking, exactly means.

The eighteen remaining lecturers are familiar with spatial thinking and could explain what spatial thinking is. A word cloud of the responses of the interviewed lecturers to the question to define what spatial thinking is, was generated, and is presented in Figure 5.3.

It is evident from the word cloud in Figure 5.3, that the terms, space, thinking, location, relationship, place and spatiality, were often used in the interviews to describe the concept of spatial thinking. Other terms that were used include time, surroundings, patterns, scale and distribution. Although none of the lecturers could provide a formal textbook definition or description of spatial thinking, their use of the relevant terms indicates that they have a good understanding of what spatial thinking is.

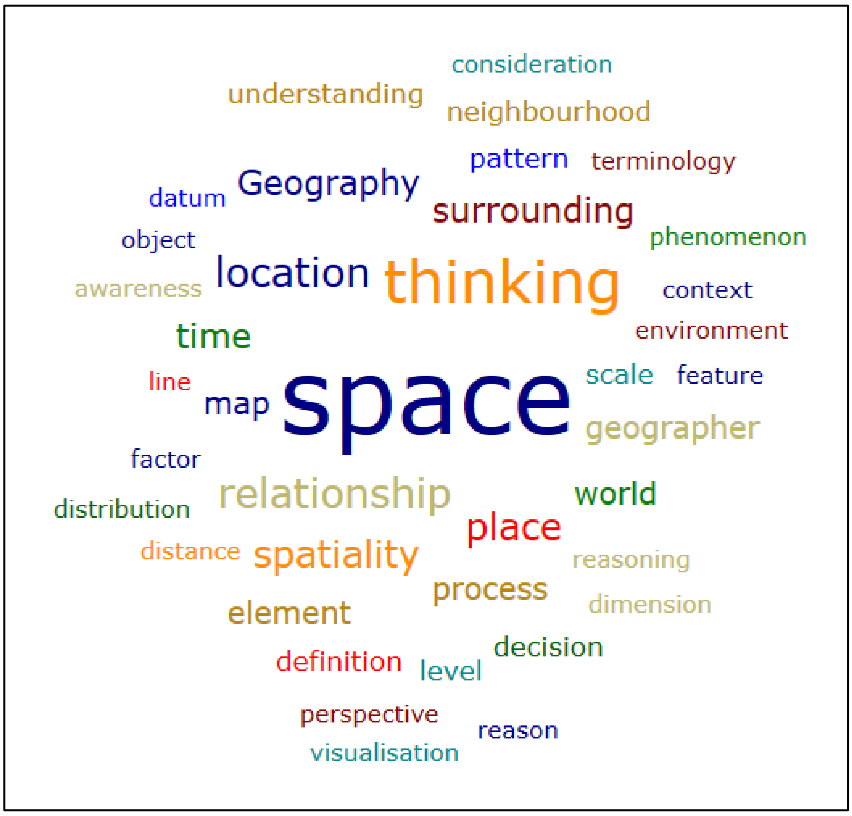


Figure 5.3: Words used to define spatial thinking.

5.5.8 Synthesis: The inclusion of spatial thinking in the way content is conveyed to students

Most lecturers who participated in this research have extensive experience in teaching undergraduate Geography at a tertiary level and in the modules constituting part of this research. The modules that they teach are updated annually and are aligned with the latest technologies, thought processes or models within the knowledge domain of Geography.

The lecturers from each department demonstrated specific considerations for module development; however, it seems that the development of new modules, although planned on a departmental level, is executed individually. Spatial thinking should be considered when developing new modules, and the inclusion of spatial thinking should be reflected in the outcomes from the onset of the process. The incorporation of a representation tool or tools should also be considered and reflected in the module outcomes.

Except for one lecturer, spatial thinking has been sufficiently incorporated into the teaching methods of all lecturers. Incorporating spatial thinking in teaching methods is essential as Geography modules are ideal avenues for improving the spatial thinking skills of students (Verma & Estaville, 2018). However, except for module J.7, the spatiality of the teaching methods applied when conveying module content to students is higher than the spatiality reflected by the module outcomes. This is due to the low integration rate of the three components of spatial thinking in the module outcomes. (Refer to Chapter 4, Section 4.8.) Therefore, departments should redefine their module outcomes to align them with the spatiality of the lecturers' teaching methods.

The lecturers generally support the notion of Bednarz (2019) that in Geography teaching, it is essential to master the foundational knowledge before moving on to apply the concepts in space. All lecturers incorporate SPBL in their teaching methods to teach students the application of concepts. Emphasis is placed on local communities, and in the provincial, South African or African context, thus representing the various scales at which SPBL is applied. Since SPBL is also pitched at a high cognitive level, SPBL should further contribute to the students' spatial thinking skills (Silviariza et al., 2021).

Although most research focuses on including GIS as a GST in the curriculum, this notion should be expanded to encompass other GSTs, such as GPS (Lee, 2020) and Remote Sensing (Ghaffari et al., 2018) as the use of these tools to improve spatial thinking skills has been proven. Although low-tech representation tools can be used to teach spatial thinking (Jo et al., 2016), the inclusion of GSTs is essential to improve students' employability (Moolman & Donaldson, 2016), attitudes, motivation and achievements (Baker, 2002). Geography departments should therefore attend to the inclusion of GSTs in their curricula and ensure through concerted efforts that the students' technical skills are developed. The use of GSTs should become transparent, so that students should then be able to focus on the module content (Madsen & Rump, 2012). A cookbook-type approach should be avoided, as warned against by Pye (2014) in Bearman et al. (2016) and by Fombuena (2017). Department B provides a good example of the use of GSTs in Geography to aid in the development of students' spatial thinking skills. An inquiry-based process, as suggested by Bearman et al. (2016), also constitutes part of GST teaching and will further contribute to the development of spatial thinking skills. Complex spatial concepts such as distributions, overlays, buffers and map projections are inherently part of GST teaching. The use of GSTs will ensure that the concepts of space are included on a complex spatial level.

One lecturer referred to the development of spatial thinking in terms of the NQF levels as 'scaffolding'. The lecturer explained this scaffolding in the following way: *'In the first year... to my mind, the student should be able to engage in braaivleis (barbeque) talk. If people ask: "But this thing about climate…What is climate change?" The student should know about El Nino. They should understand those principles; they should understand the basics of synoptic weather and the basics of global circulation. On the second-year level… and then that would lead to a discussion of: "What are the things that drive* *weather?". So those would be examples of me trying to make sure that the student finds the real facts in books and journals, journal articles… and when I engage with them, I am trying to facilitate their learning process. On the third-year level… this is the module that has to tie everything together. But we want to do this in the context of how we think as a geographer…. Space and time are integrally linked with that; "We want to help students to practise thinking in terms of space, time and Geography and to do that in different types of environment.'* The notion of a scaffolding approach as set out by this lecturer is supported, but it should be kept in mind that spatial thinking could be learned at any age and level (National Research Council, 2006) and should not be neglected on the lower NQF levels.

In cases where Geospatial tools were not being explained or used in presenting a module selected for this research, the lecturers found it challenging to respond to questions as to whether their modules were aligned with the latest technologies in their domain. It was clear that when a module tends more to be theory-based, and GSTs are not included in the teaching material or used to convey the content, the module is at least in line with the latest thought processes or models in the knowledge domain of Geography. In all instances where old-fashioned technology, such as hard copy maps, is used, the lecturers could provide a good reason why such methods should still be incorporated.

5.6 Disposition of a selection of the interviewed Geography lecturers regarding the teaching of spatial thinking

5.6.1 Measuring the dispotion of a selection of the interviewed Geography lecturers

Fifteen (15) of the 20 interviewed lecturers responded to the request to complete the questionnaire to determine their respective dispositions towards teaching spatial thinking. Two of the respondents indicated that they were not interested in participating in the questionnaire. Since the questionnaire was anonymous, the results cannot be linked to a specific lecturer or module. Instead, the results are randomly listed per department, but not connected to a specific NQF level or lecturer. The results of the questionnaire are summarised in Table 5.14.

The tool to determine the disposition of the lecturers regarding their teaching of spatial thinking is explained in detail in Chapter 3, Section 3.4.2. With one exception, the average score for each of the lecturers' responses was above or equal to four (4), thus indicating that they are well-disposed toward teaching spatial thinking. (Refer to the last column in Table 5.14.) The results per category suggest that all the lecturers believe that students' thinking skills can be developed (Cat 1.) and are, in fact, prioritised when they teach module content to their students. The lecturers understand the nature of spatial thinking and the relevance of spatial thinking in attaining educational goals (Cat. 2) and agree that spatial thinking can be taught within a Geography module (Cat. 3). The average scores in the spatial concepts category (Cat. 4) are lower than those of the other categories. Four respondents gained an average score below four (4) for the spatial concept category, pointing towards a possible lack of knowledge and confidence in teaching spatial concepts. However, it is encouraging to see that two lecturers obtained the highest possible score (five) for this category. Regarding spatial representation (Cat. 5), two of the respondents presented with an average score below four, suggesting that they are not inclined to use representation tools or Geospatial technologies to improve the development of students' spatial thinking skills.

Table 5.14: Results on the disposition of a selection of the interviewed Geography lecturers regarding the teaching of spatial thinking. (Average scores below four (4) are indicated in bold.)

Anonymous name	Cat. 1: Thinking skills	Cat. 2: Spatial thinking skills	Cat. 3: Spatial thinking in Geography	Cat. 4: Spatial concepts	Cat. 5: Spatial represent-ation	Total average score
Department A	4.6 4.3 4.0	4.7 4.9 4.4	4.7 4.2 4.3	**3.7** 5.0 4.8	4.8 4.9 4.0	4.4 4.7 4.4
Department B	4.4	4.3	4.8	4.1	4.2	4.3
Department E	4.4 4.0 4.1	4.1 4.1 4.4	4.5 4.5 4.7	**3.9** 4.6 4.5	**1.0** 4.0 4.9	**3.5** 4.3 4.6
Department F	4.1 4.1	4.7 4.4	4.7 4.8	**3.5** 4.4	4.4 4.3	4.2 4.4
Department H	4.4 4.7	4.3 4.4	4.7 4.3	**3.5** 4.9	**3.8** 4.2	4.0 4.6
Department J	4.3 4.7	4.4 4.4	4.5 4.7	4.8 5.0	4.3 4.8	4.5 4.8

As explained in Chapter 3, Section 3.4.2, the five counter statements in the questionnaire were scored on a reverse scale (strongly disagree = 5, to strongly agree = 1). Table 5.15 summarises the results and average scores obtained by the lecturers for the five counter statements. A low average score for the counter statements indicates that although the lecturers are positively disposed to include spatial thinking in teaching and learning, they have insufficient knowledge or may hold perspectives that would hinder effective implementation. Only two respondents earned an average score of four or above, indicating that they should be able to successfully implement spatial thinking in their teaching and learning. (Refer to the last column of Table 5.15.) Almost 50% of the lecturers would like the students to remember exactly what they say during lectures and practicals, while nearly 40% hold a neutral disposition (Table 5.15, CS1). When compared with their other responses in the thinking skills category of teaching, there is a possibility that at least one lecturer from each of Departments A, B, E, F, and H encourages the rote memorisation of facts.

Sixty per cent (60%) of the lecturers believe that spatial thinking forms an innate part of a person or are neutral regarding the statement (Table 5.15, CS2). This percentage could indicate that the lecturers do not have sufficient knowledge about spatial thinking and are not aware that it can be learned at any age. Should the lecturers believe that spatial thinking is innately part of a person's abilities, they might not attempt to develop students' spatial thinking skills.

The scores reflecting the belief that Geography involves factual information (Table 5.15, CS3) and is best learned through memorisation (Table 5.15, CS4) were much higher. Less than 40% of the lecturers indicated their neutrality in respect of the belief that Geography largely constitutes factual information, while only one respondent agreed with the statement. A low percentage (31%) of the lecturers indicated a neutral disposition toward believing that Geography is best learned through rote memorisation. None of the lecturers agreed or strongly agreed with this statement suggesting that they support the applied nature of Geography teaching.

Table 5.15: Summary of counter statements and scores.

(CS = Counter statement)

Anonymous Department	CS 1: I feel satisfied when students remember exactly what I have said.	CS2: Spatial thinking is a skill that is innate (natural, inborn).	CS3: Geography is a collection of factual information.	CS 4: Geography is best learned through the rote memorisation of facts.	CS 5: Students can readily interpret spatial representations without a guide or manual.	Average scores
Department A	Disagree	Disagree	Neutral	Strongly disagree	Strongly disagree	4.2
	Agree	Disagree	Agree	Neutral	Disagree	3
	Neutral	Disagree	Disagree	Neutral	Disagree	3.6
Department B	Agree	Neutral	Disagree	Strongly disagree	Disagree	3.6
Department E	Strongly agree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree	2.6
	Neutral	Neutral	Neutral	Disagree	Disagree	3.4
	Neutral	Disagree	Disagree	Strongly disagree	Disagree	4
Department F	Strongly agree	Neutral	Neutral	Strongly disagree	Disagree	3.2
	Agree	Agree	Strongly disagree	Strongly disagree	Neutral	3.4
Department H	Strongly agree	Neutral	Neutral	Strongly disagree	Disagree	3.2
	Disagree	Neutral	Neutral	Neutral	Agree	3
Department J	Neutral	Disagree	Disagree	Disagree	Disagree	3.8
	Neutral	Strongly agree	Strongly disagree	Neutral	Neutral	3

5.6.2 Synthesis on the disposition of the selection of interviewed lecturers with regard to their teaching of spatial thinking

As postulated by Lee et al. (2018), a teacher should have the necessary skills and knowledge to teach spatial thinking and be well-disposed to do so. The results of the questionnaire on the selection of interviewed lecturers' dispositions regarding the teaching of spatial thinking are encouraging. Except for one lecturer, the rest of them (all departments) were shown to be well-disposed to deal with the teaching of spatial thinking in their modules. The results from the analysis of the interviews also indicate that the lecturers prioritise the teaching of spatial thinking. However, the average scores in the categories for spatial concepts proved to be lower when compared to the other categories. Newcombe and Stieff (2012) emphasise the importance of using spatial language in precise ways to enhance spatial learning and to obtain a high level of understanding of spatial perspectives such as location, distance and direction, neighbourhood and region, scale, spatial dependence and spatial heterogeneity.

Regarding the use of representation tools or GSTs, two of the lecturers obtained an average score below four. Therefore, lecturers should focus on developing confidence in using GSTs when conveying course content to students (Collins, 2018a).

Although the lecturers appear to have a positive inclination to teach spatial thinking, the counter statements indicate that they may not yet be totally successful in the implementation of the teaching of spatial thinking in their modules. They should be aware that spatial thinking, not being innately part of a person, can be learned at any age and that the rote memorisation of facts should be discouraged.

Except for one, the lecturers who completed the questionnaire indicated that they are prepared and willing to incorporate spatial thinking in their modules. This is crucial because, without a positive disposition among lecturers with regard to teaching students spatial thinking, the inclusion of spatial thinking in curricula will not be successful (Jo & Bednarz, 2014).

5.7 Reflections on teaching spatial thinking

While Chapter 4 focused on what is included in the Geography curriculum (the module outcomes), Chapter 5 critically evaluated how the interviewed Geography lecturers at the selected universities convey the module content to undergraduate students, with specific emphasis on spatial thinking. The focus of this critical evaluation was to determine whether spatial thinking is conveyed to students in such a way that it will support the development of their spatial thinking skills. A selection of the interviewed lecturers also completed a questionnaire to gain an overview of their disposition towards teaching students spatial thinking.

Most lecturers who participated in this research have extensive experience in teaching Geography at the undergraduate level. The results obtained indicate that stronger emphasis should be placed on spatial thinking when developing new modules and that tools of representation should be incorporated from the onset. Noteworthy is that most of the interviewed lecturers follow an SPBL approach and encourage their students to participate in problem-solving activities and discussions. Although it may take time to develop, the students' participation in classroom activities improves over the course of a semester or from one NQF level to the next and serves as an indication that there is some improvement in their spatial thinking skills.

The experience of the interviewed lecturers with teaching spatial thinking is reflected in the results of the assessment of their teaching methods against the taxonomy of spatial thinking. The findings indicate that they employ various teaching methods and tools in their teaching practice, which is in line with the findings of Jo, Hong and Verna (2016). Except for one interviewed lecturer's mode of operation, there is a sufficiency of concepts of space at the correct cognitive level and the use of tools of representation to convey the module content to students. Therefore, the results of this research indicate that it is possible for the teaching methods applied by the lecturers to develop spatial thinking skills in students. This research also shows that, in most instances, the content of the Geography curriculum is conveyed at a higher spatiality than indicated by the module outcomes. This is mostly due to the low integration rate of the three components of spatial thinking in the module outcomes.

Although some of the responses to the disposition questionnaire provide indications of ideas or perceptions that may hinder the successful implementation of spatial thinking, the lecturers are generally suitably disposed to teach spatial thinking to students. Jo and Bednarz (2014) and Lee et al. (2018) indicate that a lecturer will not include the components of spatial thinking in his/her teaching processes if he/she is not adequately disposed towards spatial thinking.

The research results presented in this chapter provided sufficient evidence that the interviewed lecturers are positively disposed to teaching spatial thinking and successfully incorporate the components of spatial thinking in their teaching of the Geography modules that they offer.

The next chapter, Chapter 6, evaluates whether the formative and summative assessments of the modules align with the spatiality of the module outcomes and the teaching of the module content and whether they further contribute to developing students' spatial thinking skills. The aforementioned are also assessed to indicate gaps in the students' spatial thinking skills.

Chapter 6: Spatiality of assessments and the spatial thinking skills of students

6.1 Introduction

Assessments play a crucial role in developing the spatial thinking abilities of students and should not only be seen as a means to pass a module or to assess content knowledge (Beets, 2007). In addition, assessments should be aligned with the curriculum within each department (Ibid). To develop the spatial thinking abilities of students, assessments should test the inclusion of the three components of spatial thinking in the module content, namely a high cognitive level, the concepts of space, and the use of representation tools. The rote learning of facts does not require students to think reflectively and analytically and will not develop their spatial thinking abilities (Bednarz, 2019; Goodchild & Janelle, 2010; Ishikawa, 2013).

Although spatial thinking may be learned at any age (National Research Council, 2006), students will only develop spatial thinking abilities if they are required to personalise the process. Furthermore, the spatial thinking abilities of students are influenced by various factors such as, to name but a few, gender, educational background and socioeconomic background (Bednarz, 2019; Collins, 2018a, 2018b; Verma, 2015).

This chapter reflects on the spatiality of questions posed in formative and summative assessments and the results of an assessment of students' spatial thinking skills. The taxonomy of spatial thinking developed by Jo and Bednarz (2009) was used to evaluate the spatiality of the questions pitched in the formative and summative assessments of the modules selected for this research, while the STAT developed by Lee and Bednarz (2012) was used to assess the spatial thinking skills of the sample of students participating in this research. The results thus obtained will indicate whether the questions posed in the assessments could in fact potentially contribute to the development of the spatial thinking skills of the participating students. The results of the STAT will point towards gaps in these students' spatial thinking skills that would need further development.

The taxonomy of spatial thinking and the STAT are both known and tested instruments and are, as such, located in the upper right (UR) objective quadrant of the AQAL model. The upper right quadrant of the AQAL model allows for the use of known and tested instruments interpreted through an outside or inside "It" perspective. The STAT is a quantitative instrument with an outside ("It") perspective. Although the taxonomy of spatial thinking is also a quantitative instrument, the interpretation is partially based on the researcher's experience and has an outside ("I") perspective and is, therefore, also located in the upper left (UL) quadrant of the AQAL model. The levels, lines, states and types that will ensure that the research reaches the required level of profundity and includes all relevant perspectives will also be discussed.

This application of the taxonomy of spatial thinking within this research is unique as no published articles could be found on the use of the taxonomy to evaluate the spatiality of assessment questions. The STAT has also not been applied before in any other research within the higher education context in South Africa to gauge students' spatial thinking skills.

This chapter commences with a review of the literature relating to assessment practices to develop students' spatial thinking skills, as well as the factors that influence the development of these skills. The measurement of thinking spatially is reflected on by referring to related studies using the STAT. The taxonomy of spatial thinking is used to determine the spatiality of the formative and summative assessments that were obtained from the participating lecturers. The STAT was also used to gauge the spatial thinking abilities of respondents, and the results ensuing from the analysis of the relevant data are presented. The chapter is concluded with reflections on the spatiality of assessment questions at the participating Geography departments.

6.2 Assessment practices to develop spatial thinking

The literature shows that research regarding assessment practices and spatial thinking has mostly been conducted on a school level (Duarte, 2018; Nursa'Ban et al., 2020). However, none of this research (on school or tertiary level) covered the determination of the spatiality of assessment practices and also did not consider whether these would in fact contribute toward the development of students' spatial thinking skills.

Assessments play an essential role in teaching and learning pertaining to modules offered on the tertiary level. On this level, assessments should be used for formative and summative purposes and constitute part of the pedagogy focusing on enhancing student skills, abilities and capabilities (Beets, 2007). It has been found that a challenge faced by many school teachers is to develop assessments in Geography that are based on spatial thinking capabilities (Nursa'Ban et al., 2020). Teachers should carefully select assessment questions to ensure that they incorporate all three components of spatial thinking and that they teach and evaluate the terminology used in this context (especially on the higher-order cognitive levels) (Jo & Bednarz, 2009). Beets (2007) calls for a reflection on pedagogical practices, lecturer-student relationships and assessment practices that are aligned with the curriculum.

Goodchild and Janelle (2010) prove that the concept of critical spatial thinking (a way of thinking that partly includes spatial thinking) is reflective, sceptical and analytical. Critical spatial thinking based on these characteristics cannot be memorised, but rather requires that students apply their minds to address complex challenges (Goodchild & Janelle, 2010; Nursa'Ban et al., 2020). Related to this line of thought, Jo and Bednarz (2009) initially developed the taxonomy of spatial thinking to determine the spatiality of questions in school textbooks for Geography. Researchers followed up on this with a study to inform teachers of ways in which to select questions relevant to spatial thinking for assessment purposes (Jo et al., 2010). While it remains essential to also include questions pitched on a lower spatial level in order to test basic knowledge, the scope needs to be extended and should also provide for assessments that are adequately elevated to include higher-order spatial questions incorporating all three components of spatial thinking (Jo & Bednarz, 2011). When assessing content knowledge, lecturers should keep in mind that the development of spatial skills is not related to gaining content knowledge only (Metoyer & Bednarz, 2017). As such, assessments should be set to test students' basic knowledge, as well as their spatial thinking skills (Metoyer & Bednarz, 2017).

While much research has been conducted on the teaching of Geography, there is a lack of research on the educational contribution of assessments to develop and support higher-level learning (Beets, 2007). This gap still exists within the South African context, with most current research in South Africa focusing on decolonizing content and aligning curricula with module outcomes. (Golightly & Muniz, 2013; Knight & Robinson, 2017; Knight, 2018). It was indeed a sobering experience to discover that no scientific journal articles referring to assessments to develop and monitor students' spatial thinking skills could be found within the South African context.

6.2.1 Applying the taxonomy of spatial thinking

After Jo and Bednarz (2009) developed the taxonomy of spatial thinking, several research projects to determine the spatiality of questions in Geography textbooks at the school and university levels followed. Examples of the questions posed in textbooks that were evaluated in research projects using the taxonomy of spatial thinking included, amongst others, those about disasters in Indonesia (Ridha et al., 2019a), GIS in Indonesian textbooks (Ridha et al., 2019b), World Geography, as in four university-level World Geography course textbooks (Scholz et al., 2014), location and spatiality in Geography textbooks used at school level in Texas (Jo & Bednarz, 2011) and school Geography in textbooks from Brazil (Duarte, 2018) and Taiwan (Lay et al., 2015).

As a result, various recommendations to improve the spatiality of questions in textbooks have been made by several authors. Ridha et al. (2019a), for instance, recommend that the questions posed in Geography textbooks should be redesigned to better support the development of the spatial thinking skills of school learners living in disaster-prone areas. They believe that expanding on the spatial thinking skills of the learners will improve their decision-making skills, which would prove crucial should a natural disaster occur in the area where they live. Being able to think spatially is, according to these authors, an essential survival skill for learners living in disaster-prone regions in Indonesia (Ridha et al., 2019b). Scholz et al. (2014) found that all those questions that included a representation tool, a complex concept of space and a high output level could be expected to be scenario-based questions. Thus, these authors recommend that scenario-based questions, where students are requested to take on a role and a spatial perspective to address real-world problems, should be incorporated into university textbooks to reach a preferred level of spatiality in tertiary education. Scenario-based questions are recommended to help students develop knowledge through discovery instead of memorisation.

In cases where Geography textbooks are revised, Jo and Bednarz (2011) call on the authors to elevate the spatiality of questions included in these books. They also request teachers to select questions that incorporate aspects characterised by a high level of spatiality. To support the integration of spatial thinking into Geography textbooks, Lay et al. (2015) suggest the development of a comprehensive curriculum guideline and a policy support document.

Despite the proven importance of spatial thinking in Geography education, the contribution of the assessment questions in a textbook to the development of students' spatial thinking skills is generally not considered when it comes to selecting a Geography textbook for a university module. Lecturers indicated that they prefer to focus on previously used books or books covering the content that forms part of the specific module (Scholz et al., 2014).

It should be noted that the research projects mentioned in this section focus on assessing the spatiality of the questions posed in textbooks at the school and university levels and not on the assessment practices to develop spatial thinking skills. The taxonomy of spatial thinking should be used not only as a tool to measure the spatiality of the questions but also to design and pose questions that will significantly develop students' spatial thinking skills (Jo et al., 2010; Jo & Bednarz, 2011).

6.3 Variables influencing the development of spatial thinking skills

Research has shown that variables beyond educational pedagogies also influence how students learn to think spatially (Collins, 2018b). There are differences between people as to how quickly and how well they understand something, as well as in terms of their learning preferences (Verma, 2015). This implies that although spatial thinking may be learned at any age (National Research Council, 2006), different people may comprehend a concept differently and assimilate it at different speeds (Verma, 2015). Since reasoning and assimilation are personal capabilities, the development of spatial thinking can only happen as long as students are asked to personalise the process (Walkington et al., 2018). Personalizing the process of spatial thinking will lead to the development of students who are accustomed to thinking spatially, anticipate patterns to emerge, and are able to build comparisons, to extrapolate and to identify outliers and analogies (Sinton, 2017). Spatial (and Geospatial) thinking skills consist of combinations of overlapping skills and may be affected by variables such as the gender (Bednarz, 2019; Collins, 2018b; Verma & Estaville, 2018), demographic attributes, ethnicity and academic background of students (Verma & Estaville, 2018).

6.3.1 The influence of gender

Regarding gender, it has been suggested that women experience difficulties in specific mental rotation tasks (Bednarz, 2019). As opposed to their performance in pen-and-paper exercises, male students on the other hand perform better in executing spatial thinking tasks using Geospatial tools. Although the sample size was small, the same research confirmed that the belief that males should outperform females in spatial thinking skills is not true. Although previous studies conducted from 1990 to 2015 indicate a difference between the spatial thinking skills of male and female students (Boardman, 1990; Goldstein et al., 1990; Casey et al., 1995; Harwick et al., 2000 in Collins, 2018a), research by Metoyer and Bednarz (2017) and Collins (2018b) found no significant differences in the spatial thinking abilities of the two genders. However, a study conducted in schools in Rwanda found a considerable difference between the spatial thinking abilities of the genders (Tomaszewski et al., 2015). The difference in the spatial thinking ability of students from different genders in Rwanda is attributed to societal barriers and cultural practices in Rwandan society (Ibid).

It has also been suggested that men have a better mental rotation ability compared to women (Hegarty, 2018). However, the results of this study should be interpreted cautiously as they focus on the mental rotation abilities of Chemistry students and not Geography students. This is important to note, as it has been suggested that students who have completed Geography modules have superior spatial thinking skills (which would include their ability to effectively perform mental rotation exercises) (Verma, 2015). In the case of Geography students, therefore, the mental rotation differences in terms of gender could be smaller.

The initial difference in the performance in spatial thinking between male and female students may be diminished on account of the availability and exposure of students to maps via smartphones and online mapping applications (Collins, 2018b). However, when compared to female students with advanced spatial thinking skills, male students with advanced spatial skills were found to generally show a preference for GST methods (Metoyer & Bednarz, 2017). This observation can be considered rather as an indication that males and females interact differently with their instructional material (Metoyer & Bednarz, 2017).

6.3.2 The influence of educational background

Students who completed a Geography major or studied additional Geography courses are better equipped to think spatially than students who have not studied a Geography major or who completed fewer Geography courses (Verma, 2015). In addition, Shin, Milson and Smith (2016) found that students who study GIS possess better spatial thinking skills. Although Geography is ideally placed for developing spatial thinking skills, other disciplines, such as Art, Dance, Mathematics, Physics and Computer Science, may also have an impact on a student's spatial thinking skills (Verma, 2015).

As opposed to learners in lower grades, students in higher grades are better equipped to develop their spatial thinking skills (Collins, 2018b; Verma, 2015). The more advanced spatial thinking skills of learners in these grades could be attributed to their more rigorous course work, which contributes to the development of spatial thinking skills, and to their possible exposure to other modules that also promote spatial thinking skills (Ibid).

6.3.3 Other variables

Although it is expected that students with a favourable attitude towards Geography will find it easier to develop higher-level spatial thinking skills, Collins (2018b) proved that there is no correlation between a student's spatial thinking skills and his/her attitude toward Geography. Although paper maps may be equally effective in the teaching and learning of spatial thinking (Collins, 2018a), GSTs also improve students' attitudes, motivation and achievements in learning Geography (Kiper, 1999; Baker, 2002; West, 2003 in Collins, 2018b). There is also a weak positive correlation between students' spatial thinking skills and their travel experiences. However, more research is needed before more definite conclusions can be made in this respect (Collins, 2018b).

Although Collins (2018b) found no significant differences in the spatial thinking skills among different ethnic groups in the USA, research has shown that a person's socioeconomic background influences the development of his/her spatial thinking skills (Bednarz, 2019). In turn, Tomaszewski et al. (2015) found a significant difference between the spatial thinking skills of learners from rural and urban schools in Rwanda.

Although the relationship between gender, age and grade and spatial thinking capabilities has been determined to some extent, there is little or no research on the influence of culture, disability, socioeconomic status, ethnicity and language in this respect (Collins, 2018a).

Despite the many influences that different variables may have on spatial thinking and the uncertainties that they may evoke, spatial thinking can be taught to a person at any age and does, in fact, act as an instrument to equalise the playing field for academic performance and to improve pass rates (National Research Council, 2006; Bednarz, 2019). Furthermore, any person from any background or gender can learn spatial thinking and play an essential role as a future leader in making decisions within an ever-changing world (Bednarz, 2019).

6.4 Measurement of spatial thinking

Students with well-developed spatial thinking skills should be able to remember a specific map, carry out route planning, follow directions to a location, calculate and understand distance, interpret spatial patterns, visualise 3-D topography from different perspectives, compare the conditions of different locations and, based on a given set of criteria, choose an optimal location (Verma, 2015). In addition, a spatial thinker can critically examine and understand spatial issues concerning spatial data, spatial analysis and spatial communications (Bearman et al., 2016). In 2006, the National Research Council indicated the need to measure the spatial thinking skills of a person (National Research Council, 2006). To this end, Lee and Bednarz (2012) developed the spatial thinking ability test, also known as the STAT. (The STAT and the different categories of the STAT are explained in detail in Chapter 2, Section 2.3.3.) Although several other spatial thinking tests have been developed, the STAT focuses on psychometric scales and intelligence tests (Collins, 2018b) and is the only instrument integrating geographical content knowledge and spatial thinking skills (Ibid). In fact, in an effort to assess the spatial thinking skills of school learners and university students, many researchers have based their studies on the STAT (Fleming & Mitchell, 2017; Flynn, 2018; Ishikawa, 2013; Tomaszewski et al., 2015; Verma, 2015; Verma & Estaville, 2018).

6.4.1 Application of the spatial thinking ability test (STAT)

The STAT has been tested for validity and reliability and, as mentioned previously, has been favoured for testing the spatial thinking skills of school learners and university students (Collins, 2018b; Tomaszewski et al., 2015). (Refer to Chapter 2 Section 2.3.3.) At the school level, for example, the STAT has been used to determine whether engagement with a giant travelling map would develop the spatial thinking capabilities of sixth-grade learners (Fleming & Mitchell, 2017) or the differences in the spatial thinking skills of urban and rural learners (Tomaszewski et al., 2015). Collins (2018b) used the STAT to determine the impact of paper *versus* digital technology on the acquisition of spatial thinking skills among learners and to investigate methods to advance Geospatial learning in K-12 learners (Collins, 2018a)

At the university level, the STAT has been used to determine whether a geocaching exercise can improve the spatial thinking skills of undergraduate students (Flynn, 2018); to establish the role of Geography courses in improving Geospatial thinking (Verma & Estaville, 2018); to evaluate the differences in the Geospatial thinking skills of undergraduate students (Verma, 2015); and to investigate the relationship between Geospatial thinking and spatial ability (Ishikawa, 2013)

In all instances, the STAT has been successfully applied in determining the spatial thinking skills or the improvement in the spatial thinking skills of school learners and undergraduate students. However, Verma and Estaville (2018) have reported that regardless of their academic exposure, some of the selected questions used from the STAT to determine students' Geospatial thinking skills have in fact proved to be too difficult for the students. Along the same lines, Fleming and Mitchell (2017) have reported that the STAT questions are too difficult for Grade 6 learners.

Before conducting their research, some researchers made slight adjustments to the STAT, most of which involved changes to the metric units and to the maps – to reflect the local context and changes to the wording (Tomaszewski et al., 2015; Verma, 2015; Verma & Estaville, 2018). In addition, in some instances, questions have been added to the STAT to provide context within the educational setting of the students and learners (Fleming & Mitchell, 2017; Flynn, 2018; Tomaszewski et al., 2015; Verma & Estaville, 2018).

Although Lee and Bednarz identified eight abilities that they categorise as components of spatial thinking in the STAT, they acknowledge that spatial thinking actually combines these abilities (Lee & Bednarz, 2012). Their spatial thinking categories are nonetheless helpful in identifying intervention areas from the STAT scores (Tomaszewski et al., 2015).

Assessment tools, such as STAT, are essential for determining students' spatial thinking capabilities and generally assist in identifying misconceived understandings of the concepts of spatial thinking (Verma & Estaville, 2018). Therefore, the STAT should be used to regularly assess students' spatial thinking skills and to identify their strengths and weaknesses in addressing those spatial concepts that need attention (Ibid). The teaching material and assessments should be adjusted accordingly to identify and address the gaps in students' spatial thinking skills (Ibid).

Most research projects in the USA and Europe focus on using the STAT, or an adjusted version of it, to determine the spatial thinking skills of school learners and undergraduate students in these regions. Examples of its use in research have also been found on the African continent, firstly, where the STAT has been used to determine the spatial thinking skills of school learners in Rwandan schools (Tomaszewski et al., 2015), and secondly, in a study involving Ethiopian undergraduate students (Flynn, 2018). Noteworthy is that the spatial thinking skills of the undergraduate students from Ethiopia tested at a much lower level than those of their counterparts from American universities (Ibid).

6.5 Positioning the evaluation of assessment practices and the measurement of spatial thinking skills within the AQAL model

The taxonomy of spatial thinking, used to determine the spatiality of questions, and the STAT, used to determine the spatial thinking abilities of students, are tested instruments and are, therefore, located in the UR quadrant of the AQAL model. The results of both these instruments are interpreted from an outside 'It' perspective. However, the interpretation of the taxonomy of spatial thinking is partially based on the researcher's experience and has, therefore, also an outside ("I") component. As such, this part of the assessment is located within the UL quadrant. However, the interpretation of the results of the STAT is objective and from an outside (external) viewpoint. As such, these results are within the UR quadrant of the AQAL model.

The levels and lines of the AQAL model are explained in Chapter 5, Section 5.3. The NQF levels 5, 6 and 7 represent the levels of development of students over the three years of study. The assessment questions should become more complex as a student proceeds to the higher NQF levels. The spatiality of the taxonomy of spatial thinking is applied as lines within the AQAL model which represent the respective levels of complexity. The AQAL forms a path lecturers should follow to develop students' spatial thinking skills as they proceed through the NQF levels. The results of the STAT for the sample of students who completed this test will indicate whether the path set by the lecturers has been followed successfully. The states included in the AQAL model represent a lecturer's disposition towards their teaching of spatial thinking. If a lecturer is not well disposed to include spatial thinking in his/her teaching and assessments, the students' spatial thinking skills will not develop. The application field of the selected module represents the consistent styles of the AQAL model.

6.6 A critical evaluation of the spatiality of assessments at participating Geography departments

Formative and summative assessments were obtained from all the lecturers who participated in the interviews participating departments and critically evaluated against the taxonomy of spatial thinking to determine the spatiality of the questions. However, the formative and summative assessments that were received were inconsistent for three reasons. Firstly, some lecturers did not have documents for the three years covered by this research (2019-2021). Secondly, the number of formative assessments and how they were conducted differed among the departments or, in some instances, even within the same department. Lastly, one lecturer could not submit any assessment documentation, and another was able to submit assessments for only one year. Regardless of these limitations, the selected departments provided enough questions to use to assess and critically evaluate the spatiality of the questions.

Since both formative and summative assessments should contribute towards the development of the spatial thinking abilities of students and there was a difference in the number of questions submitted per lecturer, the results do not distinguish between these two types of assessments. Therefore, for the purpose of clarity, the formative and summative assessments are collectively referred to as "assessments".

The same process, as that explained in Chapter 2, Section 2.3.2, and Chapter 4, Section 4.8, was followed to determine the spatiality of the questions used for the assessments, except that the results were calculated differently. This was because it was necessary to consider both the number of questions pitched and the weighted contribution of each question toward the final mark of the assessment. The questions earning marks and included in an assessment were therefore captured and calculated as a percentage of the total marks for the assessment. The weighted percentage contribution of these questions to the spatiality of the assessment was then calculated. The concept of a weighted contribution in respect of the questions was essential as not all questions contributed equally to a specific assessment. For example, two questions on a high level of spatiality might contribute 60% to the total assessment, while 10 questions on a lower level of spatiality might contribute 40% to the assessment. If only the number of questions were to be considered in the determination of the spatiality of the assessment, the 10 questions on the lower level would reflect a low level of spatiality for the assessment, which in this case, would not be a true reflection of the situation.

Questions with a cell value of 10, 11, 12, 16, 17, 18, 22, 23 and 24 were pinpointed as those succeeding in effectively incorporating the three components of spatial thinking, namely the cognitive level at which the questions are pitched, the appropriate use of concepts of space and the use of representation tools. The inclusion of questions with these cell values was, therefore, essential to ensure that the questions included in the assessments would foster the students' spatial thinking skills. (Refer to Chapter 2, Section 2.3.2, and Chapter 4, Section 4.8 for more detail regarding the taxonomy of spatial thinking.) These cell values represent the integration of the three components of spatial thinking. The integration of spatial thinking is represented as the percentage of the weighted contribution of questions or the number of questions that have the abovementioned cell values.

Since the interpretation of the taxonomy of spatial thinking is partially subjective, researchers might differ from each other in their findings. However, the overall trends and conclusions of the research should still prevail. In the interest of consistency, therefore, the protocol followed in this research was that in the case of any uncertainty regarding the cognitive level or spatial concepts assessed in the questions, the option leading to the highest level of spatiality would be the one to be assigned. This ensured consistency in the application of the taxonomy of spatial thinking and to give the lecturer the benefit of the doubt.

A total of 2 620 assessment questions were evaluated against the taxonomy of spatial thinking to assess their spatiality. Table 6.1 summarises the number of questions evaluated per department. The highest number of assessment questions was submitted by Department A (849), while the lowest number was submitted by Department B (166).

Table 6.1: Formative and summative assessment questions per department and NQF level.

Anonymous name	NQF Level 5	NQF Level 6	NQF Level 7	Total per deartment
Department A	323	139	387	849
Department B	Not available	104	62	166
Department E	170	52	101	323
Department F	404	178	34	616
Department H	187	276	5	468
Department J	107	52	39	245
Total per NQF Level	1191	801	628	2620

The purpose of this research was not to compare departments with each other, but rather to determine whether and to what extend their assessment practices do include spatial thinking, demonstrate an increased level of spatiality from NQF levels 5 to 7 and provide students with the opportunity to develop their spatial thinking skills. The following sections discuss the evaluation of the questions used for assessments against the taxonomy of spatial thinking per department.

6.6.1 Department A: Spatiality of assessments

Twelve (12) assessments (323 questions) on NQF Level 5, 14 assessments (139 questions) on NQF Level 6 and 37 assessments (387 questions) on NQF Level 7 were evaluated to determine the level of spatiality of the assessments of Department A. The modules on NQF levels 5 and 6 are both Human Geography modules, while the module on NQF Level 7 is on Geospatial applications.

Components of spatial thinking in assessment questions

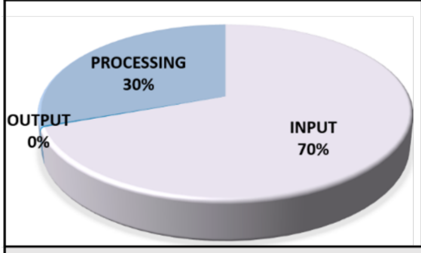
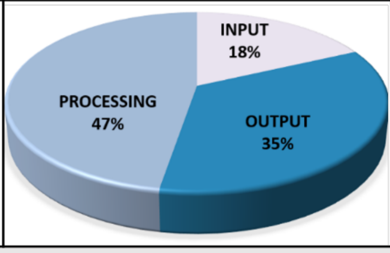
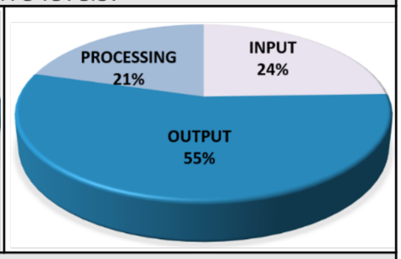
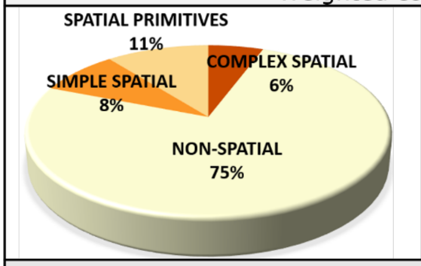
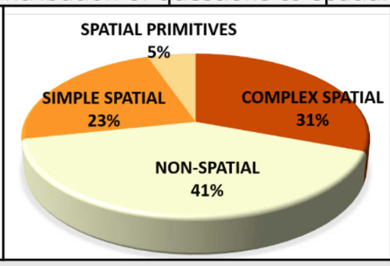
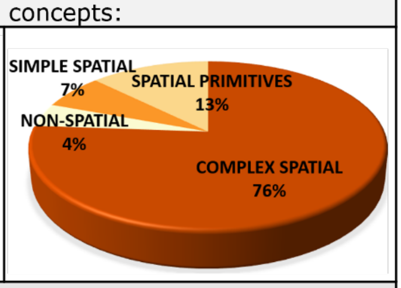
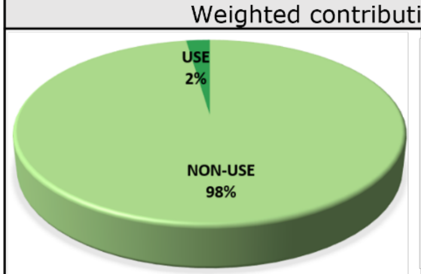
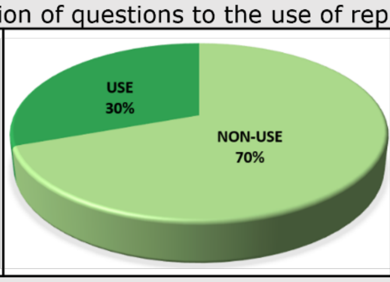
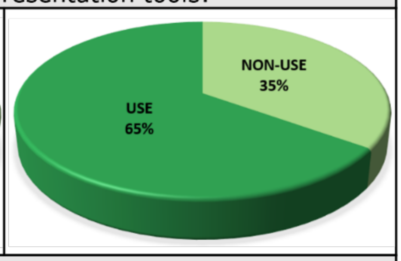
<table>
<tr><td colspan="2">NQF Level 5
Human Geography</td><td>NQF Level 6
Human Geography</td><td>NQF Level 7
Geospatial applications</td></tr>
<tr><td colspan="2">Number of assessments =12</td><td>Number of assessments =14</td><td>Number of assessments =37</td></tr>
<tr><td colspan="4">Weighted contribution of questions to cognitive levels:</td></tr>
<tr><td colspan="2">
</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions per cognitive level:</td></tr>
<tr><td>Input:</td><td>281 (87%)</td><td>58 (42%)</td><td>184 (48%)</td></tr>
<tr><td>Processing:</td><td>40 (12%)</td><td>52 (37%)</td><td>73 (19%)</td></tr>
<tr><td>Output:</td><td>2 (1%)</td><td>29(21%)</td><td>130 (34%)</td></tr>
<tr><td>Total:</td><td>323</td><td>139</td><td>387</td></tr>
<tr><td colspan="4">Weighted contribution of questions to spatial concepts:</td></tr>
<tr><td colspan="2">
</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions per spatial concept:</td></tr>
<tr><td>Non-spatial:</td><td>235(73%)</td><td>47 (34%)</td><td>55 (14%)</td></tr>
<tr><td>Spatial primitives:</td><td>43(13%)</td><td>28 (20%)</td><td>41 (11%)</td></tr>
<tr><td>Simple spatial:</td><td>30 (9%)</td><td>9 (6%)</td><td>41 (11%)</td></tr>
<tr><td>Complex spatial:</td><td>15 (5%)</td><td>55 (40%)</td><td>250 (65%)</td></tr>
<tr><td>Total:</td><td>323</td><td>139</td><td>387</td></tr>
<tr><td colspan="4">Weighted contribution of questions to the use of representation tools:</td></tr>
<tr><td colspan="2">
</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions pertaining to the use or non-use of representation tools:</td></tr>
<tr><td>Use:</td><td>4 (1%)</td><td>80 (58%)</td><td>230 (59%)</td></tr>
<tr><td>Non-use:</td><td>319(99%)</td><td>59 (42%)</td><td>157 (41%)</td></tr>
<tr><td>Total:</td><td>323</td><td>139</td><td>387</td></tr>
</table>

Figure 6.1: Department A – The inclusion of the components of spatial thinking in assessments.

Cognitive level. On NQF Level 5, the results of the evaluation of the questions against the taxonomy of spatial thinking indicate that the bulk of the weighted contribution of the questions (70%) is on a low cognitive level, namely on an input level. (Refer to Figure 6.1.) Regarding the number of questions, 87% are on an input level.

On NQF Level 6, the weighted contribution of questions on an input level decreases to 18%, with the processing and output levels increasing to 47% and 35%, respectively. However, the number of questions on an input level remains dominant (42%). On NQF Level 7, the weighted contribution of questions is the highest on an output level (55%), followed by an almost equal split on the input and processing levels (24% and 21%, respectively). The largest number of questions is on an input level (48%), with only 34% of the questions pitched on an output level.

Although there is an increase in the spatiality of the weighted contribution and the number of questions from NQF Level 5 to NQF Level 6, the percentage of questions on an output level remains low. To integrate the three components of spatial thinking and contribute toward the development of students' spatial thinking skills, output-level questions should constitute most of the questions on all three NQF levels with an increased percentage from NQF level 5 to 7. Regarding the number of questions, the questions pitched on an output level also constitute the lowest percentages. Some of the questions on a lower cognitive level should, therefore, rather be pitched at a higher level.

Concepts of space. On NQF Level 5, it was found that both the weighted contribution of questions (75%) and the number of questions (73%) in the assessments are dominated by the non-spatial category. On NQF Level 6, the weighted contribution of the non-spatial questions declines to 41%, and that of the complex spatial category increases to 31%. However, the number of complex spatial questions remains low, at 40%, followed by the non-spatial category (34%). Encouraging is that on NQF Level 7, the weighted contribution of complex spatial questions is the highest of all three NQF levels, namely 76%, while 65% of the questions are in this category. The non-spatial category proved to be insignificant, with the weighted contribution of questions at 4% and the number of questions at 14%.

From NQF levels 5 to 7, there is an increase in both the weighted contribution and number of questions in the complex spatial category. However, the high proportion of questions in non-spatial categories on NQF levels 5 and 6 is a matter for concern. Thus, the number of questions on a complex spatial level on NQF level 5 and especially NQF Level 6 should be increased to effectively develop the spatial thinking skills of students.

Representation tools. In terms of both the weighted contribution and the number of questions asked, the category for the non-use of representation tools dominates on NQF Level 5. On NQF Level 6, 70% of the weighted contribution of questions does not involve the use of representation tools, and in terms of numbers, 58% of the questions do not involve the use of representation tools. On NQF Level 7, 65% of the weighted contribution of questions contribute towards the use of representation tools.

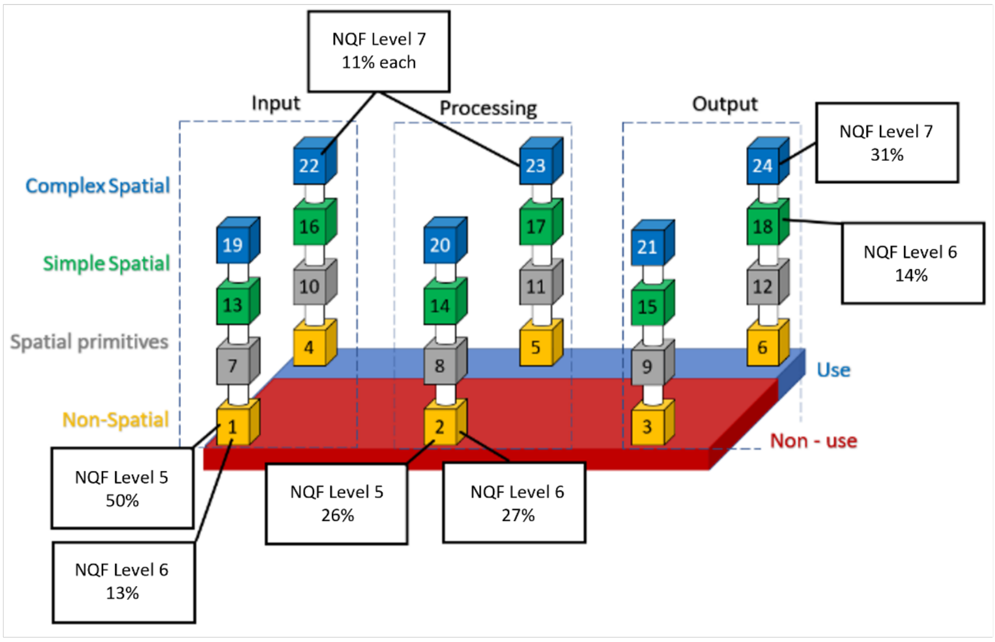
To develop students' spatial thinking skills, it is essential that representation tools are included in the assessment questions and that they should dominate in terms of both their weighted contribution and the number of questions posed. The use of representation tools on NQF levels 5 and 6 proved to be too low and needs attention.

Application of the taxonomy of spatial thinking to assessment questions

The spatiality of the assessment questions submitted for Department A, as assessed against the taxonomy of spatial thinking, is summarised in Figure 6.2. On NQF Level 5, the weighted contribution of questions shows a concentration of 76% on cell values 1 and 2. This is followed by 10% of the weighted contribution on cell value 7. The same pattern is demonstrated in terms of the number of questions asked, with 79% having cell values of 1 and 2 and 29% with a cell value of 7. There was only one question with a cell value of 23 and only 1% of the questions integrated the three components of spatial thinking and would, therefore, contribute to developing students' spatial thinking skills.

On NQF Level 6, 40% of the weighted contribution of questions have cell values of 1 and 2, followed by 15% with a cell value of 20. Regarding the number of questions on NQF Level 6, 16% have a cell value of 2, followed by 15% with a cell value of 23. The weighted contribution of questions that integrate the three components of spatial thinking on this NQF level is 29%. Despite the 15% contribution of the number of questions with a cell value of 23, the weighted contribution of these questions is only 5%. It should be noted that on NQF Level 6, the weighted contribution of questions with a cell value of 18 is 14%. Although questions with a cell value of 18 would contribute toward developing students' spatial thinking skills, the contribution of these questions cannot be regarded as a substitute for the high percentage of questions with cell values of 1 and 2.

On NQF Level 7, the questions demonstrate a much higher level of spatiality than those on levels 5 and 6. The highest weighted contribution of questions in terms of spatiality occurs in cells with values 24 (31%), 23 (11%) and 22 (11%). Cells with values of 18, 22, 23 and 24 demonstrate that the components of spatial thinking are incorporated in assessment questions and would, therefore, contribute to the development of students' spatial thinking abilities. However, questions with a cell value of 22 are on a low cognitive (input) level. Therefore, it is recommended that some of these questions be rephrased on a higher cognitive (output) level, which would significantly improve the spatiality of the questions.



(For clarity purposes, only some of the highest weighted contributions are indicated on the graph. Spatiality in red text in the table refers to the integration of all the components of spatial thinking.)

NQF Level 5			NQF Level 6			NQF Level 7		
Integrated = 1%			Integrated = 29%			Integrated = 65%		
Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions
1	50%	202	1	13%	19	1	4%	49
2	26%	33	2	27%	22	2	>1%	2
3	>1%	2	3	5%	5	3	1%	6
7	10%	41	4	>1%	3	7	>1%	2
8	1%	2	7	>1%	1	8	3%	2
13	8%	2	8	>1%	1	9	3%	9
19	2%	10	9	2%	2	10	5%	21
20	3%	4	10	3%	22	12	1%	7
23	1%	1	11	>1%	2	13	1%	8
			13	>1%	1	15	>1%	4
			15	4%	3	16	2%	12
			16	>1%	1	17	>1%	3
			18	14%	2	18	3%	12
			19	1%	1	19	2%	26
			20	15%	6	20	6%	11
			21	4%	2	21	15%	41
			22	1%	10	22	11%	66
			23	5%	21	23	11%	55
			24	5%	15	24	31%	51

Figure 6.2: Department A – Taxonomy of spatial thinking.

In terms of their spatial thinking abilities, the students on NQF levels 5 and 6 were assessed at a low level, and it is recommended that the spatiality of the assessment questions be improved to attain more significant percentages on cell values 22, 23, 24 and 18. Although the weighted contribution of questions integrating the three components of spatial thinking increases on NQF Level 7, the question to be raised is whether a 65% integration level would be sufficient for an NQF Level 7 module. The module on NQF Level 7 focuses on Geospatial applications. Geospatial tools are of an applied nature and incorporate the use of representation tools. A high level of integration of the three components of spatial thinking in the assessments could be expected in terms of the weighted contribution, as well as in the number of questions.

Table 6.2: Department A – Spatiality of module outcomes, inclusion of spatial thinking in teaching methods and spatiality of assessment questions according to the taxonomy of spatial thinking. (Bold text represents cell values integrating the three components of spatial thinking.

For clarity, the table only indicates the spatiality of cell values with the highest weighted contribution of questions expressed as percentages)

<table>
<tr><th>Module</th><th>Spatiality of module outcomes</th><th>Lecturer</th><th>Spatial thinking in teaching</th><th>Spatiality of assessment questions</th></tr>
<tr><td>A.5</td><td>2
2
3
14
21
24</td><td>AC</td><td>Yes</td><td>1
2
23
Integration = 1%</td></tr>
<tr><td rowspan="2">A.6</td><td rowspan="2">1
3
3
3
21
21
24</td><td>AA</td><td>Yes</td><td rowspan="2">1
2
18
22
23
24
Integration = 29%</td></tr>
<tr><td>AD</td><td>Yes</td></tr>
<tr><td>A.7</td><td>2
3
24
24
24</td><td>AB</td><td>Yes</td><td>22
23
24
Integration = 65%</td></tr>
</table>

To conclude this analysis, reference is made to Table 6.2, which compares the spatiality of the assessment questions with the spatiality of the module outcomes and the inclusion of spatial thinking in teaching methods and in accordance with the taxonomy of spatial thinking. On NQF Level 5, the module outcomes attain cell values of 21 and 24, while the assessment questions are primarily pitched at cell values 1 and 2. On NQF Level 6, the module outcomes match cell values of 21 and 24 whereas most of the assessment questions are associated with cell values of only 1, 2 and 18. Only 11% of the questions on NQF Level 6 have a cell value ranging between 22 and 24. On the other hand, the assessment questions and module outcomes on NQF Level 7 are more effectively aligned with the module outcomes.

6.6.2 Department B: Spatiality of assessments

Department B submitted no assessments on NQF Level 5, 29 assessments (104 questions) on NQF Level 6 and 27 assessments (62 questions) on NQF Level 7 for evaluation. The module on NQF Level 6 is a Human Geography module, while the module on NQF Level 7 is a module in Geospatial applications.

Components of spatial thinking in assessment questions

<u>Cognitive level.</u> On NQF Level 6, the weighted contribution of questions on the output level (66%) and in terms of the number of questions (31%) dominate. On NQF Level 7, the weighted contribution of questions on the output level remains dominant but declines to 61%. Most questions on NQF Level 7 (45%) are also pitched on the output level (Refer to Figure 6.3 for a summary of the statistics.)

Although most of the questions on NQF levels 6 and 7 for Department B are pitched on an output level, it is recommended that the weighted contribution of questions on the output level on NQF Level 7 be adjusted to a higher percentage than that on NQF Level 6 to ensure that the spatial thinking abilities of students are developed maximally.

<u>Processes of Reasoning.</u> The weighted contribution of questions on NQF Level 6 is the highest on a complex spatial level (46%), with most questions posed on this same level (38%), followed by questions on a non-spatial level (34%). In the case of NQF Level 7, the weighted contribution of questions incorporating a complex spatial concept of space increases to 60%, followed by the non-spatial category (20%). On NQF Level 7, most questions incorporate a complex spatial concept of space (61%), followed by the non-spatial category(26%).

On NQF Level 6, the weighted contribution of complex spatial questions should be increased to a higher percentage, while that for questions on a non-spatial level should be reduced. On NQF Level 7, it is recommended that the weighted contribution of questions in the non-spatial, spatial primitive and simple spatial categories be adjusted so that a more-or-less equal contribution can be achieved. The lecturers from Department B should be commended as they are the only ones from all six departments included in this research who encourage their students in their assessment documents to use the correct spatial concepts to answer questions.

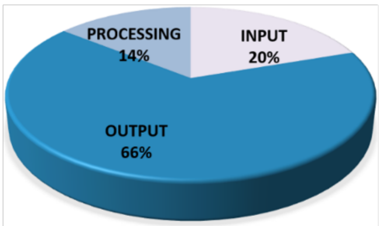
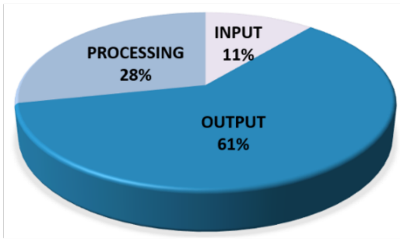
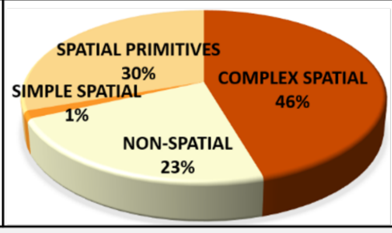
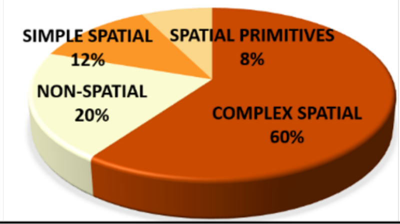
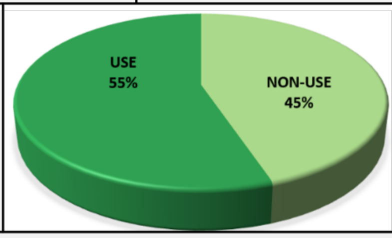
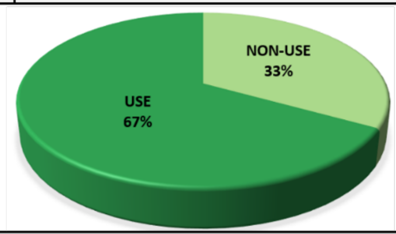
<table>
<tr><td colspan="2">NQF Level 5</td><td>NQF Level 6
Human Geography</td><td>NQF Level 7
Geospatial applications</td></tr>
<tr><td colspan="2"></td><td>Number of assessments = 29</td><td>Number of assessments = 27</td></tr>
<tr><td colspan="4">Weighted contribution of questions to cognitive levels:</td></tr>
<tr><td colspan="2">Not available</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions per cognitive level:</td></tr>
<tr><td>Input:</td><td></td><td>32 (31%)</td><td>11 (18%)</td></tr>
<tr><td>Processing:</td><td></td><td>28 (27%)</td><td>23 (37%)</td></tr>
<tr><td>Output:</td><td></td><td>44 (42%)</td><td>28 (45%)</td></tr>
<tr><td>Total:</td><td></td><td>104</td><td>62</td></tr>
<tr><td colspan="4">Weighted contribution of questions to spatial concepts:</td></tr>
<tr><td colspan="2">Not available</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions per spatial concept:</td></tr>
<tr><td>Non-spatial:</td><td></td><td>35 (34%)</td><td>16 (26%)</td></tr>
<tr><td>Spatial primitives:</td><td></td><td>27 (26%)</td><td>2 (3%)</td></tr>
<tr><td>Simple spatial:</td><td></td><td>2 (2%)</td><td>6 (10%)</td></tr>
<tr><td>Complex spatial:</td><td></td><td>40 (38%)</td><td>38 (61%)</td></tr>
<tr><td>Total:</td><td></td><td>104</td><td>62</td></tr>
<tr><td colspan="4">Weighted contribution of questions to the use of representation tools:</td></tr>
<tr><td colspan="2">Not available</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions pertaining to the use or non-use of representation tools:</td></tr>
<tr><td>Use:</td><td></td><td>43 (41%)</td><td>39 (63%)</td></tr>
<tr><td>Non-use:</td><td></td><td>61 (59%)</td><td>23 (37%)</td></tr>
<tr><td>Total:</td><td></td><td>104</td><td>62</td></tr>
</table>

Figure 6.3: Department B – The inclusion of the components of spatial thinking in assessments.

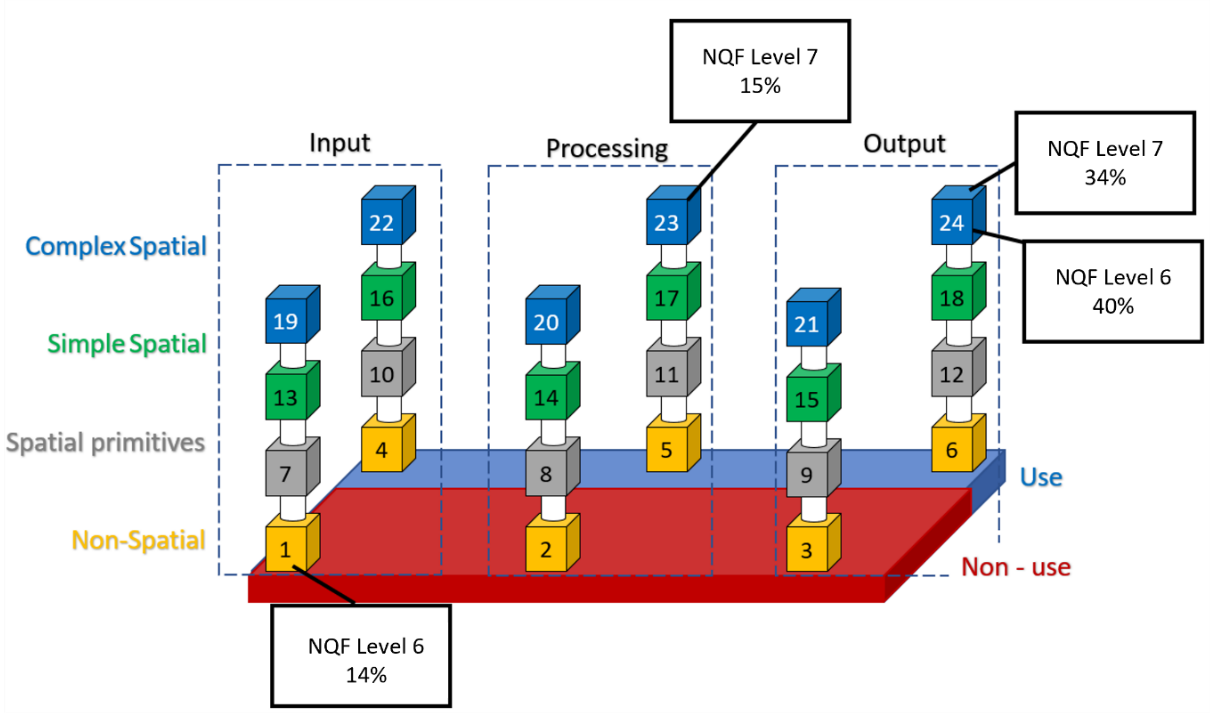
Representation tools. The weighted contribution of questions incorporating representation tools is at 55% on NQF Level 6. Regarding the number of questions, 59% do not include representation tools. On NQF level 7, the weighted contribution of questions including the use of representation tools increases to 67%. This constitutes 37% of the number of questions pitched in the assessments. Although the use of representation tools on both NQF levels 6 and 7 contributes the highest weighted contribution on both NQF levels, it is still necessary to consider whether these weighted contributions are large enough to develop students' spatial thinking skills.

Application of the taxonomy of spatial thinking to assessment questions

The respective levels of spatiality of the assessment questions submitted for Department B, as evaluated against the taxonomy of spatial thinking, are summarised in Figure 6.4. The weighted contribution of the questions on NQF Level 6 is the highest for cell value 24 (40%), followed by that for cell value 1 (14%). The number of questions on NQF Level 6 is also the highest for cell values 24 (22%) and 1 (21%). On NQF Level 6, 55% of the weighted contribution of questions incorporate the three components of spatial thinking.

The weighted contribution of questions on NQF Level 7 is the highest for cell value 24 (34%), followed by that for cell value 7 (15%). Most of the questions pitched on NQF Level 7 are for cell values 23 (19%) and 24 (22%). On NQF Level 7, the weighted contribution of questions incorporating the three components of spatial thinking increases to 61%.

Since the module on NQF Level 6 covers Geospatial applications, a high level of integration of the three components of spatial thinking could be expected. However, the weighted contribution of questions that serves to integrate the three components of spatial thinking is relatively low for both NQF levels. The assessment questions with a lower spatiality should be reviewed and need to be pitched at a higher level on the taxonomy of spatial thinking.



(For clarity purposes, only some of the highest weighted contributions are indicated on the graph. Spatiality in red text in the table refers to the integration of all the components of spatial thinking.)

NQF Level 5			NQF Level 6			NQF Llevel 7		
Integrated			Integrated = 55%			Integrated = 61%		
Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions
			1	14%	22	1	<1%	3
			2	7%	10	2	10%	9
			3	2%	3	3	10%	4
			7	1%	5	8	4%	1
			8	4%	6	9	4%	1
			9	13%	8	15	4%	1
			10	3%	1	16	8%	3
			11	<1%	1	18	1%	2
			12	8%	6	20	<1%	1
			18	1%	2	21	8%	6
			19	1%	3	22	3%	5
			20	1%	2	23	15%	12
			21	1%	2	24	34%	14
			22	<1%	1			
			23	2%	9			
			24	40%	23			

Figure 6.4: Department B – Taxonomy of spatial thinking.

To conclude this analysis, reference is made to Table 6.3, which compares the spatiality of the assessment questions with the spatiality of the module outcomes and the inclusion of spatial thinking in teaching methods according to the taxonomy of spatial thinking. In the case of the NQF Level 6 module, the spatiality of the weighted contribution of questions does not align with the spatiality of the module outcomes. In fact, too many questions with a cell value of 1 are included, which is an aspect that needs to be addressed. On NQF Level 7, the weighted contribution of questions aligns better with the spatiality of the module outcomes, although the integration level of 61% for the three components of spatial thinking is too low for a Geospatial module at this NQF level.

Table 6.3: Department B – Spatiality of module outcomes, inclusion of spatial thinking in teaching methods and spatiality of assessment questions according to the taxonomy of spatial thinking. (Bold text represents cell values integrating the three components of spatial thinking.

For clarity, the table only indicates the spatiality of the highest weighted contribution of questions expressed as percentages)

Module	Spatiality of module outcomes	Lecturer	Spatial thinking in teaching	Spatiality of assessment questions
B.5	Not available	BB	Yes	Not available
B.6	20 21	BA	Yes	1 **24** Integrated = 55%
B.7	1 20 **24**	BB BC	Yes	**23** **24** Integrated = 61%

6.6.3 Department E: Spatiality of assessments

Department E submitted six assessments (170 questions) on NQF Level 5, eight assessments (52 questions) on NQF Level 6, and 10 assessments (101 questions) on NQF Level 7. The two modules on NQF levels 5 and 6 focus on Human Geography, while the module on NQF Level 7 is a Geospatial module.

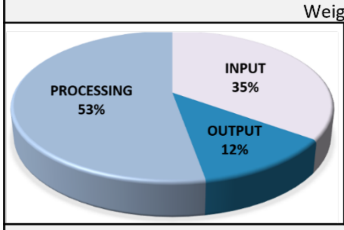
Components of spatial thinking in assessment questions

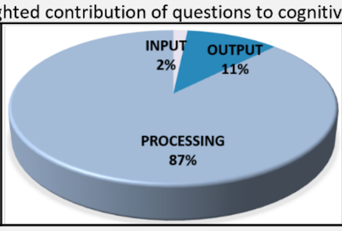
Cognitive level. The weighted contribution of questions on the processing level dominates on NQF Level 5 (53%). (Refer to Figure 6.5.) Although the weighted contribution of such questions is dominant on NQF Level 5, most questions (82%) are on an input level. On NQF Level 6, the weighted contribution of questions on the processing level increases to 87% and most of the questions are on a processing level (55%). On NQF Level 7, the weighted contribution of questions on the processing level decreases to

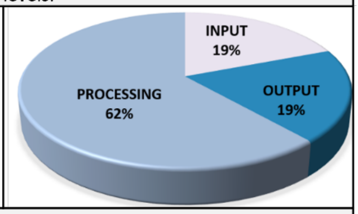
62%, while the input and output levels increase to 19% each. Most of the questions on this NQF level are on an input level (58%).

NQF Level 5 Human Geography	NQF Level 6 Human Geography	NQF Level 7 Geospatial applications
Number of assessments = 6	Number of assessments = 18	Number of assessments =12

Weighted contribution of questions to cognitive levels:



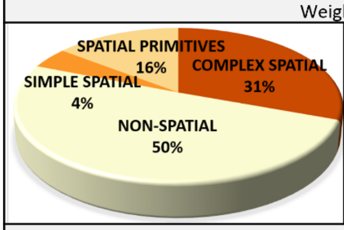


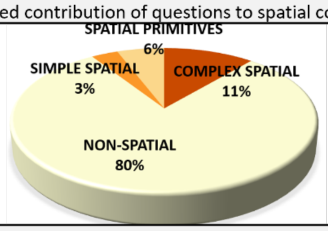


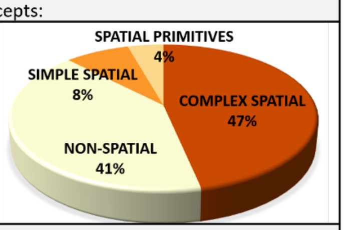
Number of questions per cognitive level:

	NQF Level 5	NQF Level 6	NQF Level 7
Input:	140(82%)	2 (4%)	59 (58%)
Processing:	27 (16%)	44 (85%)	27 (28%)
Output:	3 (2%)	6 (11%)	15 (14%)
Total:	170	52	101

Weighted contribution of questions to spatial concepts:



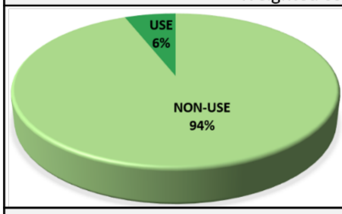


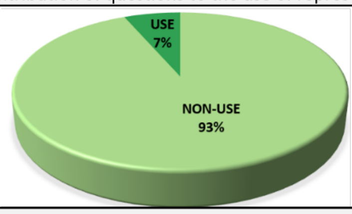


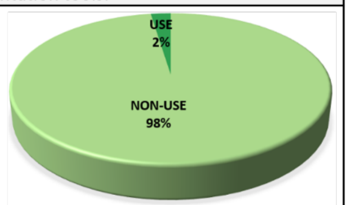
Number of questions per spatial concept:

	NQF Level 5	NQF Level 6	NQF Level 7
Non-spatial:	126 (74%)	43 (83%)	42 (42%)
Spatial primitives:	23 (14%)	4 (8%)	5 (5%)
Simple spatial:	8 (5%)	2 (4%)	10 (10%)
Complex spatial:	13 (8%)	3 (5%)	44 (43%)
Total:	170	52	101

Weighted contribution of questions to the use of representation tools:







Number of questions pertaining to the use or non-use of representation tools:

	NQF Level 5	NQF Level 6	NQF Level 7
Use:	2 (1%)	5 (10%)	3 (3%)
Non-use:	168(99%)	47 (90%)	98 (97%)
Total:	170	52	101

Figure 6.5: Department E – The inclusion of the components of spatial thinking in assessments.

The number of assessment questions on the output level for all three NQF levels should be increased in terms of their weighted contribution to constitute the highest percentage. In fact, this contribution should increase from NQF levels 5 to 7.

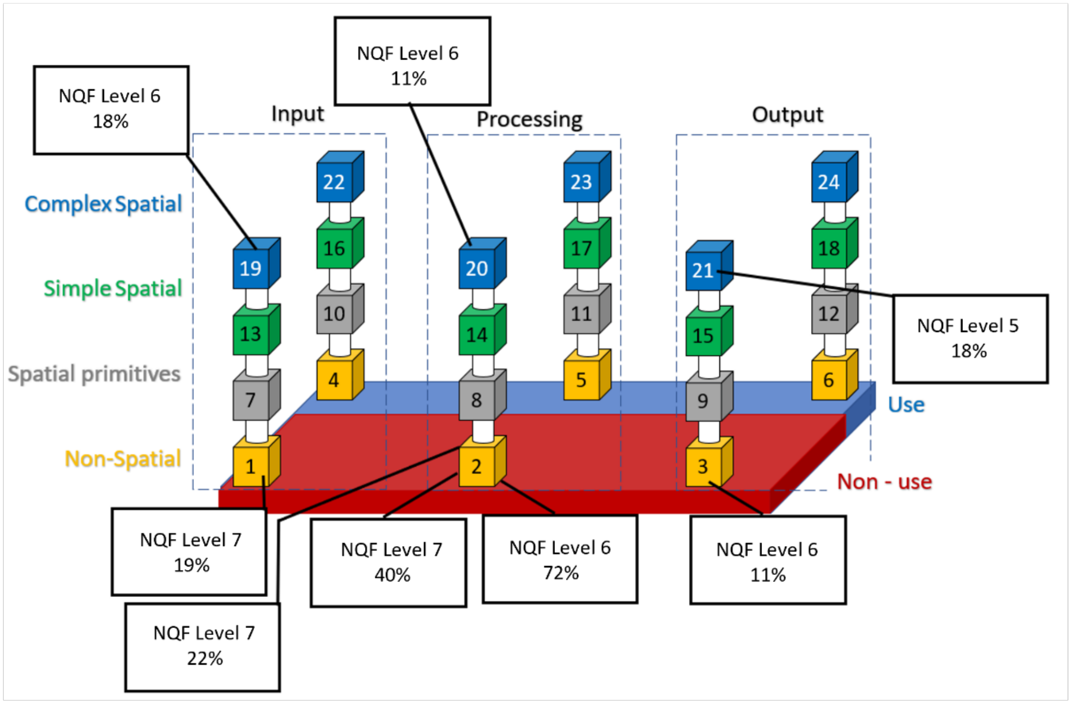
Concepts of space. The weighted contribution of questions around non-spatial concepts of space attained the highest contribution on NQF Level 5 (50%). Regarding the number of questions, most have a non-spatial component (74%). The weighted contribution of questions with a non-spatial component increases to 80% on NQF Level 6, while decreasing to 11% for questions on a complex spatial level . However, most of the questions (83%) on NQF Level 6 have a non-spatial component. On NQF Level 7, the weighted contribution of the questions in the complex spatial category increases to 47%, followed closely by the non-spatial category at 41%.

The assessment questions in the non-spatial category on all three NQF levels should be reduced in terms of both the number of questions and the weighted contribution of the questions. In contrast, the number of assessment questions in the complex spatial category should be increased on all three levels, with an increasing weighted contribution from NQF levels 5 to 7.

Representation tools. The weighted contribution of questions not using representation tools is similar on all thee NQF levels with 94% on NQF Level 5, 93% on NQF Level 6 and 98% on NQF Level 7. The number of questions follows a similar pattern, with 99% of the questions on NQF Level 5 demonstrating the non-use of representation tools, 90% on NQF Level 6 and 97% on NQF Level 7. A high percentage for the weighted contribution and number of questions for the non-use of a representation tool will lead to a low integration percentage in respect of the three components of spatial thinking and will not contribute to the development of students' spatial thinking skills. The use of representation tools is considered too limited on all three NQF levels.

Application of the taxonomy of spatial thinking to assessment questions

Figure 6.6 summarises the results of the evaluation of the assessment questions submitted for Department E against the taxonomy of spatial thinking. On NQF Level 5, the weighted contribution of questions is the highest on cell values 2 (40%) and 21 (18%). Regarding the number of questions, most (65%) have a cell value of 1, followed by questions with cell values of 2 and 7 – both 11%. The weighted contribution of questions on NQF Level 6 has a lower spatiality than that for the questions on NQF Level 5, with 72% of the questions having cell values of 2 and 11% of the questions having cell values of 3 and 20. Regarding the number of questions, a similar pattern is observed, with 75% of the questions having a cell value of 2, 12% having a cell value of 3, and 6% having a cell value of 20. On NQF Level 7, the highest weighted contribution of questions (22%) has a cell value of 2, followed by 19% with a cell value of 1 and 18% with a cell value of 19.



(For clarity purposes, only some of the highest weighted contributions are indicated on the graph. Spatiality in red text in the table refers to the integration of all the components of spatial thinking.)

NQF Level 5			NQF Level 6			NQF Level 7		
Integrated = 1%			Integrated = 2%			Integrated = 3%		
Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions
1	14%	110	2	72%	39	1	19%	26
2	40%	18	3	11%	6	2	22%	16
7	3%	18	8	4%	2	3	1%	1
8	10%	4	10	2%	2	7	1%	2
12	1%	1	20	11%	3	8	1%	1
13	1%	6				9	2%	2
19	1%	6				13	7%	8
20	12%	5				16	1%	1
21	18%	2				19	18%	21
						20	13%	9
						21	13%	12
						22	1%	1
						23	1%	1

Figure 6.6: Department E – Taxonomy of spatial thinking.

In the case of all three NQF levels, the integration of the three components of spatial thinking is too limited, with the percentage for integration on NQF Level 5 at 1%, on NQF Level 6 at 2%, and on NQF Level 7 at 3%. The low integration of the three components of spatial thinking is attributed to both the high weighted contribution and high number of questions on NQF levels 5 and 6 for the category of non-spatial concepts of space and for all three NQF levels for the category of non-use of representation tools. In addition, although the module on NQF Level 7 is a Geospatial module, it appears that the assessment questions do not include the use of Geospatial tools.

Table 6.4: Department E ─ Spatiality of the module outcomes, inclusion of spatial thinking in the teaching methods and spatiality of assessments according to the taxonomy of spatial thinking. (Bold text represents cell values integrating the three components of spatial thinking.

For clarity, the table only indicates the spatiality of the highest weighted contribution of questions expressed as percentages)

Module	The spatiality of module outcomes	Lecturer	Spatial thinking in teaching	The spatiality of assessment questions
E.5	3 19 **21** **24**	EA EB	Yes	2 20 21 Integrated = 1%
E.6	3 19 20 21	EA EB	Yes	2 3 20 Integrated = 2%
E.7	**3** **21** **24**	EC	Yes	1 2 19 Integrated = 3%

On NQF Level 5, the spatiality of the assessment questions is lower than the spatiality of the module outcomes. The highest level of spatiality in terms of the questions posed has a cell value of 21, while the module outcomes attain their highest level of spatiality at 24. (Refer to Table 6.4.). The spatiality of the questions on NQF Level 6 is therefore aligned with the spatiality of the module outcomes. However, the module outcomes do not include the use of representation tools. Should representation tools be included in the outcomes, the integration of the three components of spatial thinking in the module outcomes would increase to cell values 23 and 24, while the level of spatiality of the questions would increase to 23. The spatiality of the questions on NQF Level 7 are related mainly to cell values of 1, 2 and 19. Although there are some questions with a cell value of 23, the weighted contribution of these questions is only 1%. Therefore, the questions on NQF Level 7 are at a lower level in terms of their spatiality than for the module outcomes.

The spatiality of assessment questions on all the NQF levels for Department E should be reviewed to align with the spatiality of the module outcomes. The non-use of representation tools also needs to be addressed. A concerted effort should be made to ensure a greater level of integration of the three components of spatial thinking in assessment questions.

6.6.4 Department F: Spatiality of assessments

Department F submitted a total of 616 assessment questions for evaluation. For NQF Level 5, a total of 404 questions in 16 assessments was submitted; for NQF Level 6 a total of 178 questions in 12 assessments; and for NQF Level 7, a total of 34 questions in six assessments. The module on NQF Level 5 focuses on an integrated offering of Physical and Human Geography, while the modules on NQF levels 6 and 7 both focus on Human Geography.

Components of spatial thinking in assessment questions

<u>*Processes of Reasoning.*</u> On NQF Level 5, the weighted contribution of the questions on the input level prevails at 63%. (Refer to Figure 6.7.) Regarding the number of questions, this equates to 81% on an input level. On NQF Level 6, the weighted contribution of questions on the output level increases to 26%, while the processing level decreases to 27%; however, the input level remains dominant, with a weighted contribution of 47%. The number of questions is highest on the input level at 71%. On NQF Level 7, there are no questions on an input level. The weighted contribution of questions is highest on the processing level (71%), followed by that on the output level (29%). Regarding the number of questions, the processing level dominates (79%).

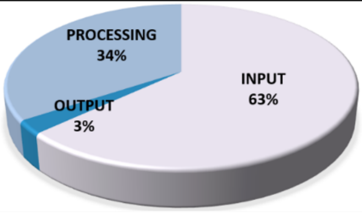
The weighted contribution of the questions and the level at which the number of questions on all three NQF levels are pitched are at a low cognitive level. The cognitive level for all three levels should be adjusted so that the output level has the highest weighted contribution on all levels and shows an increase from NQF Level 5 to NQF Level 7.

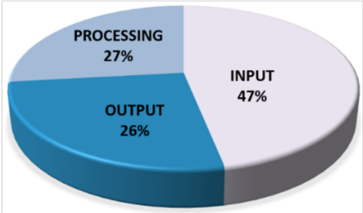
<u>*Concepts of space.*</u> The weighted contribution of questions in the non-spatial category (76%) for NQF Level 5 dominates the assessments. The non-spatial category is followed by the complex spatial category (13%). The number of questions is also the highest for the non-spatial category (74%). The non-spatial category declines to 39% on NQF Level 6, while the complex spatial category increases to 45%. However, the number of questions in the non-spatial category remains high at 57%. It is encouraging to see that the weighted contribution of questions in the complex spatial category increases to 74%

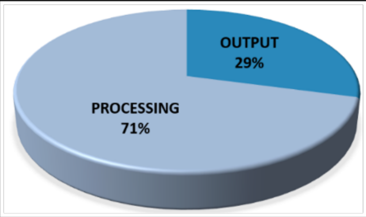
on NQF Level 7, followed by the spatial primitive category. The number of questions posed follows the same pattern as the weighted contribution of the questions, with 68% of the questions on a complex spatial level.

	NQF Level 5 Physical and Human Geography	NQF Level 6 Human Geography	NQF Level 7 Human Geography
	Number of assessments = 16	Number of assessments = 12	Number of assessments = 6

Weighted contribution of questions to cognitive levels:



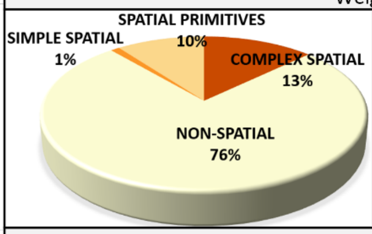


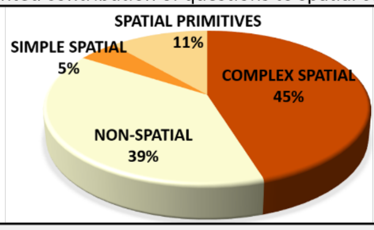


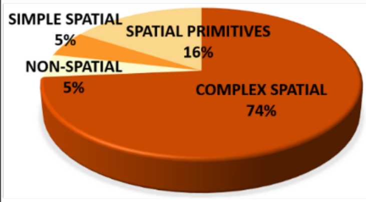
Number of questions per cognitive level:

Input:	329 (81%)	126 (71%)	0
Processing:	64 (16%)	31 (17%)	27 (79%)
Output:	11 (3%)	21 (12%)	7 (21%)
Total:	404	178	34

Weighted contribution of questions to spatial concepts:



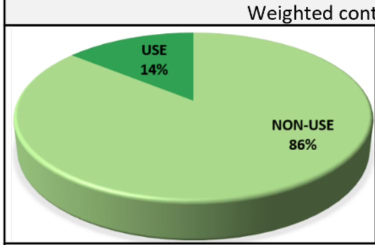


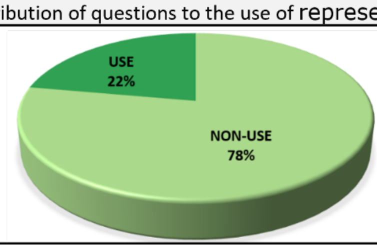


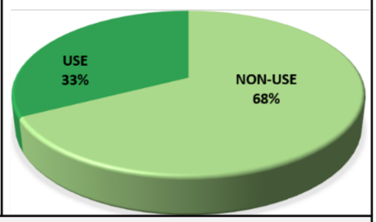
Number of questions per spatial concept:

Non-spatial:	298 (74%)	102 (57%)	3 (9%)
Spatial primitives:	67 (17%)	18 (10%)	4 (12%)
Simple spatial:	3 (1%)	9 (5%)	4 (12%)
Complex spatial:	36 (9%)	49(28%)	23 (68%)
Total:	404	178	34

Weighted contribution of questions to the use of representation tools:







Number of questions pertaining to the use or non-use of representation tools:

Use:	55 (14%)	21 (12%)	4 (12%)
Non-use:	349 (86%)	157 (88%)	30 (88%)
Total:	404	178	34

Figure 6.7: Department F – The inclusion of the components of spatial thinking in assessments.

The non-spatial category on NQF levels 5 and 6 needs to be reduced, while the complex spatial, spatial primitive and simple spatial categories should be increased to achieve the highest weighted contribution. The high weighted contribution of the complex spatial category and the low weighted contribution of the non-spatial category on NQF Level 7 are commendable.

Representation tools. The weighted contribution for the use of representation tools on NQF Level 5 is 14%. On NQF Level 6, this percentage increases to 22%; on NQF Level 7, it is 33%. Regarding the number of questions asked, only 14% of the questions include the use of representation tools at NQF Level 5 and 12% at NQF levels 6 and 7. Although there is a slight increase in the weighted contribution for using representation tools in questions at NQF levels 5 to 7, their weighted contribution is too low. The inclusion of representation tools is considered crucial for reaching a high level of spatiality on the taxonomy of spatial thinking and for effectively contributing to the development of students' spatial thinking.

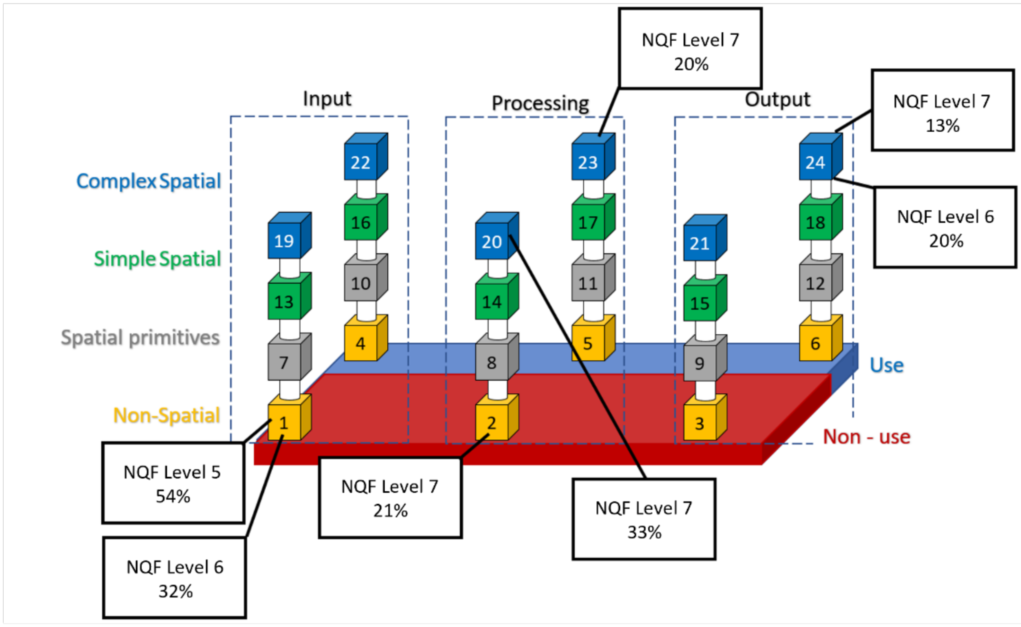
Application of the taxonomy of spatial thinking to assessment questions

The findings issuing from the evaluation of the assessment questions against the taxonomy of spatial thinking are summarised in Figure 6.8. The highest weighted contribution of questions on NQF Level 5 is for cell value 1 (54%), followed by cell value 2 (21%). The number of questions with cell values of 1 and 2 constitutes 74% of the total number of questions asked. Only 15% of the weighted contribution of questions on NQF Level 5 integrate the three components of spatial thinking and should contribute to the development of students' spatial thinking skills.

On NQF Level 6, 32% of the weighted contribution of questions have a cell value of 1, followed by 20% with a cell value of 24. Most of the questions have a cell value of 1 (52%), while only 15 questions (8%) have a cell value of 24. The integration level of the three components of spatial thinking in terms of the weighted contribution of questions increases by 8% from NQF Level 5 to NQF Level 6 but remains low at 23%.

On NQF Level 7, the highest weighted contribution of questions has a cell value of 20 (33%), followed by a weighted contribution of 20% with a cell value of 23, and 13% with a cell value of 24. Regarding the number of questions asked, 17 questions (50%) have a cell value of 20 whereas only four questions (12%) have combined cell values of 23 and 24. Although the integration of the three components of spatial thinking in the weighted contribution of the questions further increases from NQF Level 6 to 33% on NQF Level 7, it remains too low.

It is recommended that both the weighted contribution and the number of questions pitched at a high level of spatiality be increased on all three NQF levels to ensure that more questions integrate the three components of spatial thinking.



(For clarity purposes, only some of the highest weighted contributions are indicated on the graph. Spatiality in red text in the table refers to the integration of all the components of spatial thinking.)

NQF Level 5			NQF Level 6			NQF Level 7		
Integrated = 15%			Integrated = 23%			Integrated = 33%		
Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions
1	54%	280	1	32%	94	2	9%	6
2	21%	17	2	8%	9	8	9%	2
3	1%	1	7	4%	8	9	7%	2
7	6%	38	8	3%	6	15	2%	1
8	<1%	1	9	4%	4	20	33%	17
9	<1%	2	13	2%	3	21	8%	2
10	1%	5	17	2%	5	23	20%	2
11	3%	20	19	9%	20	24	13%	2
12	<1%	1	20	14%	11			
16	1%	3	21	3%	2			
20	3%	5	22	<1%	1			
21	1%	5	24	20%	15			
22	1%	3						
23	8%	21						
24	<1%	2						

Figure 6.8 Department F – Taxonomy of spatial thinking.

Table 6.5 compares the spatiality of assessments against the spatiality of the module outcomes and the inclusion of spatial thinking in respect of the teaching of the module according to the taxonomy of spatial thinking. Most of the weighted contributions of the assessment questions on NQF Level 5 are for cell values 1 and 2, while the outcomes are for cell values 13, 14 and 24. On NQF Level 6, the weighted contributions of the questions have cell values of 1 and 24, while the outcomes have cell values of 14, 19 and 24. The weighted contributions of questions on NQF Level 7 are for cell values of 23 and 24 and are comparable with the values for the module outcomes. However, the limited number of questions with a high spatiality in the case of the NQF Level 7 module is a matter for concern. The overall result for this department is that the spatiality of the assessment questions is at a lower level than the spatiality of the module outcomes.

Table 6.5: Department F – Spatiality of the module outcomes, inclusion of spatial thinking in the teaching methods and spatiality of assessments according to the taxonomy of spatial thinking. (Bold text represents cell values integrating the three components of spatial thinking.

For clarity, the table only indicates the spatiality of the highest weighted contribution of questions expressed as percentages)

Module	The spatiality of module outcomes	Lecturer	Spatial thinking in teaching	The spatiality of assessment questions
F.5	13 14 **24**	FA	Yes	1 2 Integrated = 15%
F.6	14 19 **24**	FB	Yes	1 **24** Integrated = 23%
F.7	**23** **24**	FC	Yes	20 **23** **24** Integrated = 33%

6.6.5 Department H: Spatiality of assessments

Department H submitted a total of 468 assessment questions for evaluation. The number of questions was unequally distributed across the three NQF levels. On NQF Level 5, 187 questions constitute eight assessments; on NQF Level 6, 276 questions constitute 12 assessments, and on NQF Level 7, five questions constitute two assessments. The modules on NQF levels 5 and 7 focus on Physical Geography, while the module on NQF Level 6 focuses on Human Geography.

Since only two assessments for one semester were submitted for NQF Level 7, the evaluation of the spatiality of the questions summarises the findings for the submitted assessments and should not be interpreted as a general trend for the module or NQF Level 7.

Components of spatial thinking in assessment questions

Processes of Reasoning. On NQF Level 5, the weighted contribution of questions is the highest on an output level (50%). (Refer to Figure 6.9.) Regarding the number of questions on NQF Level 5, 145 of 187 (77%) of the questions are on an input level, while 32 of 187 (17%) are on an output level. At NQF Level 6, the output level has increased to a weighted contribution of 77%. On this NQF level, 204 of 276 (74%) of the questions are on an input level. The five questions submitted for NQF Level 7 indicate an output level of 67% and an input level of 33%. At NQF levels 5 and 6, the questions attain an acceptable cognitive level, with an increase in the weighted contribution of questions from NQF levels 5 to 6. It is worth noting that the number of questions submitted for NQF Level 7 was too low to draw any conclusions regarding the contribution of questions to the respective cognitive levels.

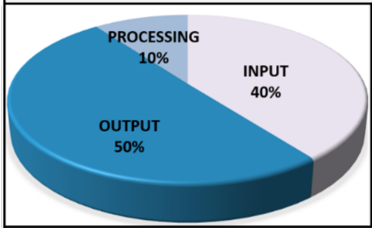
Concepts of space. The weighted contribution of questions on a complex spatial level dominates on NQF Level 5 (47%). Most questions (78%) fall into the non-spatial category. On NQF Level 6, the use of complex spatial concepts of space increases to 55%, while the non-spatial category decreases to 16%. On a non-spatial level, the number of questions submitted for NQF Level 6 amounted to 191 of 276 (70%). All the questions submitted on NQF Level 7 are on a spatial primitive level.

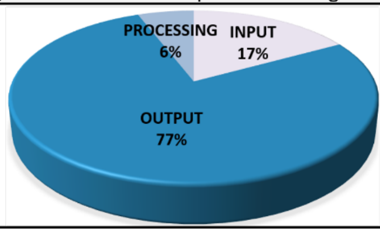
On NQF levels 5 and 6, the number of questions in the non-spatial category should be reduced, and the number of questions in the complex spatial category should be increased. Although the questions submitted for NQF Level 7 may not be representative of the assessments for this module, they are in the spatial primitive category, which is too low for an NQF Level 7 module. On this level, questions on the concepts of space should rather be featured as part of the complex spatial category.

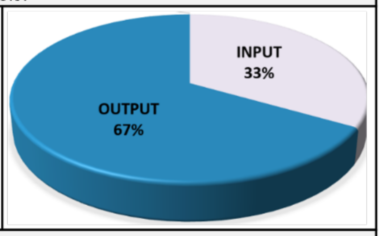
Representation tools. The weighted contribution of the use of representation tools is 62% on NQF Level 5. Sixteen percent (16%) of the questions include the use of such a tool. On NQF Level 6, the use of representation tools decreased to 20%, and in terms of the number of questions, to 5%. The weighted contribution for the use of representation tools for the five questions submitted on NQF Level 7 increased to 33%. The weighted contribution of questions incorporating the use of such tools is acceptable on NQF Level 5, but too low on NQF Level 6 and too low for the submitted questions on NQF Level 7. This will negatively impact the integration of the three components of spatial thinking on these two NQF levels.

NQF Level 5 Physical Geography	NQF Level 6 Human Geography	NQF Level 7 Physical Geography
Number of assessments = 8	Number of assessments = 12	Number of assessments = 3

Weighted contribution of questions to cognitive levels:

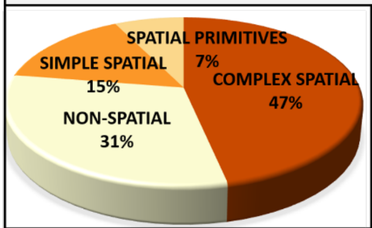


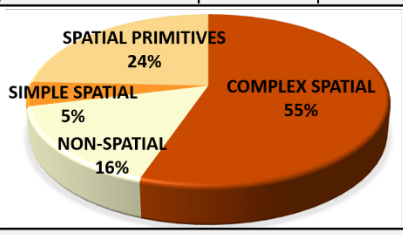


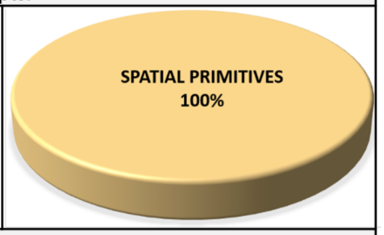


Number of questions per cognitive level:			
Input:	145(78%)	204 (74%)	1 (20%)
Processing:	10 (5%)	4 (1%)	0 (0%)
Output:	32 (17%)	68 (25%)	4 (80%)
Total:	187	276	5

Weighted contribution of questions to spatial concepts:

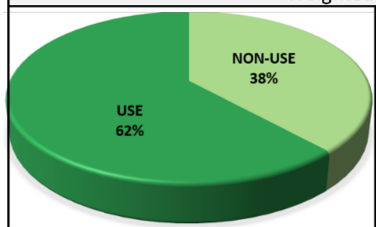


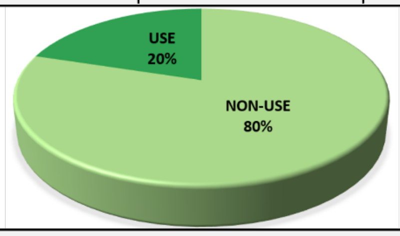


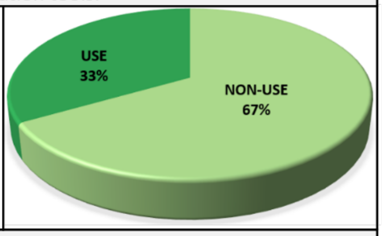


Number of questions per spatial concept:			
Non-spatial:	145 (78%)	191 (70%)	0 (0%)
Spatial primitives:	7 (4%)	56 (20%)	5 (100%)
Simple spatial:	10 (5%)	6 (2%)	0 (0%)
Complex spatial:	25 (13%)	23 (8%)	0 (0%)
Total:	187	276	5

Weighted contribution of questions to the use of representation tools:





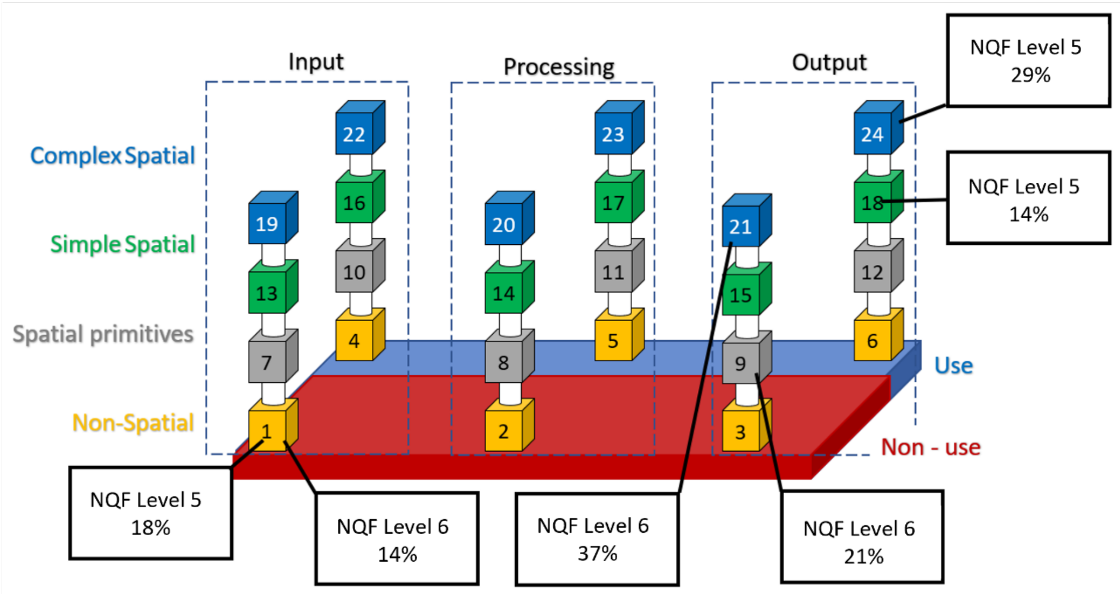


Number of questions pertaining to the use or non-use of representation tools:			
Use:	30 (16%)	15 (5%)	1 (20%)
Non-use:	157 (84%	261 (95%)	4 (80%)
Total:	187	276	5

Figure 6.9: Department H: The inclusion of the components of spatial thinking in assessments.

Application of the taxonomy of spatial thinking to assessment questions

Figure 6.10 summarises the findings in respect of the evaluation of the submitted assessment questions of Department H against the taxonomy of spatial thinking. Since the number of questions submitted for the NQF Level 7 module was very low, the evaluation results for this level are not indicated in the figure.



(For clarity purposes, only some of the highest weighted contributions are indicated on the graph. Spatiality in red text in the table refers to the integration of all the components of spatial thinking.)

NQF Level 5			NQF Level 6			*NQF Level 7		
Integrated = 62%			Integrated = 20%			Integrated = 33%		
Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions
1	18%	122	1	14%	167	9	67	4
2	10%	10	3	2%	19	10	33	1
3	3%	14	6	<1%	5	*Not indicated on the taxonomy of spatial thinking		
7	1%	5	7	3%	30			
9	1%	1	8	1%	1			
10	6%	1	9	21%	25			
13	<1%	3	13	<1%	1			
18	14%	6	15	<1%	3			
19	2%	1	18	4%	2			
21	4%	1	19	1%	6			
22	13%	13	20	2%	2			
24	29%	10	21	37%	9			
			23	3%	1			
			24	13%	5			

Figure 6.10: Department H – Taxonomy of spatial thinking.

On NQF Level 5, the weighted contribution of the assessment questions is the highest for a cell value of 24 (29%), followed by 18% for a cell value of 1 and 14% for a cell value of 18. Most of the questions (65%) have a cell value of 1. Those questions integrating the three components of spatial thinking and that could, therefore, foster the development of students' spatial thinking skills in terms of the weighted contribution are at 62%.

On NQF Level 6, the highest weighted contribution of questions (37%) has a cell value of 21, followed by 21% with a cell value of 9 and 14% with a cell value of 1. Regarding the number of questions, most (51%) have a cell value of 1, followed by 28% with a cell value of 7 and 32 % with a cell value of 10. On NQF Level 6, the weighted contribution of questions demonstrates a low level of integration (20%) in respect of the three components of spatial thinking. The questions on NQF Level 6, with a cell value of 21 (37%), are on a high (output) cognitive level and are indicative of the use of complex concepts of space, but the non-use of representation tools is a matter for concern. Should representation tools be included in these questions, the cell value would increase to 24. This would contribute significantly to the integration of the three components of spatial thinking.

The weighted contributions of questions submitted for NQF Level 7 have low cell values, namely 9 and 10. Since the number of questions submitted was very low, they are not representative of the assessments of the module, and are, therefore, not further discussed.

It is suggested that the weighted contribution of questions that incorporate the three components of spatial thinking be increased on NQF levels 5 and 6 to contribute more effectively towards the development of the spatial thinking skills of students.

Table 6.6, applicable to Department H, compares the spatiality of the module outcomes, the inclusion of spatial thinking in the teaching methods and the spatiality of assessments according to the taxonomy of spatial thinking.

On NQF Level 5, the spatiality of the assessments is higher than the spatiality of the module outcomes; however, the integration of the three components of spatial thinking remains low. Since spatial thinking can be taught at any age or level, it is suggested that the module outcomes and assessment questions be adjusted to reflect a higher level of spatiality. The spatiality of the assessment questions on NQF Level 6 aligns to a certain extent with the spatiality of the module outcomes with both reaching a cell value of 24. The integration of the components of spatial thinking in the questions and module outcomes is too limited to effectively develop the spatial thinking abilities of students. The assessment questions submitted for NQF Level 7 have a lower spatiality than the module outcomes, but owing to the low number of questions submitted, this might not be a meaningful result.

Table 6.6: Department H – Spatiality of the module outcomes, inclusion of spatial thinking in the teaching methods and spatiality of assessments according to the taxonomy of spatial thinking. (Bold text represents cell values integrating the three components of spatial thinking.

For clarity, the table only indicates the spatiality of the highest weighted contribution of questions expressed as percentages)

Module	The spatiality of module outcomes	Lecturer	Spatial thinking in teaching	The spatiality of assessment questions
H.5	1 2 19 20	HC	Yes	1 **18** **24** Integrated = 62%
H.6	1 2 3 19 **24**	HA	Yes	1 9 **24** Integrated = 20%
H.7	8 9 19	HB	Yes	*9 *10 *Integrated = 33

*(*The spatiality of assessment questions is not representative of the assessments for this module)*

6.6.6 Department J: Spatiality of assessments

Department J submitted a total of 16 assessments for evaluation. On NQF Level 5, six assessments containing 107 questions were submitted, five containing 52 questions on NQF Level 6, and six containing 39 questions on NQF Level 7. The module on NQF Level 5 is a Physical Geography module, while the module on NQF Level 6 integrates Physical and Human Geography and the module on NQF Level 7 focuses on Geospatial applications.

Components of spatial thinking in assessment questions

<u>*Processes of Reasoning.*</u> The weighted contribution of questions on the processing level (59%) dominates on NQF Level 5. Regarding the number of questions asked, most questions (65%) on NQF Level 5 are on an input level. On NQF Level 6, the processing level decreases to 48%, the input level decreases by 3% from that of NQF Level 5 to 32%, and the output level increases to 20%. Most questions (40%) are on a processing level. On NQF Level 7, the weighted contribution of questions on the processing level

dominates at 89%. Most of the questions are pitched on a processing level (64%). Figure 6.11 summarises the results.

The processing level dominates the questions on all three NQF levels. Although there is an increase from NQF levels 5 to 6 in the number of questions on an output level, the overall weighted contribution of questions on an output level decreases on NQF Level 7 . Thus, the reduction in the number of questions from NQF levels 5 to 7 in respect of their output levels should be addressed to ensure that the questions increase in complexity with an increase in the NQF level.

Concepts of space. The weighted contribution of questions in the non-spatial category (62%) dominates in terms of concepts of space on NQF Level 5. In terms of the number of questions, 79% of the questions on NQF Level 5 fall within the non-spatial category. On NQF Level 6, the weighted contribution of questions in the non-spatial category decreases to 41%, while the complex spatial category increases to 37%. Most of the questions (43%) include complex spatial concepts of space, followed closely by the non-spatial category (38%). On NQF Level 7, the dominant category of the weighted contribution of questions is in the complex spatial level (75%), followed by the simple spatial category (25%). The non-spatial category on NQF Level 7 amounts to only 2%. On NQF Level 7, most of the questions (79%) fall within the complex spatial level.

The weighted contribution and the number of questions associated with the complex spatial concepts category should be adjusted to show an increase from NQF Level 5 to NQF Level 6. The relatively high weighted contribution of questions in the complex spatial concepts category on NQF Level 7 is commendable.

Representation tools. The weighted contribution of questions that include representation tools is low for all three NQF levels with 15% on NQF Level 5, 11% on NQF Level 6 and 14% on NQF Level 7. The number of questions pitched in conjunction with the use of representation tools is 5% on NQF Level 5, 13% on NQF Level 6 and 13% on NQF level 7. The limited use of representation tools on all NQF levels is a matter for concern as without such a tool, students will not be well prepared to develop their spatial thinking skills optimally.

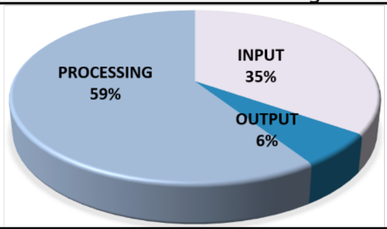
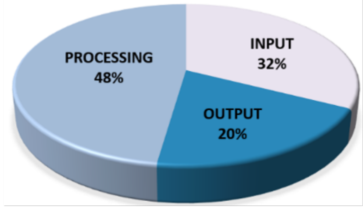
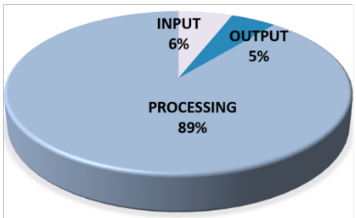
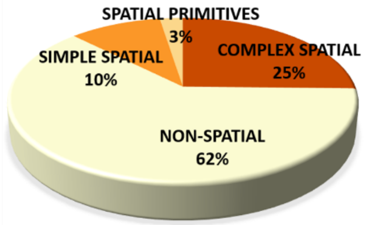
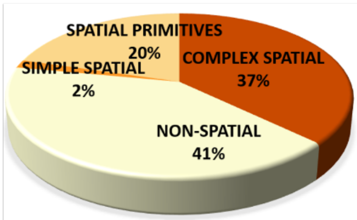
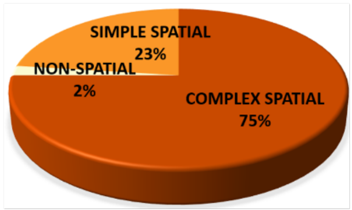
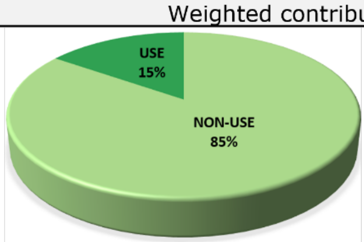
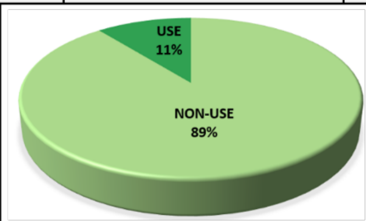
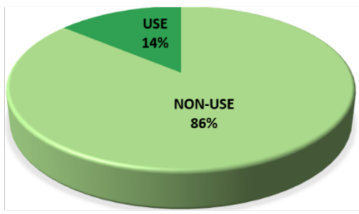
<table>
<tr><td colspan="2">NQF Level 5
Physical Geography</td><td>NQF Level 6
Physical and Human Geography</td><td>NQF Level 7
Geospatial applications</td></tr>
<tr><td colspan="2">Number of assessments =6</td><td>Number of assessments = 4</td><td>Number of assessments = 6</td></tr>
<tr><td colspan="4">Weighted contribution of questions to cognitive levels:</td></tr>
<tr><td colspan="2">
</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions per cognitive level:</td></tr>
<tr><td>Input:</td><td>70 (65%)</td><td>19 (37%)</td><td>12 (31%)</td></tr>
<tr><td>Processing:</td><td>32 (30%)</td><td>21 (40%)</td><td>25 (64%)</td></tr>
<tr><td>Output:</td><td>5 (5%)</td><td>12 (23%)</td><td>2 (5%)</td></tr>
<tr><td>Total:</td><td>107</td><td>52</td><td>39</td></tr>
<tr><td colspan="4">Weighted contribution of questions to spatial concepts:</td></tr>
<tr><td colspan="2">
</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions per spatial concept:</td></tr>
<tr><td>Non-spatial:</td><td>85 (79%)</td><td>20 (38%)</td><td>3 (8%)</td></tr>
<tr><td>Spatial primitives:</td><td>2 (2%)</td><td>9 (17%)</td><td>0 (0%)</td></tr>
<tr><td>Simple spatial:</td><td>6 (6%)</td><td>1 (2%)</td><td>5 (13%)</td></tr>
<tr><td>Complex spatial:</td><td>14 (13%)</td><td>22 (43%)</td><td>31 (79%)</td></tr>
<tr><td>Total:</td><td>107</td><td>52</td><td>39</td></tr>
<tr><td colspan="4">Weighted contribution of questions to the use of representation tools:</td></tr>
<tr><td colspan="2">
</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Number of questions pertaining to the use or non-use of representation tools:</td></tr>
<tr><td>Use:</td><td>5 (5%)</td><td>7 (13%)</td><td>5 (13%)</td></tr>
<tr><td>Non-use:</td><td>102(95%)</td><td>45 (87%)</td><td>34 (87%)</td></tr>
<tr><td>Total:</td><td>107</td><td>52</td><td>39</td></tr>
</table>

Figure 6.11: Department J – The inclusion of the components of spatial thinking in assessments.

Application of the taxonomy of spatial thinking to assessment questions

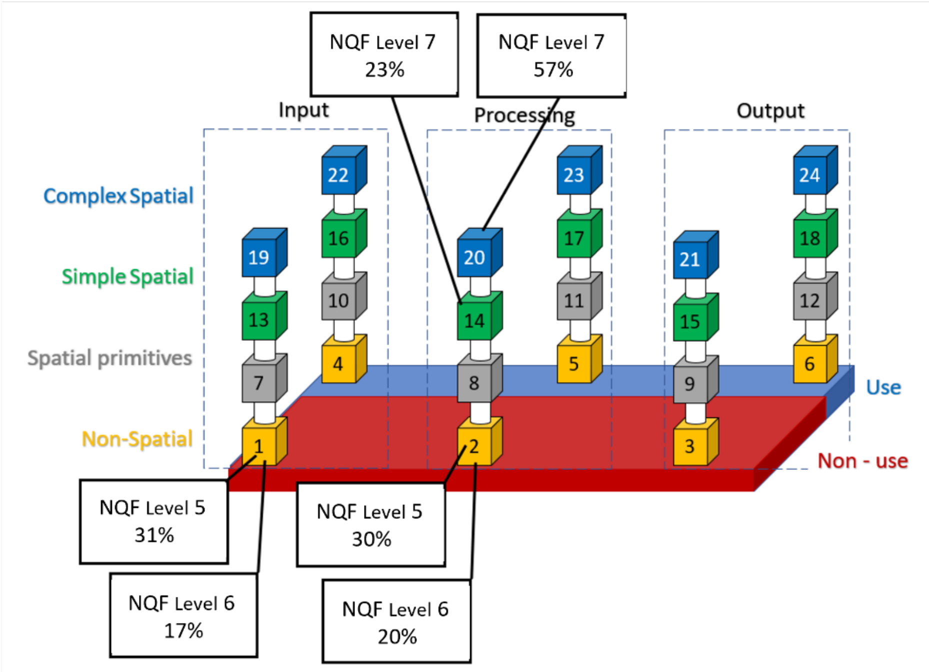
The results of the evaluation of the assessment questions submitted by Department J against the taxonomy of spatial thinking are summarised in Figure 6.12. On NQF Level 5, the weighted contribution of questions is mainly associated with a cell value of 1 (31%) and a cell value of 2 (30%), followed by a weighted contribution with a cell value of 20

(16%). The number of questions follows the same pattern with values of 58%, 19% and 7% for cell values of respectively 1, 2 and 20. Because the weighted contribution and number of questions are mainly associated with cell values of 1, 2 and 20, only 14% of the weighted contribution of the questions on NQF Level 5 integrate the three components of spatial thinking.

On NQF Level 6, most of the weighted contribution of the questions are associated with cell values of 1 (17%) and 2 (20%), followed by questions with a cell value of 8 (14%). The number of questions is also mostly associated with cell values of 1 (17%) and 2 (15%), followed by questions with a cell value of 21 (13%). The weighted contribution of questions that incorporate the three components of spatial thinking is 12%.

On NQF Level 7, the weighted contribution of the questions is mainly associated with a cell value of 20 (57%), followed by cell values of 14 (23%) and 23 (9%). Regarding the number of questions, 44% have a cell value of 20, 26% have a cell value of 19 and 13% have a cell value of 14. In the case of NQF Level 7, only the questions with a cell value of 23 will contribute toward developing students' spatial thinking skills. Therefore, the integration of the three components of spatial thinking at this NQF level is low – at 13%.

The integration of the three components of spatial thinking in the assessment questions and module outcomes in Department J is limited. This is mostly due to the large percentage of questions in the non-spatial category on NQF levels 5 and 6 and the lack of the inclusion of representation tools in assessment questions on all three NQF levels. The lack of representation tools on NQF Level 7 is a matter for concern as the module focuses on Geospatial applications, and with representation tools which are inherently part of such modules.



(For clarity purposes, only some of the highest weighted contributions are indicated on the graph. Spatiality in red text in the table refers to the integration of all the components of spatial thinking.)

NQF Level 5			NQF Level 6			NQF Level 7		
Integrated = 14%			Integrated = 12%			Integrated = 13%		
Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions	Spatiality	Weighted contribution	Number of Questions
1	31%	62	1	17%	9	1	1%	2
2	30%	20	2	20%	8	6	1%	1
3	4%	4	3	3%	2	14	23%	1
8	<1%	1	4	<1%	1	19	5%	10
9	2%	1	7	4%	2	20	57%	17
13	1%	4	8	14%	5	23	9%	3
17	7%	1	9	2%	1	24	4%	1
19	3%	4	10	<1%	1			
20	16%	8	17	2%	1			
23	7%	2	19	7%	5			
			20	11%	6			
			21	11%	7			
			22	3%	1			
			23	2%	1			
			24	4%	2			

Figure 6.12: Department J – Taxonomy of spatial thinking.

Table 6.7: Department J ─ Spatiality of the module outcomes, inclusion of spatial thinking in the teaching methods and spatiality of assessments according to the taxonomy of spatial thinking. (Bold text represents cell values integrating the three components of spatial thinking.

For clarity, the table only indicates the spatiality of the highest weighted contribution of questions expressed as percentages)

Module	The spatiality of module outcomes	Lecturer	Spatial thinking in teaching	The spatiality of assessment questions
J.5	2 14 20	JA	Yes	1 2 20 Integrated = 14%
J.6	21 **23** **24**	JB	Yes	1 2 8 Integrated = 12%
J.7	**23** **24**	JC	Yes	14 20 **23** Integrated =13%

Table 6.7 compares the spatiality of the module outcomes, the inclusion of spatial thinking in the teaching methods and the spatiality of the assessments according to the taxonomy of spatial thinking. Most of the weighted contributions of questions on NQF Level 5 have cell values of 1, 2 and 20 that align with those of the module outcomes. However, the levels of spatiality of both the module outcomes and the assessment questions are too low and will not develop students' spatial thinking skills. The questions with the highest spatiality on NQF Level 5 have a cell value of 23. However, the weighted contribution of these questions amounts to only 7%, or only two questions, which is very low. On NQF Level 6, most of the weighted contributions of questions have cell values of 1 (17%), 2 (20%) and 8 (14%) which are lower than those for the module outcomes with cell values of 21, 23 and 24. Although some of the questions on NQF Level 7 reach a high level of spatiality with cell values of 22, 23 and 24, both their weighted contributions and numbers are low. Only 3% or one (1) of the total number of questions has a cell value of 22, 2% or one question has a cell value of 23, and 4% or two questions have a cell value of 24. On NQF Level 7, the module outcomes and questions attain a level of spatiality associated with cell values of 23 and 24. However, in terms of number and weighted contribution, most of the questions on NQF Level 7 have a measure of spatiality, with cell values of 14, 19 and 20, but these are much lower than the levels of spatiality presented in the outcomes. Thus, the weighted contribution of the questions and number of questions pitched at a higher level of spatiality should be

increased. This will also ensure the more effective integration of the three components of spatial thinking at all three NQF levels.

6.7 Spatial thinking skills of students who completed the STAT

An explanation of the STAT and the way in which this test can be used to gauge the spatial thinking abilities of students is presented in Chapter 2, Section 2.3.3. The different categories of the STAT and the spatial thinking components covered by the questions are summarised in Chapter 2, Table 2.3.

A total of 200 students from the various Geography departments that participated in the research completed the online STAT. Initially, 227 students accessed the link to the test, but 27 indicated that they were not interested in completing it. These students were excluded from the rest of the research.

The number of students who completed the test varied from nine to 127 per department. Since the total number of students per department who completed the test was relatively low, the results were interpreted for all the departments together and not per individual department. Furthermore, on account of the combined numbers of students who completed the test, their spatial thinking skills would not be representative of those of all undergraduate Geography students in South Africa. Thus, the interpreted results are indicative only of the gaps in the spatial thinking skills with respect to the participants who completed the test.

Figure 6.13 summarises general information regarding the students who participated in the research as regards their gender, whether they are considering further studies in Geography, the NQF level of the modules they are registered for, and whether they are registered for or have already completed additional spatial modules.

The participants who completed the test comprised 117 females (58%) and 82 males (41%). One student chose not to answer the question on gender. This student was excluded from the study at the point when the relationship between gender and spatial thinking skills was determined. Most participants (86%) indicated that they were considering further studies in Geography or were currently studying Geography on NQF Level 7. While a student's attitude toward Geography does not influence his/her ability to learn spatial thinking (Collins, 2018b), it is nonetheless interesting to know that the participants have a keen interest in furthering their studies in Geography. One would also believe that they chose to complete the test because they are interested in the discipline. Most of the participants (62%) have completed or are currently enrolled in modules covering Cartography, GIS, Remote Sensing or Map Reading. For ease of reference, these modules are referred to as spatial modules. Related studies indicate that students studying GIS or related modules have spatial thinking skills that are superior to those of students who have not completed a GIS module (Shin et al., 2016).

Most participants who completed the test were registered for modules on a first-year level (46%), followed by those on a second-year level (34%) and those on a third-year level (20%). This might influence the results of this research as students on a lower level of study are expected to be more limited in terms of their spatial thinking skills (Collins, 2018b; Verma, 2015).

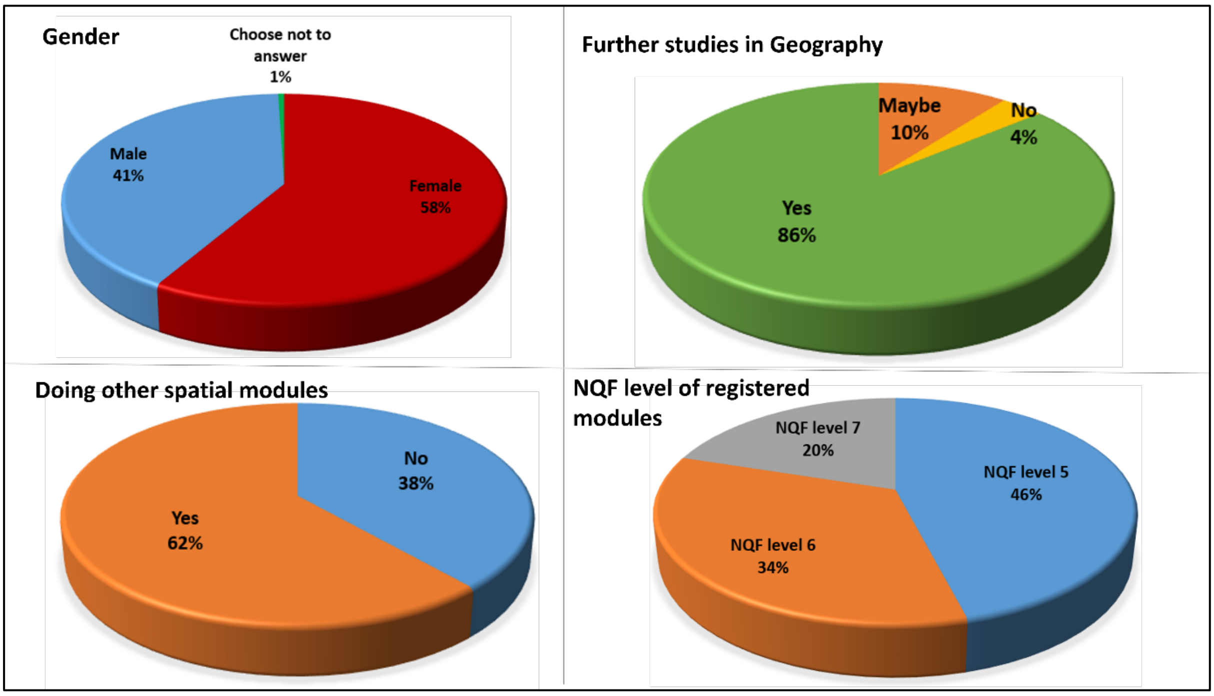


Figure 6.13: General information pertaining to students who completed the test.

The main limitation of this research was the limited number of participants who completed the online test. Furthermore, additional limitations include the lack of information on the influence of other modules, such as Geology, Mathematics or Environmental Studies. Furthermore, while this could also play a role, no information regarding the socio-economic background of the participants was captured to add to the depth of this research.

6.7.1 Level of study: results and discussion

Table 6.8 summarises the average performance of the participants on the STAT per NQF level of the modules students are registered for.

Table 6.8: Average performance in STAT per NQF level.

NQF level	Average result for STAT (%)	Minimum score per student (%)	Maximum score per student (5)
NQF Level 5	43%	13%	75%
NQF Level 6	46%	13%	88%
NQF Level 7	52%	6%	88%

The overall average performance in the STAT was low. The participants registered for NQF Level 5 Geography modules scored an average of 43%; those registered for NQF Level 6 scored 46%, and those for NQF Level 7, 52%. The minimum score for participants registered for NQF levels 5 and 6 modules was 13%, while the maximum scores were 75% and 88%, respectively. The minimum and maximum scores for participants registered for NQF Level 7 Geography modules were 6% and 88%, respectively. For NQF Level 5, 35% of the participants could correctly answer half of the questions in the STAT, for NQF Level 6, 49% and for NQF Level 7, 55%. The average score for all participants who completed the test was 7.4 out of a possible 16 correct answers. This score is lower than the average score for students from selected universities in the USA who scored 8.9 in a STAT (Flynn, 2018). After completing a geocaching exercise, the students from the USA improved their spatial thinking abilities even further to 9.5. The average score for the South African students who participated in this research proved to be higher than that for students in Ethiopia who scored 5.57 (Flynn, 2018). After completing a geocaching exercise, the Ethiopian students improved their spatial thinking skills to 6.14, which is still lower than the 7.4 scored by the South African students (Ibid). However, an essential difference is that the students from the USA and Ethiopia who participated in the research conducted by Flynn (2018) had not completed any Geography modules.

Although there appears to be an increase in the level of spatial thinking in the case of the South African participants from NQF Level 5 to NQF Level 7, two separate t-tests were performed to determine whether there were, in fact, significant differences between the scores for the respective NQF levels. (The results are indicated in Table 6.9.)

Table 6.9: The relationship between NQF level and spatial thinking skills.

	T	Df	p-value	Mean Difference	Std Error Difference
Improvement in spatial thinking ability from NQF Level 5 to NQF Level 6	-0.977	158	.335	0.44	0.44
Improvement in spatial thinking ability from NQF Level 6 to NQF Level 7	-1.636	106	.136	-1.025	0.627

The t-tests indicated no significant difference in the spatial thinking abilities of the participants who completed the STAT and are registered for NQF Level 5 and NQF Level 6 Geography modules and for NQF Level 6 and NQF Level 7 Geography modules. The results of the t-tests for participants registered for Geography modules stand in contrast to the findings of Verma (2015) and Collins (2018b), who found that students on a higher study level should possess more superior spatial thinking skills.

Figure 6.14 summarises the results of the STAT per question number and per NQF level. The graphs indicate that the results for all three NQF levels display similar patterns, with Question 9 (overlaying and dissolving map layers) and Questions 13 and 16 (dimensionality of geographic features) presenting exceptions. From the results of the overall view and Figure 6.14, it appears that participants on NQF Level 7 outperform participants on a lower NQF level – at least in respect of some of the categories of the STAT.

Participants registered for NQF Level 5 Geography modules recorded the lowest scores for Question 9, and those registered for NQF levels 6 and 7 modules the lowest for Question 12. Both these questions refer to the overlaying and dissolving of layers. The reason why all the NQF levels scored low in this category is not known.

The highest scores for participants registered for first and second-year modules were recorded for Question 3, and in the case of participants registered for third-year modules, for Question 13. These questions focus on comparing a map and graphic information and the dimensionality of geographic features, respectively. A possible reason for the high score in Question 3 could be that mapwork modules are typically offered as NQF Level 5 modules at South African universities, while GIS modules that focus on comprehending geographic features that are represented as points, lines or polygons are typically offered on a higher NQF level. Most of the students on NQF Level 7 (88%) indicated that they had completed additional spatial modules, the content of which typically covers the representation of features as points, lines and polygons. In comparison, 48% of the participants registered for NQF Level 5 modules and 65% registered for NQF Level 6 modules had already completed additional spatial modules.

Figure 6.14: Percentage of correct answers per NQF level.

T-tests were performed to determine whether there were any significant differences in the STAT components per NQF level. (Refer to Chapter 2, Table 2.3.) The results indicate that there were no significant differences between the scores for the components of the STAT in the case of participants registered for Geography modules on NQF levels 5 and 6. However, there were significant differences in the scores for questions 13, 14, 15 and 16, where the participating students registered for Geography modules on NQF Level 7 outperformed students registered for NQF Level 6 modules. (Refer to Table 6.10.) Students on NQF Level 7 outperformed students on NQF Level 6, because three of the modules that formed part of this research focus on Geospatial applications, where the module content typically covers the comprehension of features represented as points, lines or polygons. Students registered for the identified modules were invited to complete the STAT, which could lead to a higher average score in the STAT for students registered on NQF Level 7.

Table 6.10: Results of the t-test for questions 13-16. Second and third-year Geography modules.

	T	Df	p-value	Mean Difference	Std Error Difference
Questions 13-16 (Comprehending geographic features represented as points, lines or polygons)	-2.722	106	.0083	-0.6	0.22

6.7.2 Gender: results and discussion

Female participants who completed the test scored an average of 44% in the STAT, and male participants, 48%. (Refer to Table 6.11.) The minimum scores for male participants varied from 6% to 88% and for female participants from 13% to 88%.

Table 6.11: Average performance per gender.

Gender	Average results for STAT (%)	Minimum score (%)	Maximum score (5)
Female	44%	13%	88%
Male	48%	6%	88%

Although male participants scored a better average result, a t-test indicated that the difference in scores between the male and female participants was not significant. (Refer to Table 6.12.)

Table 6.12: The relationship between gender and spatial thinking skills.

	T	Df	p-value	Mean Difference	Std Error Difference
Gender	-1.454	197	.147	-0.619	0.427

In contrast, a study by Tomaszewski et al. (2015) in Rwanda found differences between the spatial thinking skills of male and female school learners. These researchers attributed the differences to societal barriers and practices in Rwandan society. Although the sample size of South African participants was small, the findings of this research support the research of Metoyer and Bednarz (2017) and Collins (2018), which found no significant difference in the spatial thinking skills between the two genders. The differences between these studies might be diminished as a result of the availability and exposure of students to maps via smartphones and online mapping applications (Collins, 2018b). It could be speculated that in South Africa, male and female students have equal access to spatial technologies such as smartphones and online mapping, which could lead to a narrowing of the gap in spatial thinking skills between the genders.

Figure 6.15 summarises the results of the STAT per question and gender. The female participants achieved the best results (77%) in Question 3, where they were required to compare a map and graphic information, and the lowest (12%) in Question 12, where the overlaying and dissolving of layers were tested. On the other hand, the male participants scored their highest marks (83%) in Question 15 and their lowest (16%) in Question 11. It is interesting to note that both these questions were about the overlaying and dissolving of layers. The largest difference in scores between the genders occurred for Questions 5 and 8. These two questions were about the visualisation of slope profiles and the visualisation of 3-D images from 2-D images. In both instances, the male participants outperformed the female participants. The reasons why male participants outperformed female participants in these two questions within the South African context are unknown.

Figure 6.15: Percentage of correct answers per gender.

Although the overall results indicate that there is no significant difference in the performance of female and male students on the STAT, t-tests were performed to determine whether there were significant differences in the scores for the respective questions pitched in the STAT. (The results are indicated in Table 6.13.)

Table 6.13: Results of t-test per STAT component and gender.

	T	Df	p-value	Mean Difference	Std Error Difference
Question 5 (Visualisation of a slope profile from a topographic map)	-2.209	197	.0282	-0.158	0.072
Question 8 (Visualisation of 3-D images from 2-D images)	-3.115	197	.0020	-0.22	0.071

A significant difference between the genders was observed in the scores for Question 5 (visualisation of a slope profile from a topographic map) and Question 8 (visualisation of 3-D images from 2-D images). In both instances, the male participants outperformed the female participants. These findings confirm the results of studies indicating that female participants experience difficulties in specific mental rotation tasks (Bednarz, 2019).

6.7.3 Additional spatial modules completed: results and discussion

Table 6.14 summarises the overall performance of participants who had completed additional spatial modules and those who had not. Participants who had completed additional spatial modules scored an average of 46% for the STAT, while those who had not scored an average of 44%. The minimum scores obtained were 12% for participants who had completed additional spatial modules and 6% for those who had not. The maximum scores were the same, namely, 93%, for all participants.

Table 6.14:Overall performance of participants per additional spatial module versus in the absence thereof.

Spatial modules	Average result of STAT (%)	Minimum score (%)	Maximum score (5)
Additional spatial modules	46%	12%	93%
No additional spatial modules	44%	6%	93%

A t-test was performed to determine whether the scores for participants who had completed additional spatial modules, as opposed to those who had not, differed significantly. The t-test results are summarised in Table 6.15.

Table 6.15: Results of the t-test for a comparison between participants who had completed additional modules and spatial thinking skills as opposed to those who had not.

	T	Df	p-value	Mean Difference	Std Error Difference
Spatial modules (Modules in Cartography, GIS, Remote Sensing or Map Reading)	0.901	198	.368	0.422	0.468

The results of the t-test indicate no significant differences in the scores of participants who had completed spatial modules as opposed to those who had not. The results of this research stand in contrast to the findings of the research conducted by Shin, Milson and Smith (2016), who found that students who had completed a module in GIS would possess higher spatial thinking skills than those who had not. The reason why participants who had completed or who were currently enrolled for spatial modules did not outperform students who had not lies in the spatiality of the module outcomes and the assessments. The results of this research indicate that apart from one module (J.3), the level of integration of the three components of spatial thinking in the module outcomes in Geospatial applications was low. (Refer to Chapter 4, Figure 4.7, module A.7, B.7 and E.7.) Indeed, the spatiality of the assessments for all the Geospatial modules that formed part of this research was low. (Refer to Figures 6.2, 6.4, 6.6 and 6.11.) Figure 6.16 compares the scores of the participants who had completed spatial modules as opposed to those who had not.

Participants who had not studied additional spatial modules scored the lowest (9%) in Question 12 (the overlaying and dissolving of map layers) and the highest (84%) in Question 3 (comparison of a map and graphic information). Participants who had completed additional spatial modules scored the lowest (19%) in Questions 11 and 12 (both questions on the overlaying and dissolving of map layers) and the highest (77%) in Question 15 (comprehending geographic features represented as points, lines or polygons).

Figure 6.16: Percentage of correct answers by participants who had completed spatial modules as opposed to those who had not.

Participants who had not completed additional spatial modules outperformed students who had completed an additional module in Question 2 (comprehending direction and orientation) and Question 3 (comparison of a map and graphic information). Participants who had completed additional spatial modules outperformed those who had not completed additional spatial modules in Question 6 (connecting spatially distributed phenomena) and Question 12 (the overlaying and dissolving of map layers). The reason why participants who had completed additional spatial modules outperformed students who had not can be found in the content covered by the modules in Geospatial applications. Concepts such as the spatial distribution of phenomena (or spatial correlation), map overlays (e.g. intersect, union and clip) and the dissolving of map layers (e.g. the generalisation of map layers) are often covered by the content of modules in Geospatial applications.

Although no significant difference could be determined in the spatial thinking abilities of participants who had completed additional spatial modules and in participants who had not (Refer to Figure 6.16), t-tests were conducted to determine whether there were any significant differences in the performance of these two groups of participants in the different components of the STAT. The results of the t-tests are summarised in Table 6.16, which only shows the results of the questions for which significant differences were determined.

Table 6.16 Results of the t-test per STAT component and additional spatial module completed.

	T	Df	p-value	Mean Difference	Std Error Difference
Questions 6 and 7 (Connecting spatially distributed phenomena)	2.412	198	0.017	0.2111	0.0576

The results of the t-tests indicate that participants who had completed additional spatial modules scored significantly higher in Questions 6 and 7 (connecting spatially distributed phenomena) than participants who had not completed additional spatial modules.

6.7.4 Synthesis: assessments and the spatial thinking skills of students

Assessments should be designed to develop students' spatial thinking skills and should be aligned with the curriculum (Beets, 2007). The results obtained in this research indicate that lecturers in the selected departments face the same challenges as teachers in Indonesian schools when they have to compile Geography assessments based on spatial thinking capabilities (Nursa'Ban et al., 2020).

The challenges can be seen firstly in the cognitive level at which submitted questions are pitched. In most instances, the questions are at a relatively low cognitive level. More than 60% of all the questions from all the departments were on an input cognitive level, while only 20% were on an output level. It remains important to test basic Geography concepts, but the questions should be increase in complexity to reflect higher cognitive levels, especially for modules on NQF levels 6 and 7.

Secondly, 56% of the submitted questions were in the non-spatial category and only 25% in the complex spatial category. For modules in a discipline such as Geography where the spatial dimension is important in many of them, these percentages are too low. Geography students should be actively encouraged to use spatial concepts when answering questions and be assessed on their use of spatial concepts. Only the lecturers from Department B encourage their students to focus on the correct use of spatial terms in their answers to the questions.

Lastly, only 21% of the submitted questions were found to include representation tools. The greatest hindrance to including spatial thinking in assessments is the non-use of representation tools in the questions. Geography is a visual and creative subject (De Jager, 2014). Students should be encouraged to hypothesise, predict and imagine situations and to use representation tools to explain their answers. Only two lecturers in this research encourage their students to use representation tools when answering assessment questions; however, the use of such tools is optional. Thus, even if they do not use representation tools, such students might still be able to attain full marks for a question. Students should be encouraged to use maps, graphs and sketches to illustrate and enhance their answers and be assessed accordingly. Since many of the assessments focus largely on sentence structure and grammar, it is recommended that stronger emphasis should instead be placed on the use of the correct spatial concepts and geographical terminology for students to develop a SHOM.

The integration of the three components of spatial thinking in assessment questions and module outcomes was found to be limited in all the departments that participated in this research. In fact, the highest level of integration was 65%, while the lowest was 1%. Since the use of representation tools is required in modules covering Geospatial applications, it is to be expected that such modules would score much higher in terms of their integration of the three components of spatial thinking.

Half of the modules investigated in this research assess the students on the same level of spatiality as the module outcomes. Although the spatiality of half the modules aligns with the module outcomes, the integration of the three components of spatial thinking remains low. The weighted contribution and number of assessment questions with a high level of spatiality are also generally low.

Furthermore, this research indicates that the spatiality of the assessment questions demonstrates no increase in spatiality over the three years of undergraduate study. Therefore, the lesson to be learned from this research is that the assessment questions should become more complex as students proceed to a higher NQF level.

The low level of spatiality measured in the assessments is reflected in the spatial thinking abilities of the participants. Although participants registered for Geography modules on NQF Level 7 achieved the highest average score (52%) in the STAT, there was no significant difference in the scores for students registered for NQF levels 5 and 6 modules and for those registered for NQF levels 6 and 7 modules. The results of this research indicate that the overall scores of the participating students on the STAT were low. Related research found that students on a higher study level should outperform those on a lower level (Lee & Bednarz, 2012; Verma, 2015) because they are better equipped to develop their spatial thinking skills (Collins, 2018b; Verma, 2015). This seems not to be the case for the students who participated in this research.

In the light of the poor scores obtained in the STAT which are representative of neither any specific department nor all Geography students in South Africa, it is evident that there are some gaps in the spatial thinking abilities of the participants. These gaps include the ability to select the best location when given a set of criteria, to visualise 3-D images from 2-D images and to overlay and dissolve map layers.

The results of this analysis indicate that the assessment practices of the departments which participated in this research will not contribute to the spatial thinking skills of the students. Indeed, the analysis of the results of the STAT confirms that the spatial thinking skills of the participants are generally poor.

6.8 Reflections on the spatiality of assessment questions and the spatial thinking skills of students

This chapter focused on determining the spatiality of assessment questions in selected undergraduate Geography modules at South African universities and gauging the spatial thinking skills of the students who participated in this research. The taxonomy of spatial thinking was used to assess the level of spatiality of 2,602 assessment questions obtained from the six Geography Departments that participated in this research, while the STAT was used to gauge the spatial thinking skills of the 200 students who participated in the research.

The results of this research indicate that, in most instances, lecturers find it challenging to formulate questions that will contribute to developing students' spatial thinking skills. These challenges are evident in the cognitive level at which the questions are pitched, with only 20% of the assessment questions on an output level. In terms of the use of concepts of space, a large proportion of the questions (56%) were found to be in the non-spatial category. Thus, for modules in Geography — in which the spatial component is essential — the questions should include more complex concepts of space. This research also showed that the proportion of representation tools in the assessment questions contributes little (a low percentage of 21%) to the spatiality of the assessment questions and module outcomes. This has indeed proved to be the greatest hindrance to integrating the three components of spatial thinking in the assessment questions.

Owing to the limited integration of the three components of spatial thinking in the assessment questions, only 50% of the module outcomes were found to align with the spatiality of the assessment questions. Although the module outcomes and the assessment questions of half the modules were indeed aligned, the integration of the three components of spatial thinking proved to be limited. In the light of these findings, the assessment questions will contribute to a limited extent to the development of students' spatial thinking skills. As a partial solution to the problem, it is to be recommended that, amongst others, more representation tools be included in the assessment questions.

The results of the STAT indicate that, generally, the participants possess relatively poor spatial thinking skills. The results for the small sample of participants indicate that there is no significant difference in the scores for participants registered on NQF levels 5, 6 and 7. The results also show no significant differences in the scores of the male and female students and that students who had completed additional spatial modules did not necessarily achieve higher scores than those who had not. Some reasons for these significant differences, or lack thereof, were provided, but these are merely speculative and require further research to be conclusive. The major gaps in the spatial thinking abilities of students were identified as follows: selecting the best location when given a set of criteria, visualising 3-D images from 2-D images and overlaying and dissolving map layers.

This chapter concluded with the finding that the spatial thinking abilities of participants are generally not well-developed and that the assessment practices of the researched departments will contribute, but only in a limited way, to developing students' spatial thinking skills.

The next chapter, Chapter 7, aims to propose a strategy for improving spatial thinking in undergraduate Geography at South African universities based on the results obtained through this research and the shortcomings that were pinpointed.

Chapter 7: A strategy for improving spatial thinking in undergraduate Geography in South Africa

7.1 Introduction

Spatial thinking is a 'vast and ubiquitous skill' that can be acquired and improved in many ways (Collins, 2018a). Despite the importance of spatial thinking and the many ways in which spatial thinking can be improved, there is no consensus on how to teach and foster the spatial thinking skills of students (Metoyer & Bednarz, 2017). It has been proven that Geography is a suitable academic subject that can help undergraduate students to acquire essential spatial thinking skills – including Geospatial thinking skills (Verma & Estaville, 2018). Should spatial thinking in the Geography curriculum be overlooked, the key ways in which the brain comprehends and organises information would indeed be neglected (Gersmehl, 2012).

In 2006, the National Research Council advocated for an educational programme at school level in the USA that would systematically enhance the spatial thinking skills of learners. Since it has been proven that spatial thinking can be learned at any age (National Research Council, 2006), the same argument applies to Geography teaching and learning at the tertiary level. This thesis is, therefore, a call for approaches to curriculum development at undergraduate level that will improve the spatial thinking skills of Geography students. As such, Geography lecturers should become pioneers in developing students' spatial thinking skills (Collins, 2018b) so that they can think creatively and critically about themselves, their communities and the world (Walkington et al., 2018).

This chapter proposes a strategy for improving spatial thinking skills in undergraduate Geography modules at South African universities. Such a strategy is essential since the findings of the study confirm that spatial thinking is not sufficiently incorporated into the Geography curriculum of the participating departments in this research.

This chapter explains how the strategy proposed by this thesis for improving spatial thinking in undergraduate Geography in South Africa has been derived through the research to achieve the objectives of this thesis and the research on which it is based as defined in Chapter 1, which presents the framework for this chapter. In the sections to follow, explanations show how each objective has been achieved and how the findings for each objective feed into the proposed strategy.

7.2 Development of a strategy for the improvement of spatial thinking in undergraduate Geography in South Africa

To develop a strategy for improving spatial thinking in undergraduate Geography in South Africa, all the information collected for attaining Objectives 1, 2 and 3 of this thesis was processed and analysed to feed into the strategy. The data were collected primarily through interviews, evaluations that were made against the taxonomy of spatial thinking, and through the analysis of the feedback on the disposition questionnaire and the results of the STAT. Interviews were conducted with 21 lecturers from the six participating departments. In turn, the taxonomy of spatial thinking was used to determine the spatiality of the module outcomes, the way in which module content is conveyed to students and assessment questions. The interviewed lecturers completed the online disposition questionnaire to determine whether they are inclined to include spatial thinking in their way of conveying module content to students. Lastly, the spatial thinking abilities of the students who completed the questionnaires from the participating departments were gauged using the STAT. (Refer to Chapter 3, Section 3.4 for more information on the relevant methodologies which were selected for application.)

Once an initial version of the strategy had been developed, the participating departments were invited to provide feedback on it during a focus group session. At this session, the proposed strategy was presented to the lecturers for their comments, which were taken into consideration in the development of the final version of the strategy.

The final research steps in the development of a strategy for improving spatial thinking in undergraduate Geography in South Africa are positioned in the lower left quadrant of the AQAL model. The lower left quadrant of the AQAL model presents an inter-subjective view of reality. The feedback, ideas and information collected from all the participating departments, as well as the researcher's experiences, were combined to develop a strategy for improving spatial thinking. As such, these final steps in the research process incorporated inside and outside 'we' perspectives.

The following sections of this chapter indicate how the findings obtained through the achievement of Objectives 1, 2 and 3 of the thesis feed into the development of the initial version of the proposed strategy for improving spatial thinking to achieve Objective 4. Following this, the feedback obtained from the lecturers regarding the strategy is discussed, whereafter the final version of the proposed strategy is presented.

7.3 Achievement of Objective 1

Objective 1 of the thesis aimed to determine the extent and nature of incorporating spatial thinking into the syllabi of undergraduate Geography modules at South African universities. Modules that potentially include spatial thinking were identified by scrutinizing the module descriptions available on the websites of the Geography departments of all South African universities. In some instances, the module outcomes were available on the websites. The heads of the Geography departments were then contacted and their departments invited to participate in this research. In cases where the module outcomes were not available on the internet, the heads of departments were requested to provide the researcher with a document containing the outcomes. The outcomes were then evaluated against the taxonomy of spatial thinking to determine their spatiality.

In most instances, the module outcomes were written in general terms to allow for course content changes without the customary application required for reapproval through SAQA. To ensure consistency in applying the taxonomy of spatial thinking and to give the lecturer the benefit of the doubt, should any uncertainty arise, the option that would give the outcome a higher spatiality would then be assigned to that particular outcome. The notional hours per outcome were not considered.

The findings of the research regarding Objective 1 indicated that spatial thinking is not well integrated into the module outcomes. Based on the module outcomes, it was found that as long as representation tools are lacking, modules are at risk of failing to reach a desirable cognitive level. However, this research did indeed find that concepts of space are generally well integrated into the module outcomes. The fact that the cognitive level was mostly low and that representation tools were also mostly lacking led to the conclusion that there was a low level of integration of the three components of spatial thinking in the module outcomes.

Through the interviews with the lecturers, it became clear that although the development of new modules is generally discussed at departmental level, the module outcomes are developed in isolation without consideration being given to the level of spatiality at which the other modules are offered. Furthermore, although the development of the modules is usually discussed on a departmental level, implementation usually lies with the individual lecturers. The interviews indicated that most of the participating departments do not consider spatial thinking or the three components of spatial thinking when developing a new module. The use of representation tools was also found to be largely lacking.

The process of defining module outcomes should be a concerted effort involving the entire department. In this process all modules and their outcomes should be considered. The department should agree on a developmental path for a module forming part of the Geography curriculum to ensure that students' spatial thinking skills are improved from NQF level 5 through to NQF level 7. To set up a module that will lead to the development of the spatial thinking skills of students, the spatiality of the outcomes should be considered from the outset, at the stage when a new module is initiated and then developed. Alternatively, the spatiality of the outcomes should be used to review and improve the spatiality of an existing module. The eight spatial thinking areas, as determined by the STAT, could further be used to design a curriculum that would be suitable for the development of the spatial thinking skills of Geography students.

The next two subsections propose a developmental path for presenting the content of the module outcomes. They are followed by an example of how the spatiality of an outcome can be enhanced and how the STAT can be used for the effective development of outcomes.

7.3.1 Proposed developmental path: module outcomes

None of the papers researched for this thesis proposes a developmental path for defining outcomes to enhance the spatial thinking skills of students. The proposed developmental path illustrated in Figure 7.1 is based on the proven fact that spatial thinking can be learned at any age (National Research Council, 2006) and that the outcomes define the exit level a student should achieve at the end of a teaching semester. Therefore, ideally one would not include outcomes on an input level and non-spatial concepts since these levels these will be included in the teaching and assessments of a module and create a development path to exit the module on a higher cognitive level and concepts of space. It could be assumed that small proportion of the outcomes may include the non-use of representation tools to instil the underlaying theories of Geography.

The proposed developmental path does not indicate the proportion of module outcomes per cognitive level, concepts of space or use of representation tools, but rather how the spatiality of outcomes can be increased to develop the spatial thinking skills of students.

Module outcomes should be pitched on a high cognitive level. However, in the case of NQF Level 5, although some outcomes may be included on an input and processing level, the proportion of modules defined on these levels should decrease on NQF Level 6. The module outcomes on NQF Level 7 should all be on a processing and output level that would develop the spatial thinking skills of the student. If an input level is included in NQF level 7, it should form a small proportion of the total outcomes. The outcomes pitched on a high cognitive level align with the problem-solving nature of Geography and its potential for including applications (Charcharos et al., 2016).

Likewise, the concepts of space should be developed in a similar incremental manner. On NQF Level 5, module outcomes may feature on the non-spatial, spatial primitive and simple and complex spatial levels. However, on NQF Level 6, the proportion of outcomes on the complex spatial level should be increased, with a further increase of the outcomes on NQF Level 7 being on a complex spatial level. Since Geography is focused on investigating, for example, patterns, interactions and associations in space, it would be expected for module outcomes to reach a complex spatial level from as early as NQF Level 5.

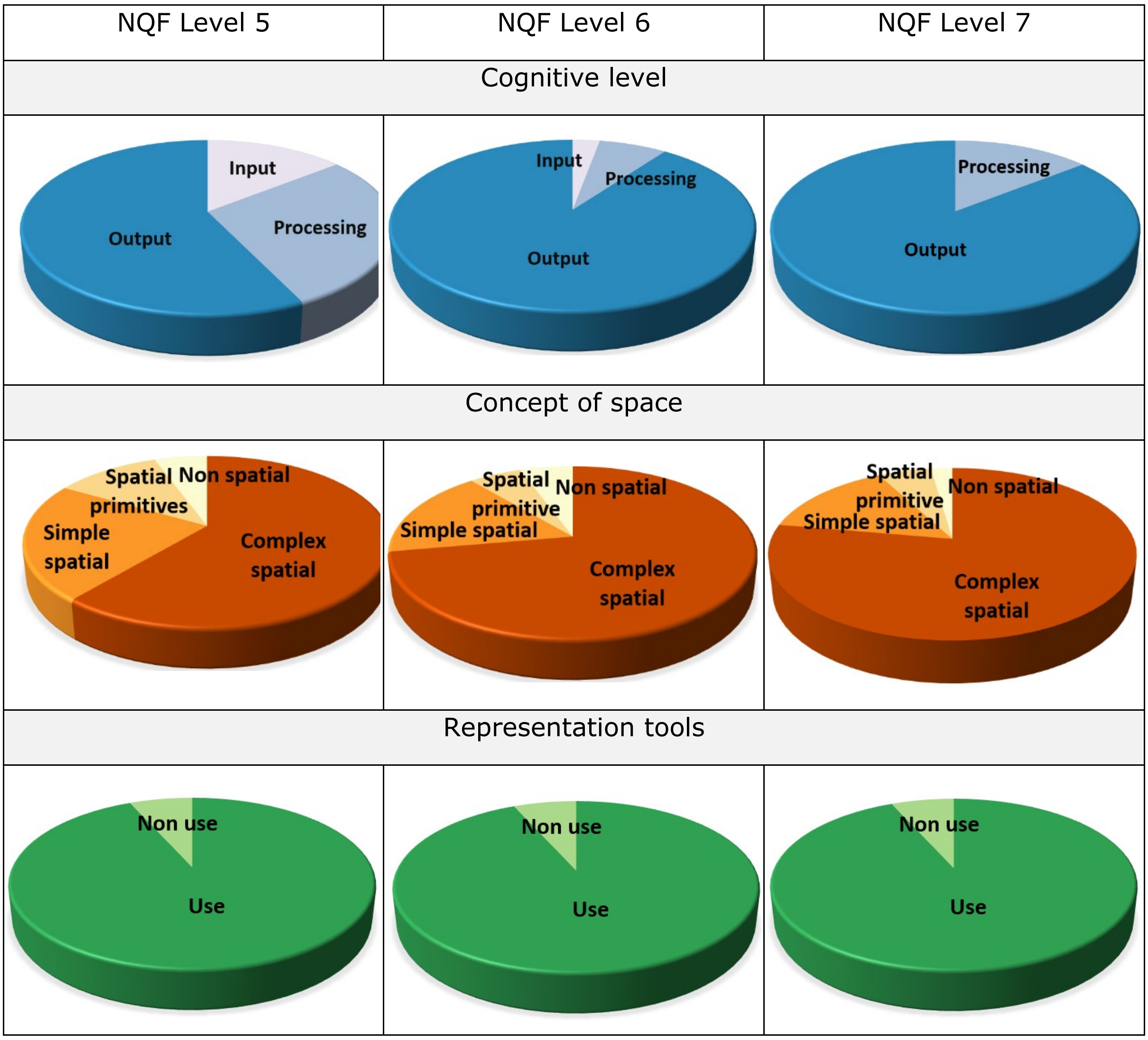
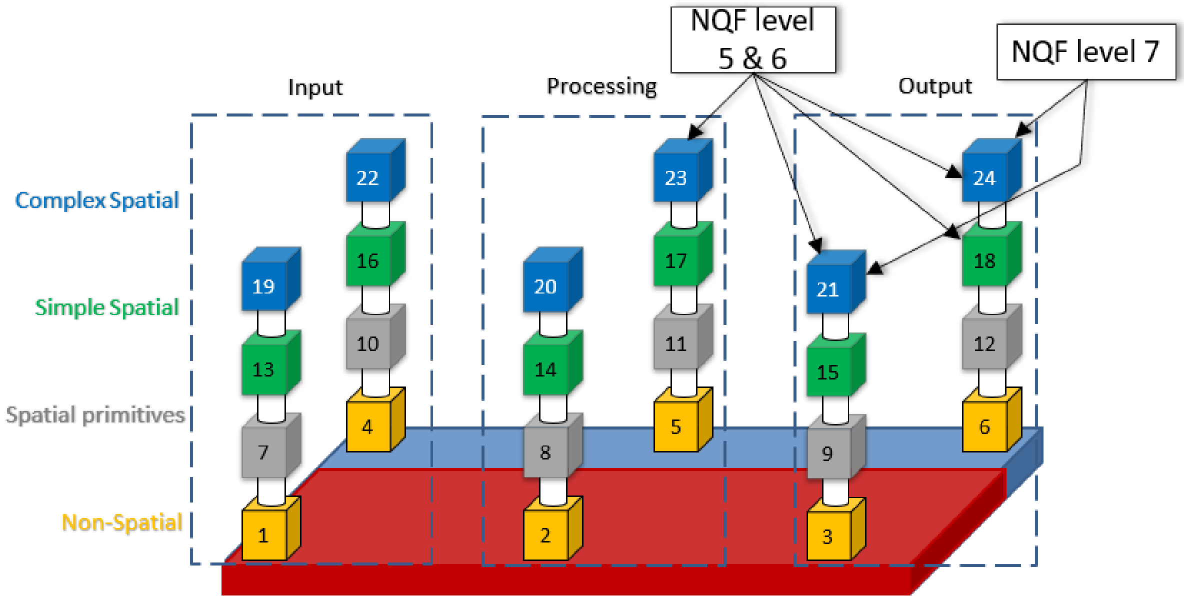


Figure 7.1: Proposed developmental path for module outcomes.

It could be assumed that some of the module outcomes may not include the use of representation tools. However, these should be kept to a minimum as Geography is a visual and creative discipline (De Jager, 2014), and one would, therefore, expect to observe the frequent usage of representation tools.

The three components of spatial thinking indicated in Figure 7.1 should be integrated to ensure that module outcomes reach a high level of spatiality. Figure 7.2 illustrates the scenario where the cognitive levels, the concepts of space and the tools of representation are integrated in an acceptable way and with module outcomes which will achieve a high level of spatiality. The combination of an output cognitive level with a complex concept of space and the use of representation tools will result in module outcomes with a high cell value of 24 on the taxonomy of spatial thinking. If a processing cognitive level is combined with a complex concept of space and representation tools, the outcome will have a spatiality of 23. On the other hand, integrating an outcome defined on an output level involving a simple concept of space and the use of representation tools will lead to an outcome with a spatiality of 18. However, if a processing cognitive level is combined with a simple concept of space and the non-use of representation tools, the spatiality of the outcome will have a cell value of only 14. This low cell value will not contribute to the development of the spatial thinking skills of students (Jo & Bednarz, 2009).



	NQF level 5	NQF level 6	NQF level 7
Integration of the three components	70%+	80%+	90%

Figure 7.2: Integration of the three components of spatial thinking to define module outcomes.

As illustrated in Figure 7.2, by combining the three components of spatial thinking, it is possible to achieve a high level of integration of the components of spatial thinking on all NQF levels. In the case where representation tools are not used, it is essential for outcomes to be pitched at a high cognitive level.

7.3.2 Increasing the spatiality of outcomes: an example

Module outcomes should, from the outset, be defined with the aim of fostering the spatial thinking skills of students. Outcomes should therefore be assessed against the taxonomy of spatial thinking to ensure that a high level of spatiality is achieved.

To demonstrate how the spatiality of an outcome can be increased, we will start with a basic outcome: *'Explain urbanisation in South Africa'*. The outcome is on a processing level (explain) and includes location as a simple primitive concept of space (South Africa), but a representation tool is not included. An outcome defined in this way will have a cell value of 8 in the taxonomy of spatial thinking and will not contribute toward developing the spatial thinking skills of students. (Compare against Figure 7.3.)

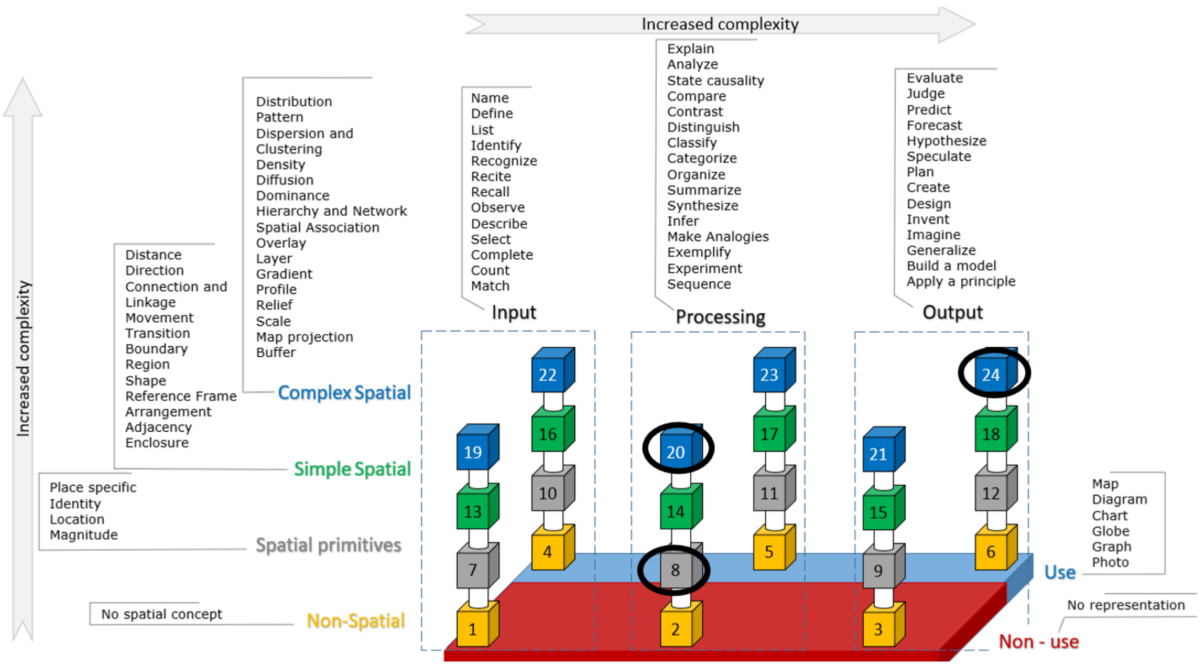


Figure 7.3: Increasing the spatiality of outcomes.

If the wording of this outcome is changed to *'Explain the growth and patterns of urbanisation in South Africa'*, its spatiality is increased to a cell value of 20. (Refer to Figure 7.3.) The outcome is still defined on a processing level but paired with a complex concept of space (pattern). Still, a representation tool is lacking.

If the outcome is rephrased to: '*Evaluate the growth and patterns of urbanisation in South Africa using geospatial tools*', the spatiality is increased to a cell value of 24. The outcome is defined on an output level (evaluate), a complex concept of space is included (pattern), and also a representation tool (Geospatial tool). This outcome integrates the three components of spatial thinking and will contribute to the development of the spatial thinking skills of students.

7.4 Achievement of Objective 2

The aim of Objective 2 of the thesis is to critically assess whether the way in which lecturers convey the content of undergraduate Geography modules to students will contribute to the development of their spatial thinking skills and determine whether the lecturers are well disposed to doing so. To obtain the information for this objective, the lecturers were interviewed and then asked to complete the disposition questionnaire , as developed by Jo and Bednarz (2014). Objective 2 was achieved by comparing the information collected through the interviews against the taxonomy of spatial thinking and by analysing the results of the disposition questionnaire. (Refer to Chapter 3, Section 3.4.2 for more detail.)

The research results demonstrate that most of the interviewed lecturers are experienced in teaching Geography on an undergraduate level and in the modules that form part of the research. Analysis of the information collected through the interviews indicates that spatial thinking is sufficiently primarily incorporated into the way module content is conveyed by the vast majority of lecturers. All the lecturers incorporate SPBL when conveying the course content to students, while half of them provide students with steps to follow when solving a problem. However, some lecturers do not include GSTs when conveying module content to students but rely on outdated methods or the limited use of technology. The results of the disposition test confirm that most of the lecturers are positively disposed to including spatial thinking in their teaching methods.

7.4.1 A problem-solving process to develop a spatial habit of mind

Students who are formally taught to develop their spatial thinking skills perform better than students who are not formally taught to do so (National Research Council, 2006; Collins, 2018b). Since spatial thinking is a personal attribute, students should be informed that they will be taught how to think spatially and be provided with steps to be able to address spatial problems. Such direct instruction in spatial thinking will develop a spatial habit of mind (SHOM) and lead to the application of spatial thinking skills when needed (Bednarz & Bednarz, 2008).

Bearman et al. (2016) proposes a geographical problem-solving process. This problem-solving process includes the processes of data identification, acquisition and management, analysis and output, through a communication medium such as a map or a graph. (Ibid).

Figure 7.4 illustrates steps that could be followed when addressing spatial problems. The steps are generalised to correspond with a spatial problem-solving process within Geography teaching. The proposed steps may be used as presented in this figure, or they could be adapted to correspond with a specific focus or application field. They are aimed at developing the spatial thinking skills of students, but also for the purpose of identifying the resources required to address the problem, assessing the quality of the resources obtained and conducting a spatial analysis of the resources. These are steps that will contribute to developing the spatial thinking skills of students (Bearman et al., 2016). Central to the proposed steps is always the basic geographical knowledge that should never be neglected (Bednarz, 2019). The purple arrows in Figure 7.4 illustrate the constant flow of the subject knowledge to the specific focus or application field. It is recommended that departments should adopt a suitable problem-solving process for their specific contexts, so that this knowledge can be implemented in all their modules. Using the same or a similar problem-solving process in all modules should aid in developing a SHOM and instilling the process of applying spatial thinking when addressing spatial problems.

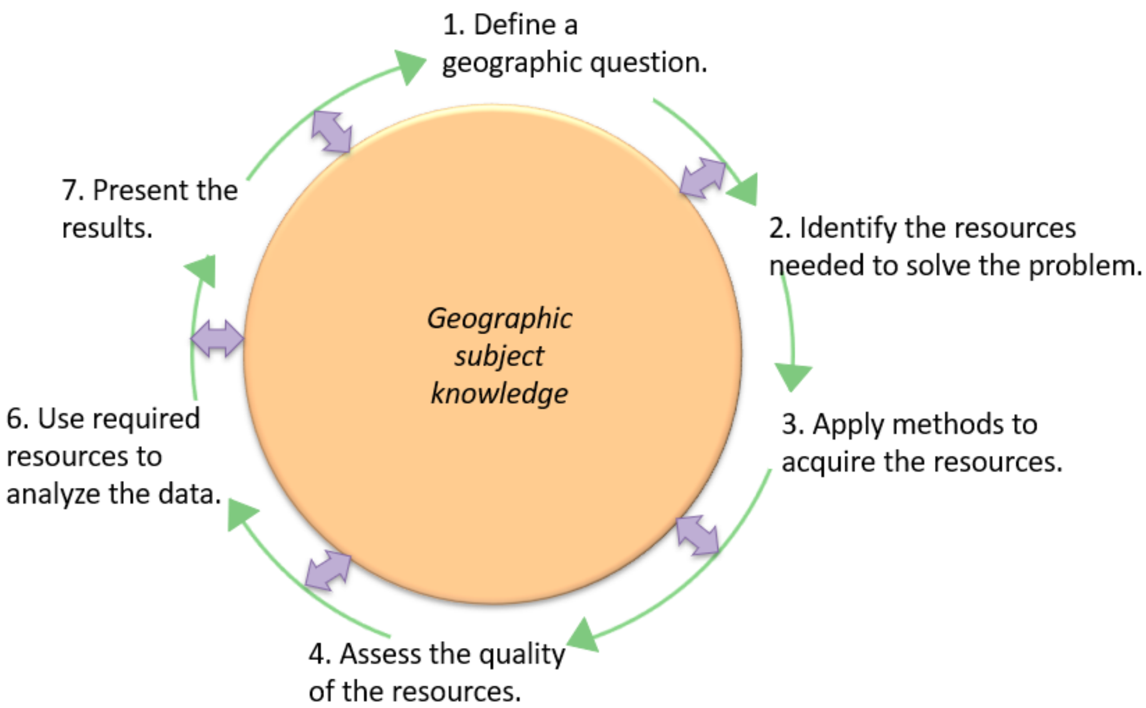


Figure 7.4: The geographical problem-solving process to develop a SHOM.

(Based on Favier (2011); Bearman et al. (2016))

7.4.2 Teaching at a high cognitive level

Teaching Geography to develop the spatial thinking skills of students should not only involve problem-based learning (PBL) but should also focus on spatial problem-based learning (SPBL) (Silviariza and Handoyo, 2021). SPBL suits the applied and spatial nature of Geography and is offered at a high cognitive level (Charcharos et al., 2016). SPBL requires students to evaluate a specific situation and to predict what may happen or allows them to apply basic and advanced knowledge to address challenges. Conventional teaching methods lead students to become passive listeners, relying on the lecturer to supply them with information (Silviariza and Handoyo, 2021) instead of following a spatial problem-solving approach.

It is recommended that an SPBL method be applied to convey geographical content to students. Within SPBL teaching environments, students can further personalise spatial thinking provided that they can control their study area, make choices regarding the spatial project and be creative when conducting geographical investigations. Such an approach will also fit into the current drive to localise, decolonise and Africanise all modules offered at universities in South Africa and is also suitable for teaching geographical content.

7.4.3 Using concepts of space when teaching

To enable students to become spatially intelligent (Goodchild et al., 2014), lecturers need to adopt a spatial perspective when teaching Geography. In addition, for students to become spatial thinkers, they should have an advanced understanding of spatial concepts such as scale, spatial dependence, location, distance and spatial heterogeneity, to mention but a few. A person who does not have spatial intelligence will not be able to adopt a spatial perspective when addressing problems (Goodchild et al., 2014). A lack of spatial intelligence also leads to the uncritical use of spatial tools (Ibid). This is often evident in GIS modules where students accept the results of a GIS analysis without interpreting its validity.

It is recommended that lecturers should deliberately use spatial language, and do so in a precise way (Newcombe & Stieff, 2012), instead of just referring to spatial concepts superficially. For example, instead of referring to an area of no development around a wetland, a lecturer could refer to the buffer of no development. And, instead of referring to a plant species occurring in an area, a lecturer could refer to the distribution of the plant species. The researcher's own experience has shown that lecturers are inclined to describe a spatial concept rather than using the precise term or wording when the language of teaching is not the same as the student's home language.

7.4.4 Using tools of representation when teaching

Many tools are available that can be used as aids in the teaching of spatial thinking skills. During the interviews, lecturers referred to the use of paper-based maps *versus* technologies, such as GIS. Based on the specific topics dealt with, lecturers need to select the type of representation tool that will benefit the students most. In this regard, GSTs serve as an example. Knowing and gaining the necessary knowledge and skills to use GSTs would improve students' employability, attitudes, motivation and achievements (Collins, 2018a). Using GSTs further improves the development of spatial thinking skills, such as pattern recognition, and the ability to spatially describe and visualise phenomena (Verma, 2015). Students with a knowledge of GSTs also have a better understanding of data reliability, can better use spatial concepts and are able to compare and analyse data and problems.

The use of GSTs in addressing spatial problems is in line with Geography's spatial nature. Within the 4IR environment, the use of the latest technologies can also be regarded as essential. The very fact that GSTs are used as additional aids in teaching distinguishes teaching in Geography from teaching in most other subjects. It also needs to be considered that most of the students currently studying at universities are millennials. The Millennial Generation benefits from the inclusion of experiential-based learning for improved spatial thinking (Flynn, 2018). Furthermore, the millennials use technology, such as the internet, mobile devices and social media daily. The millennials and later generations (such as Generation Z) have grown up and are familiar with technology, which should be reflected when curriculum content is taught to them (Şeremet & Chalkley, 2016).

The inclusion of GSTs does not guarantee that students' spatial thinking skills will necessarily improve but does indeed lead to greater gains in respect of content knowledge (Metoyer & Bednarz, 2017). When including GSTs in teaching, lecturers should avoid a 'cookbook' or '*buttonology*' approach, as described by Pye (2014) in Bearman et al. (2016) and Fombuena (2017). Such an approach will not develop the spatial thinking skills of students. At first, the incorporation of GSTs in teaching will tend to be opaque; this will be the case until students become more familiar with the software. The GSTs should then become more transparent and assist in addressing spatial problems on a higher cognitive level.

It is recommended that the incorporation of GSTs as an aid in conveying module content should commence at the lower NQF levels and increase in use at the higher NQF levels. The developmental path in the use of GSTs, from an opaque instrument to a transparent tool to assist in spatial problem-solving, should be conducted in a concerted way and prioritised by departments. This will ensure that the students will be able to apply their GST knowledge in all modules without the opaqueness of the tool making the content of some modules obscure and distracting the attention of students from the content.

7.4.5 Proposed developmental path: conveying content to the students

By following the recommendations in Subsections 7.4.1 to 7.4.4, the way lecturers convey module content to students should contribute to developing the students' spatial thinking skills. The proposed spatiality of module outcomes (Refer to Figure 7.2) and the proposed developmental path to convey module content to students are summarised in Table 7.1.

Since spatial thinking can be learned at any age or level, an output cognitive level and a complex concept of space could be expected on three of the NQF levels. If SPBL is applied and used in conjunction with complex concepts of space and GSTs as tools of representation, the lecturers' way of conveying module content to students should contribute to the development of the spatial thinking skills of their students. The way in which module content is conveyed to students will then also be in line with the spatiality of the module outcomes.

Table 7.1: Proposed developmental path to foster spatiality in module outcomes and to convey module content to students.

NQF level	The spatiality of module outcomes		Cognitive level	Concept of space	Representation Tool	Spatial thinking in Teaching
	No integration	Integration				
5	21	18 23 24	Input Process Output (SPBL)	Should include concepts of space on all levels	Yes (GST)	Yes
6	21	18 23 24	Processing Output (SPBL)	The use of complex spatial concepts should increase to become dominant	Yes (GST)	Yes
7	21	24	Output (SPBL)	Should focus mostly on a complex spatial level	Yes (GST)	Yes

7.4.6 Proposed strategy: disposition of lecturers towards the teaching of spatial thinking skills

If Geography lecturers are not well disposed to the teaching of spatial thinking, their teaching efforts in this regard will not be successful. All lecturers in Geography departments should be encouraged to complete the disposition questionnaire. The counter statements indicate the presence of any misconceptions and/or shortfalls that could potentially hinder the successful teaching of spatial thinking. The disposition tool can also be used in interviews to inform questions and ensure that a potential employee is well-disposed to teaching spatial thinking.

Fortunately, the disposition of lecturers towards the teaching of spatial thinking skills can be moulded and changed. Based on the results of the disposition questionnaire, training can be planned and formulated to address misconceptions and/or shortfalls regarding spatial thinking.

By using the disposition questionnaire to address such misconceptions and/or shortfalls, departments should be able to offer modules pitched at the desired level of spatiality; to implement teaching methods that would develop the spatial thinking skills of students and in the case of lecturers, to instil a positive disposition to teaching students spatial thinking.

7.5 Achievement of Objective 3

Objective 3 of the thesis critically reflects on the spatiality of the questions included in the formative and summative assessments and the spatial thinking capabilities of undergraduate Geography students at the selected Geography departments at South African universities. Objective 3 was achieved by evaluating the assessment questions provided by the lecturers against the taxonomy of spatial thinking, while the students were requested to complete the STAT to gauge the level of their spatial thinking skills. (Refer to Chapter 3, Section 3.4.3. for more detail.)

The results of this research indicate that, like international findings, the participating lecturers face challenges in developing assessment questions that incorporate a high level of spatiality. The spatiality of the questions in the Geography departments at the participating universities was generally low and would not, therefore, contribute to a limited extend to developing the spatial thinking skills of students.

Unfortunately, the number of students who completed the STAT was low and the results therefore not representative of the students attached to specific universities or departments. Nevertheless, general observations from the results could be made and do indeed indicate that the spatial thinking skills of the participants are generally poor.

7.5.1 The relationship between the type of assessment questions and their spatiality

The evaluation of the assessment questions against the taxonomy of spatial thinking indicated the presence of three types of questions: straight forward MCQs (multiple-choice questions), MCQs based on scenarios, and (non-MCQ) scenario-based questions. The reason for the low spatiality of the assessment questions, as revealed by this research, may be due to the type of questions asked. Table 7.2 summarises the spatiality of the three different types of questions. The green rows in the table highlight the cell values that integrate the three components of spatial thinking and should contribute to the development of students' spatial thinking skills.

Table 7.2: Spatiality of types of assessment questions. (Rows highlighted in green represent cell values that integrate the three components of spatial thinking.)

Spatiality	Straig forward MCQs	MCQs based on scenarios	Scenario (Non-MCQs)	Grand Total
1	**1025**		16	**1041**
2	18		29	47
3	11	20	10	41
4			5	5
6		5		5
7	142	2	5	149
8		1	17	18
9	2	26	30	58
10	2		61	63
11	8	12	12	32
12		1	13	14
13	49		2	51
15	1	6	2	9
16			30	30
17			18	18
18		1	40	41
19	66		16	82
20		2	33	35
21	4	34	43	81
22	4		93	97
23	4	11	135	150
24	1	3	160	164
Total	**1337**	124	770	**2231**

A total of 2 231 assessment questions were evaluated against the taxonomy of spatial thinking. A large percentage of the questions (46%) was associated with spatiality associated with a cell value of 1. A total of 1 337 (60%) of the questions were straight forward MCQs, 1 025 (77%) of which had a spatiality of 1. Only 1% of the straight forwards type of MCQs integrated the three components of spatial thinking and should foster the development of students' spatial thinking skills. In the case of MCQs based on scenarios, the proportion of questions that integrated the three components of spatial thinking increased to 23%, while it was 73% for the scenario-based questions which require written answers.

The reason why such a large percentage of straight forward MCQs were used for assessments became clear during the interviews with the lecturers. Many of the residential universities had to switch to emergency measures in the form of distance learning when they were temporarily closed for physical attendance during the COVID-19 pandemic. At that stage, since the computer automatically marks MCQs, universities found it most convenient to conduct assessments online. Many of the lecturers indicated that they would like to continue using MCQs because such a system reduces the marking load in classes with large student numbers. However, the low spatiality of these questions is a matter for concern and needs to be addressed.

7.5.2 Proposed developmental path: assessment questions

As indicated by Bednarz (2019), the basic knowledge that emanates from the teaching of Geography should not be neglected. However, assessment questions around such knowledge should reach an appropriate level of spatiality to develop students' spatial thinking skills. This can be done by evaluating assessment questions against the taxonomy of spatial thinking. Geography departments should proactively establish a clear developmental path to ensure that modules on different NQF levels not only cover the basics, but also move on to assess knowledge and application of knowledge on higher levels of spatiality. A proposed developmental path that incorporates the three components of spatial thinking is presented in Figure 7.5. The proposed developmental path includes questions for both formative and summative assessments.

Because of the applied nature of Geography and its spatial focus, it can be expected that assessment questions should attain a high level of spatiality. The inclusion of questions on the input level will ensure that basic knowledge is not neglected. However, it is important that the proportion of questions on an input cognitive level should decrease from NQF levels 5 to 6 and be phased out on NQF Level 7. Assessment questions on NQF Level 7 should consist primarily of output-level questions, followed by questions on a processing level.

To ensure that the students become spatially literate, emphasis should be placed on the use of concepts of space. NQF Level 5 should include all levels pertaining to concepts of space. Most of the assessment questions should be pitched on a complex spatial level, while the questions on a non-spatial level should be kept to a minimum. In the case of NQF Level 6, the proportion of assessment questions on a complex spatial level should increase, while those on a non-spatial level should decrease. The remainder of the assessment questions on NQF levels 5 and 6 should consist of questions on the simple spatial and primitive spatial levels. This will ensure that the basic knowledge of Geography is not neglected on these levels. However, it is essential that on NQF Level 7 assessment questions on the non-spatial level should be excluded and that most of the questions should be on the complex spatial level.

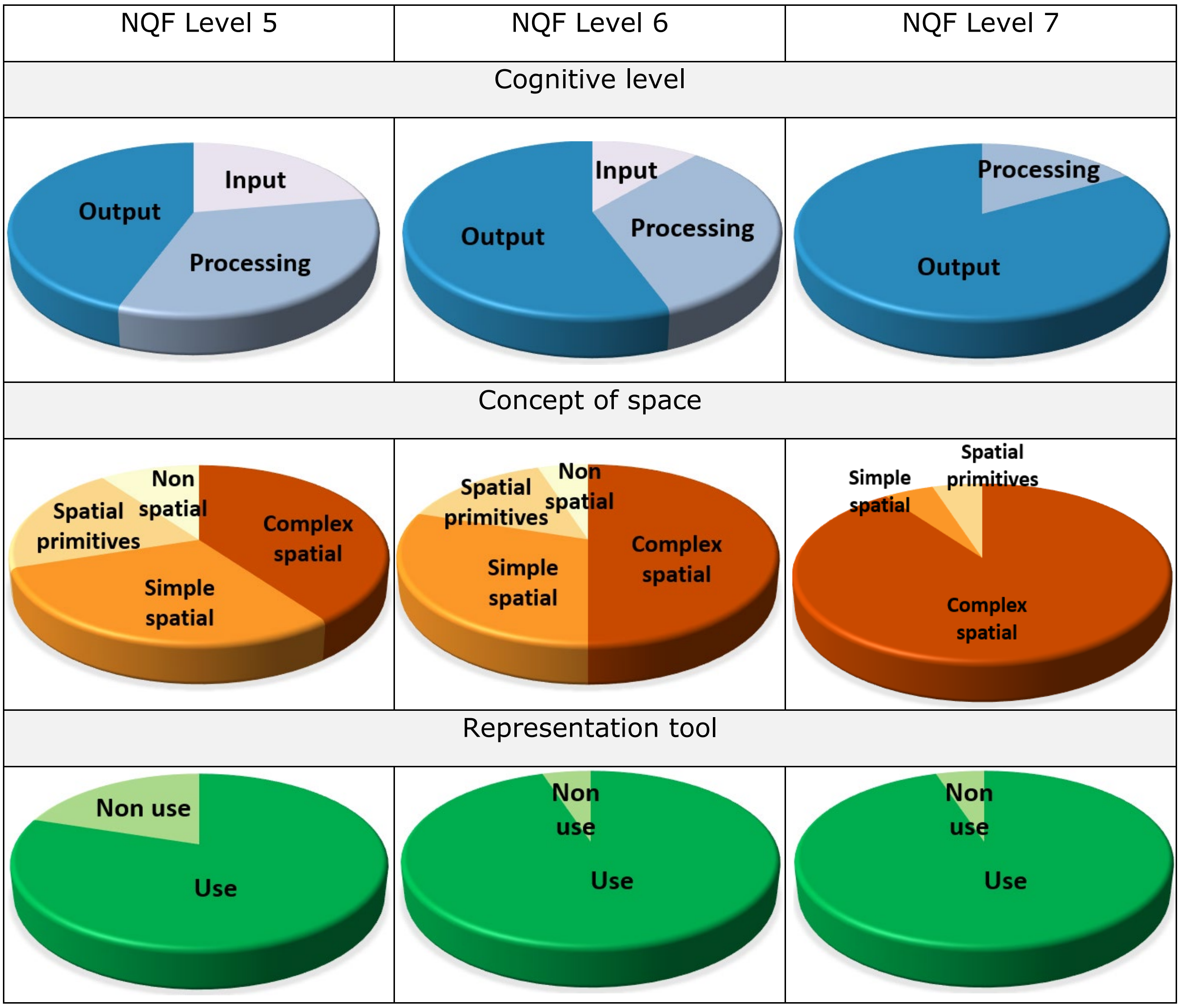


Figure 7.5: Developmental path for assessment questions.

The use of a representation tool or tools should be included for a large proportion of the assessment questions on all NQF levels. The assumption is that the proportion of questions that includes representation tools should be much higher than that for the non-use of representation tools. It is also suggested that the assessment questions should include the use of GSTs, such as GIS, remote sensing, or mobile GIS, to effectively address real-world problems.

The three components of spatial thinking, as indicated in Figure 7.5, should be integrated in the assessment questions to ensure that basic knowledge is not neglected, while ensuring that these questions attain a high level of spatiality. Figure 7.6 demonstrates the levels of spatiality that formative and summative assessment questions could potentially reach in terms of the taxonomy of spatial thinking.

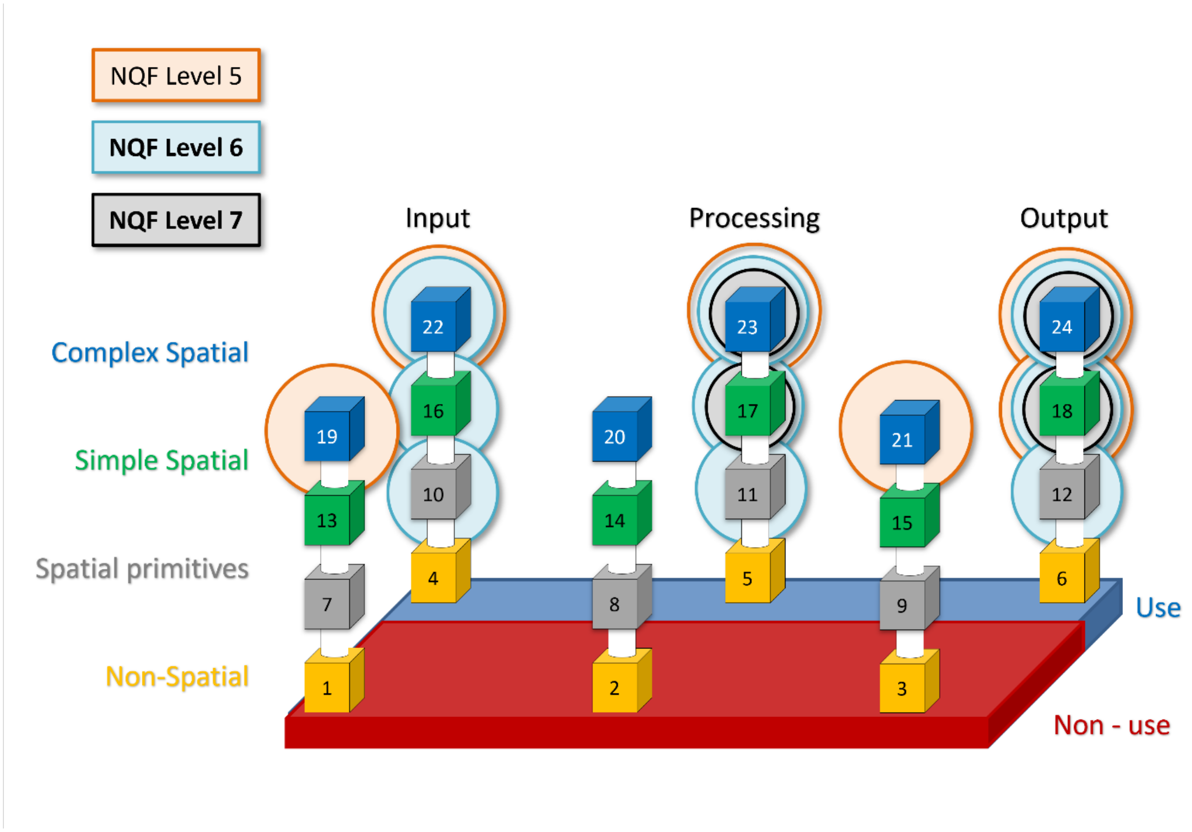


Figure 7.6: Spatiality of assessment questions that could potentially be reached.

On NQF Level 5 (shown in orange circles in Figure 7.6), assessment questions could potentially be pitched on any level of spatiality, but should include cell values of 18, 23 and 24 as these cell values are considered to have the highest spatiality on the taxonomy of spatial thinking and could, therefore, effectively foster the students' spatial thinking skills. (Refer to Chapter 2, Section 2.3.2.) On NQF levels 6 (shown in blue circles in Figure 7.6) and 7 (shown in grey circles in Figure 7.6), questions should be pitched on a high level of spatiality and include cells 10 to 12,16 to 18 and 22 to 24, all of which should include the three components of spatial thinking. As such, these questions on a high level of spatiality should foster students' spatial thinking skills. Lecturers should decide how this developmental path will be implemented by considering the type of questions to be pitched in the formative and summative assessments. For example, the first semester test may focus on questions on a lower level of spatiality, followed by a second semester test on a higher level of spatiality The summative assessment may include questions on both a lower and higher level of spatiality. Lecturers may also choose to include questions varying from low to high levels of spatiality in each formative and summative assessment. For both these scenarios, assessment questions on a high level of spatiality should have the highest weighted contribution within each assessment.

Based on the proposed developmental path for assessment questions, the spatiality of questions should align with the spatiality of both the module outcomes and the way in which the module content is conveyed to students. If this is the case, a positive contribution to the development of the spatial thinking skills of students should be possible.

7.5.3 Increasing the spatiality of assessment questions: examples

Text box 7.1 contains two examples of questions on a high level of spatiality. To ensure the anonymity of the departments and protect the integrity of the assessments, the questions were slightly adjusted, but in such a way that they maintained the level of spatiality at which the questions were pitched.

> Text box 7.1
>
> **Example 1:** With reference to the map of Cape Town, identify three landforms and explain how these were formed. Use annotations on the map to support your explanation. (The map of Cape Town includes contours and built-up areas.)
>
> **Example 2:** Use the attached base map of the Limpopo River in conjunction with the table showing population movement and outbreaks of the disease, to plot the spread of cholera among communities residing alongside the river. Use arrows to indicate the movement of people and add a key to indicate the carriers of the disease.

Example 1 is an interesting way in which to identify and explain, by means of a map, how the landforms were formed. This question challenges students as the landforms may be of natural origin and/or impacted by human activities. Using a map, the student should interpret patterns such as a change gradient of the contours to determine different landforms. The student is also required to perform a cognitive visualisation from a 2-D image to a 3-D profile to describe the different landforms. A representation tool is used, and the concept of space (pattern and profile) is at a complex spatial level. The student must also identify (input level) and explain (processing level) how the landform was formed. Therefore, the question in Example 1 would have a cell value of 23 on the taxonomy of spatial thinking.

Example 2 includes a map and a table that are needed to interpret the outbreak of a disease. The answers to the questions also need to be annotated on the map. The question includes concepts of space such as movement (simple spatial level) and distribution (complex spatial level). The question requires students to compile a map and apply spatial principles and is, therefore, on a high cognitive level. This question has a cell value of 24 on the taxonomy of spatial thinking.

As specified in Table 7.2, assessment questions based on scenarios and requiring written answers are associated with the highest level of integration (73%) of the three components of spatial thinking, while the level of integration for straight forward MCQs is low (1%). Table 7.3 provides an example of how the spatiality of a straight forward MCQ can be adjusted to a higher level.

In the initial example provided in Table 7.3, the question (a straight forward MCQ) is at an input level (identify), and a representation tool has not been included. The question is about the shapes of countries and, therefore, representative of a simple concept of space. This example has a cell value of 13 on the taxonomy of spatial thinking.

In the adjusted example, a world map is added as a representation tool. The question now requires students to identify the different shapes of states on the map and evaluate and apply that knowledge to the given options. This increases the cognitive level of the MCQ to an output level. The concept of space remains on a simple spatial level, but the spatiality of the question is raised to a cell value of 18 on the taxonomy of spatial thinking. While an MCQ with a cell value of 13 will not develop the spatial thinking skills of students, a question with a cell value of 18 represents a higher level of spatiality that will indeed contribute to the development of students' spatial thinking skills.

The example in Table 7.3 could be further adjusted by replacing the map as a tool with a GST. Students could use a GIS to locate the countries, evaluate the shape of the countries and apply their knowledge to determine the correct answer to the questions. Using a GIS as a representation tool will not, however, increase the spatiality of the MCQ, but the many benefits of using GSTs, as explained in Section 7.4.4, will come into play.

Table 7.3: Increasing the spatiality of a straight forward MCQ.

<table>
<tr><th>Example question</th><th>Level of spatiality</th></tr>
<tr><td>

<u>Original question</u>

Identify which of the state shapes listed below should foster internal communication.

a) Compact
b) Elongated
c) Fragmented
d) Prorupted
e) Perforated

</td><td>13</td></tr>
<tr><td>

<u>Adjusted question</u>

Evaluate the shapes of the countries indicated on the world map. Which country has a shape that should foster internal communication?

a) Kenya b) Chile c) Indonesia d) Thailand e) South Africa

</td><td>18</td></tr>
</table>

7.5.4 Proposed developmental path: spatial thinking skills of students

Apart from pedagogical factors, the spatial thinking skills of students are also influenced by factors such as gender, other modules already completed or registered for, educational background and various other potential factors not yet tested or proven (Collins, 2018b). It is the researcher's experience that these factors are not usually considered when setting up assessment questions to develop students' spatial thinking skills. Lecturers would usually focus on module outcomes and module content to compile the questions that should be included in an assessment. However, the STAT categories could also be used to guide the compilation of assessment questions by identifying gaps in students' spatial thinking skills. Lecturers can then provide additional exercises to fill in on these gaps. The next subsection provides examples of assessment questions based on the STAT that could be used to develop areas where there are gaps in the spatial thinking skills of students.

Questions based on the STAT: examples

The results of the STAT, as completed by the students, indicated three categories in which the lowest marks were earned. The three categories are as follows: selecting the best location when given several spatial factors, the visualisation of 3-D images from 2-D images and the overlaying and dissolving of map layers.

Table 7.4 provides an example of a question that could assist students in finding locations based on a set of criteria.

Table 7.4: Finding locations based on a set of criteria.

Question	Level of spatiality
Predict which communities in the Greater Tshwane area are potentially at risk of food insecurity. Communities at risk of food insecurity are communities that: - have a low income. - have a high unemployment rate. - Have a low level of education. - are not located close to nutritional food outlets. Use the GIS data layers to predict the communities at risk of food insecurity. Write an essay to motivate the criteria used to perform the analysis.	24

The question in Table 7.4 has a cell value of 24 on the taxonomy of spatial thinking and requires students to use GIS data layers to find locations at risk of food insecurity. When answering this question, students could use a GIS and apply the problem-solving process, as suggested in Section 7.4.1. This implies that it can be regarded an example of SPBL.

Figure 7.7 contains two images from open data sources that could be used to test the ability of students to visualise 3-D images from 2-D images.

Image A in Figure 7.7 illustrates map contours and can be used to identify landforms. The map could also be used to formulate a question at a higher level of spatiality that requires a student to predict possible landslides or soil erosion in the area. Image B is a synoptic weather map of South Africa. It could be used to identify weather phenomena or the spatiality of the questions could be increased to predict weather conditions for a specific location, larger areas or the whole region. Like the question in Table 7.4, the above-mentioned questions could be answered using a GIS, require students to follow a problem-solving approach and could be an example of SPBL. The level of spatiality of these questions could vary between a cell value of 10 and 24, depending on how they are formulated.

<table>
<tr>
<td>Image A

Identify two landforms illustrated in the map below

Image taken from ArcGIS online: Esri, USGS | Esri, HERE, Garmin, FAO, NOAA, USGS</td>
<td>Image B

Identify the weather phenomena occurring at Point A

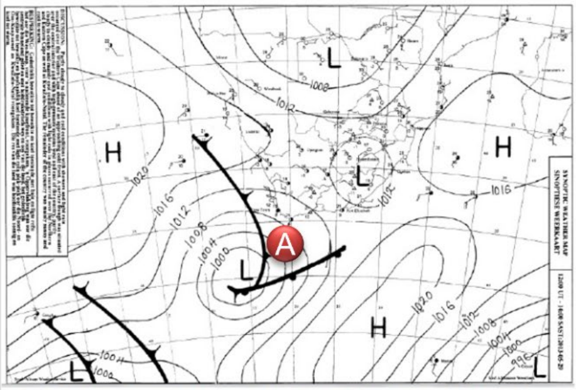


Figure 2: Surface synoptic weather map showing a cold front approaching South Africa (South African Weather Service, 2018).

Source:
http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-447X2019000300006</td>
</tr>
</table>

Figure 7.7: Visualisation of 3-D images from 2-D images.

Regarding the challenges, students appear to have struggled to perform overlays and dissolve map layers. Figure 7.8 contains two maps that could be used to compile a question to address this gap in their spatial thinking skills. Map A indicates fire incidents and Map B indicates different biomes. Students could use the information to create a new layer indicating biomes in Africa that are most likely to be affected by fires.

Like the two example questions in Figure 7.7, the question to address challenges regarding overlays and the dissolving of map boundaries could be answered by using a GIS, recognizing that this is an example of a question in the context of SPBL and which could, as such, potentially reach a high level of spatiality on the taxonomy of spatial thinking.

Map A: Fire incidents	Map B: Biomes
	
Source: Source: NASA LANCE - VNP14IMG_NRT active fire detection – World *Available in ArcGIS online*	*Source: Bioscience, An Ecoregions-based Approach to Protecting Half the Terrestrial Realm DOI: https://doi.org/10.1093/biosci/bix014* *Available in ArcGIS online*

Figure 7. 8: Overlaying and dissolving map layers.

7.6 Achievement of Objective 4

The fourth objective of this thesis is to propose a strategy for improving spatial thinking in undergraduate Geography at South African universities. The strategy is based on the findings of Objectives 1, 2 and 3. The findings of the research and how these feed into the strategy are presented in Sections 7.3, 7.4 and 7.5 of this chapter.

As a final step in the research, the participating departments were invited to attend feedback sessions on the proposed strategy for improving spatial thinking in undergradate Geography in the form of focus group discussions. Only two departments were interested in attending these sessions. Feedback obtained from participants in these sessions was used to adjust, fine-tune and finalise the strategy to improve spatial thinking in undergraduate Geography at South African universities.

7.6.1 Feedback received during the focus group discussions

The proposed developmental paths for module outcomes and assessment questions were presented to the participants during the focus group discussions. They were asked for feedback, to propose alternatives or to make suggestions.

The proposal that the strategy for improving spatial thinking skills be coordinated and implemented on a departmental level was supported. The participants were also in agreement with the suggestion that the coordination should encompass all modules. However, the question was raised as to whether the same developmental path could be applied by modules focusing on the Philosophy of Geography, especially with reference to representation tools. The focus group concluded that the same developmental path could be followed by these modules. The philosophy of Geography deals with issues such as how space and place are perceived and represented. Although these modules may not include GSTs as representation tools, other representation tools, such as diagrams and charts, may be used to demonstrate or support module content. It remains essential that the implementation of spatial thinking skills be discussed on the departmental level to accommodate and allow lecturers to apply their perspectives within the overall strategy.

The participants indicated that a cell value of 21 on the taxonomy of spatial thinking for module outcomes should be taken as the benchmark. This benchmark appears to be an academic exercise as they feel that there will always be new terminology that will need to be tested, but without the use of representation tools on every NQF level. This concession should, however, be minimised and module outcomes should generally be presented on a high cognitive level.

The question was also raised as to how time-intensive it would be to set up MCQs at a high level of spatiality on the taxonomy of spatial thinking. The researcher's experience has shown that setting up MCQs at a high level of spatiality may at first be more time-consuming. Nevertheless, this should become easier once a lecturer has internalised the process of applying the taxonomy of spatial thinking. It is also easier to take existing MCQs and increase their level of spatiality rather than to compile new questions.

The addition of tools of representation, such as graphs and figures, should not present a challenge since these are readily available in the creative commons environment on the internet. In addition, various open datasets and open-source GSTs are also available that could easily be incorporated into module content to increase the level of spatiality when conveying module content to students, as well as in assessment questions.

7.6.2 The proposed strategy for the improvement of spatial thinking in undergraduate Geography in South Africa

There is no all-encompassing method for teaching Geography (Metoyer & Bednarz, 2017); therefore, a strategy for improving spatial thinking should allow for fine-tuning and adjustments within each department and within the context of different focus fields. Figure 7.9 summarises the proposed strategy diagrammatically.

The grey circle represents the concerted effort and accommodating environment to foster spatial thinking that departments should establish. The implementation of spatial thinking should be considered on both a departmental level and per NQF level.

The orange square represents the disposition of lecturers to teach spatial thinking. Without a positive disposition shown by lecturers and support on a departmental level, the implementation of spatial thinking practices will not be successful. In fact, the disposition of lecturers to teach spatial thinking is one of the most critical elements of the strategy. Without a positive disposition on the part of lecturers, the implementation of spatial thinking as part of the curriculum will not be successful. As seen in the figure, the disposition of lecturers to teach spatial thinking touches on the circular implementation process and supports the implementation of spatial thinking practices.

The blue circle and arrows represents the process to follow when implementing spatial thinking in modules. Initially, the implementation of spatial thinking should be considered at the design stage of the Geography curriculum, when the module outcomes are formulated. A developmental path of module outcomes to foster the spatial thinking skills of students is discussed in Section 7.3.1 and presented in Figures 7.1 and 7.2. Once the curriculum has been designed and the module outcomes have been formulated, lecturers need to consider how the module(s) will be developed. It is preferable that from the outset, lecturers need to plan for the implementation of spatial thinking as part of the curriculum to ensure that the spatiality of the module design aligns with the spatiality of the outcomes.

The spatiality of how module content is conveyed to students should align with the spatiality of the module design and of the outcomes. This can be achieved by inviting students to participate in the problem-solving process, instead of just answering questions, thereby actively teaching them how to think spatially. A problem-solving approach to teaching is proposed and discussed in Section 7.4.1. and illustrated in Figure 7.4. To ensure that the module content is conveyed at a high cognitive level, an SPBL method should be employed. In addition, lecturers should deliberately use concepts of space when conveying content to students and employ GSTs as tools of representation. These ways of conveying module content to students are discussed in Sections 7.4.2, 7.4.3 and 7.4.4. Lecturers also need to ensure that the spatiality of the formative and summative assessments aligns with the spatiality of the way in which module content is conveyed, design considerations and outcomes to ensure that there is adequate scope for the development of the spatial thinking skills of students. A proposed developmental path for assessment questions is discussed in Section 7.5.2 and illustrated in Figures 7.5 and 7.6.

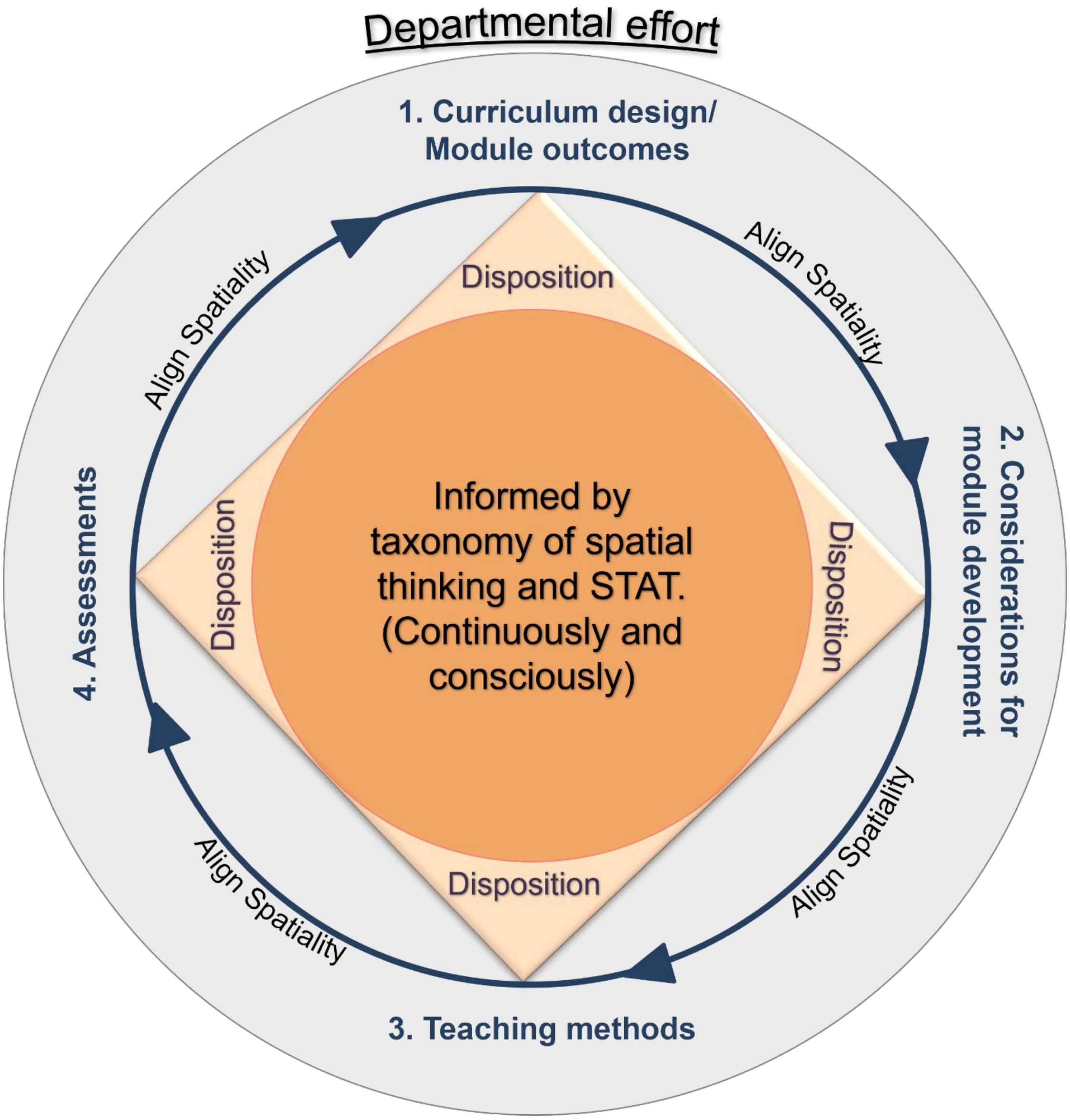


Figure 7.9: A strategy for improving spatial thinking in undergraduate Geography.

Should the circular process, as suggested in Figure 7.9 not be followed, or should the spatiality of the different steps in the strategy not align, there will not be adequate scope for the spatial thinking skills of students to be developed. To ensure the successful implementation of spatial thinking as part of the Geography curriculum, the taxonomy of spatial thinking, as developed by Jo and Bednarz (2009), and the STAT, as developed by

Lee and Bednarz (2012) need to take centre stage (shown by the orange circle in Figure 7.9). These are the two tools currently available that can be used to ensure that the prevailing teaching and learning methods are indeed fostering the spatial thinking skills of students.

The place of 4IR and spatial citizenship within the proposed strategy

New geographical techniques used in GST, such as remote sensing, real-time systems telemetry and climate modelling, to name but a few, are representative of the environmental applications of geographical research that are vital for addressing challenges in sub-Saharan Africa (Knight, 2015; Knight & Robinson, 2017). The use of GSTs is the first step toward distinguishing the spatial thinking offered in Geography modules from the spatial thinking offered in other disciples such as Medicine, Engineering and Architecture (Jo et al., 2018). A definite niche exists in the job market for graduates who offers Geography in conjunction with the application of GSTs and provides a step towards developing a modern technology- and a technique-driven curriculum.

This section concludes by referring to Sections 1.2 and 2.2.1, where the term "spatial citizenship" was briefly discussed. By employing the strategy presented in this chapter in undergraduate Geography at South African universities, Geography students will be equipped to become spatial citizens. By implementing the proposed strategy as part of the teaching and learning process, Geography students will be adequately prepared to participate in responsible decision-making processes through the critical use of GSTs, as suggested by Bednarz (2019). The proposed strategy will also ensure that lecturers will be able to successfully teach the next generation of spatial citizens, established through the teaching of a brand of Geography that includes spatial thinking competencies at an adequate level to ensure practical applications in real-world contexts (Ibid).

7.7 Reflections on the proposed strategy for improving spatial thinking

Despite the importance of spatial thinking, this concept does not, unfortunately, receive the same attention as numerical and reading skills (Goodchild & Janelle, 2010). It has been proved that Geography is a suitable subject for promoting the spatial thinking skills of students (Verma & Estaville, 2018). This research calls on universities to attend to this gap in the importance attached to *versus* the attention given to spatial thinking in education, with an increased emphasis on the importance of Geography and the role it can play in the development of students' spatial thinking skills. This thesis calls for a review of learning outcomes; the way in which module content is conveyed to students; and assessment questions to foster the improvement of spatial thinking in undergraduate Geography in South Africa. A strategy that can be used to successfully implement and foster spatial thinking in undergraduate Geography in South Africa is proposed.

This chapter integrated the findings of Chapters 4, 5 and 6, leading to the formulation of a strategy for the successful implementation and fostering of spatial thinking. This proposed strategy drew on information collected through interviews with lecturers from participating departments, various applications of the taxonomy of spatial thinking, the questionnaire to gauge the disposition of lecturers to teach spatial thinking and the STAT. The data were analysed, and the findings were fed into the proposed strategy. The methodological framework employed, namely, the AQAL model, allowed for the strategy to be based on data collected through known instruments and analysed through statistical methods, the views and experiences of the interviewed lecturers, thematic analyses and the experience of the researcher.

This chapter demonstrated how Objectives 1, 2 and 3 of the thesis were achieved and how the findings were fed into the proposed strategy. The findings indicate that spatial thinking is currently not well integrated into the outcomes and assessment questions of modules. Despite this limited integration of spatial thinking, the way in which module content is conveyed to students does indeed include a measure of spatiality; furthermore, the lecturers are generally well disposed to teaching spatial thinking. However, the spatial thinking skills of students were gauged to be low.

Spatial thinking skills should be formally taught to students (National Research Council, 2006; Collins, 2018b). To this end, an adapted problem-solving process with generic steps is proposed. The problem-solving process could be used by students to address challenges and should foster the development of a SHOM. It is also recommended that SPBL be employed in conjunction with GSTs as tools of representation.

Examples of developmental paths for developing module outcomes, the way in which module outcomes are conveyed and assessments with a high spatiality are proposed. It is also recommended that the disposition questionnaire be completed by current lecturers to identify misconceptions and/or shortfalls that may hinder the successful implementation of spatial thinking. The disposition questionnaire could also be used to inform questions when interviewing potential lecturers for employment.

The successful implementation of spatial thinking in Geography teaching depends on a department's concerted efforts and the lecturers' positive disposition towards spatial thinking. The proposed strategy to improve spatial thinking in undergraduate Geography embodies a circular process. To commence, spatial thinking should be included in the curriculum planning phase when module outcomes are defined. The spatiality of the module outcome should align with the considerations for module development, and the spatiality of the way module content is conveyed to students by the lecturers and through assessment questions. Central to the process is the taxonomy of spatial thinking and the STAT that should be used to assess the spatiality of the pedagogy being used and to inform the compilation of assessment questions that will support the development of the spatial thinking skills of students. Since there is no all-encompassing way of teaching Geography (Metoyer & Bednarz, 2017), the proposed strategy allows for each lecturer to convey content according to his/her preferences and teaching style. By employing this strategy, students will be suitably equipped to become spatial citizens to address complex challenges within an ever-changing world.

The next chapter, Chapter 8, concludes this thesis by discussing the value of this research and its contribution to the body of knowledge of improving spatial thinking in undergraduate Geography, as well as the value of the methodological framework applied in this research. Also, the recommendations and further research topics emanating from this research are presented in a summarised format.

Chapter 8: Recommendations and Conclusions

8.1 Introduction

Although various factors should be considered and included when reviewing, redeveloping or developing new Geography curricula, the importance of spatial thinking cannot be over-emphasised. The call by Johnson (1997) more than 27 years ago for the inclusion of spatial thinking in the Geography curriculum is still just as relevant today (Metoyer & Bednarz, 2017; Bednarz, 2019; Nursa'Ban et al., 2020). In this regard, Alderman (2018) proposes a new radical Geography curriculum that will enable students to solve societal problems, while Bednarz (2019) emphasises that the inclusion of spatial thinking in curricula will bring Geography modules closer to such a radical curriculum.

This research highlights the importance of developing the spatial thinking skills of undergraduate students in South Africa when teaching Geography while pointing towards several shortcomings in the *status quo* and providing a strategy for improvement. The available literature on spatial thinking was reviewed and summarised to serve as a benchmark and to inform this research. The research was based on the existing spatial thinking tools for collecting data to ultimately present spatial thinking in undergraduate modules in selected Geography departments at South African universities from various angles. The data were analysed and interpreted, thus informing the development of a strategy that will foster the development of spatial thinking skills in students enrolled for undergraduate Geography modules at South African universities and which will, in turn, enable students to solve complex problems in an ever-changing world.

This final chapter focuses on making recommendations to promote the inclusion of spatial thinking in Geography modules currently offered at the selected universities in South Africa and in new modules still to be developed. These recommendations are followed by a discussion on the limitations of this research, a reflection on the significance of this research, and suggestions for further research on this critical topic. Finally, the chapter concludes with reflections on applying the AQAL approach of Integral Theory as a methodological framework for this research.

8.2 Recommendations

Geography education should offer discipline-specific capabilities such as spatial thinking (Walkington et al., 2017); therefore, lecturers at South African universities should recommit to their vision of including spatial thinking as an integral part of Geography curricula. The following subsections explain the recommendations regarding spatial thinking that should be considered for implementation when teaching Geography modules. The recommendations are based on the achievement of the four objectives of this thesis and are discussed accordingly.

8.2.1 Recommendation 1: Module outcomes and descriptions

Module descriptions and outcomes should be worded in such a way that they indicate that spatial thinking forms part of the curriculum. It should, therefore, be considered to include keywords and/or phrases directly referring to spatial thinking in module descriptions and outcomes (e.g., references to the solving of problems, the application of various scales, the evaluation of spatial data, and interpretations and interrelationships, to name but a few). Such inclusions could serve as pointers showing that the modules in question deal with the concept of spatial thinking.

Module outcomes propose the exit level that students, having achieved a high level of proficiency in their spatial thinking ability, should have reached at the end of a teaching semester. While it is possible to achieve such outcomes in the cases where the three components of spatial thinking have been integrated in the module teaching and content, this research determined that this integration features in a rather limited way in the module outcomes of the participating South African Geography departments. Module outcomes should provide a clear path from NQF levels 5 to 7 towards the development of the spatial thinking skills of students, be defined on a high cognitive level and include complex concepts of space and representation tools. This research determined that representation tools are largely lacking in the module outcomes defined by the participating departments. More attention should, therefore, be paid to including such tools in the module outcomes, which should help improve the spatiality of those outcomes. The inclusion of the concepts of space in the module outcomes should be regarded as a necessity for providing students with the opportunity to develop their spatial thinking skills from NQF levels 5 to 7 in the case of Geography modules oriented towards spatiality.

The development of module descriptions and outcomes should be approached as a concerted effort at departmental level to ensure that the outcomes reach the desired level of spatiality and that the spatiality of modules on the same NQF level is aligned. The spatiality of module outcomes should also provide a developmental path to achieve higher levels of spatiality with higher NQF levels.

Lastly, it is recommended that the current module descriptions be reviewed to align with the above recommendations, even if it means that the modules need to be re-accredited by SAQA. This will allow departments to align the spatiality of their existing modules per NQF level and ensure that a developmental path is created for improving students' spatial thinking skills. It is suggested that the departments should also redefine the spatiality of the outcomes of the modules being offered to align with the spatiality of the presentation of the module content as it is conveyed to the students.

8.2.2 Recommendation 2: Conveying module content and determining the disposition of lecturers

The inclusion of spatial thinking in the way in which module content is conveyed to students should also be considered from the outset when a new module is developed redeveloped or reviewed. However, this planning should be in the students' interests and should focus on methods that will improve their employability and spatial thinking skills.

This research has found that according to the lecturers interviewed, spatial thinking has already been incorporated into the way in which module content is conveyed to the students and that the *status quo* in this regard should be retained. In addition, the interviewed lecturers are in agreement that the underlying foundational knowledge of Geography should not be neglected (Bednarz, 2019), and that Geography teaching should also move beyond the mere memorisation of facts (National Research Council, 2006; Jo & Bednarz, 2011; Ishikawa, 2013) and find applications in space (Bednarz, 2019). This can be achieved by employing SPBL as a teaching method, as proposed by Silviarizaand Handoyo (2021). During the interviews with the lecturers, it became clear that SPBL is indeed being applied as a teaching method by virtually all of them; in fact, they recommended that this method be maintained and developed further. However, more direct teaching in spatial thinking is needed for students to develop a SHOM (Bednarz & Bednarz, 2008): — they should be provided with a problem-solving method. (A problem-solving approach is proposed in Section 7.4.1.)

Departments should guard against creating and retaining modules with no prerequisites and should discourage rote learning – especially on the higher NQF levels. Modules without prerequisites should be awarded sufficient notional hours to ensure that the desired depth in spatial thinking be reached in the teaching content. Geography departments should continuously consider the level of spatiality at which modules are developed and taught to ensure that the level of spatiality and the ways in which the module content is conveyed aligns with the level of spatiality of both the module outcomes and the module assessments.

While various representation tools are included in the way in which module content is conveyed to students, the increased use of GSTs should also be considered. In fact, the use of modern GSTs distinguishes Geography from other disciplines and improves students' employability. The application of outdated technologies to convey content to students should, therefore, be limited and carried out in such a way that students are exposed to and familiarise themselves with the latest GSTs available. Departments should also be careful not to teach GSTs as a stand-alone tool but should instead infuse these technologies in modules across the board to foster spatial thinking among their students. Lecturers should also be exposed to regular training sessions to stay abreast of the latest technological developments. This will also ensure that lecturers remain confident in their use of GSTs when conveying module content to students.

The positive disposition of lecturers in respect of their teaching of spatial thinking is commendable. Geography departments should maintain this position by encouraging all current lecturers to complete the disposition questionnaire. The departments should also ensure that new lecturers are well disposed to teaching spatial thinking. The disposition questionnaire could, for example, also be used to inform the questions asked during interviews and identify the misconceptions that interviewees might have regarding spatial thinking. Current lecturers should also be encouraged to complete the disposition questionnaire to identify any misconceptions that they might have. Appropriate steps can then be taken to address these gaps.

8.2.3 Recommendation 3: Spatiality of assessment questions and the spatial thinking ability of students

Assessment questions should be carefully compiled to include all three components of spatial thinking. Although this research found that lecturers find it challenging to integrate the three components of spatial thinking in assessment questions for the modules which they create and present, this skill can be developed by using the taxonomy of spatial thinking as a guideline. Lecturers must pay attention to pitching questions at an appropriate cognitive level, incorporating a relevant concept of space and using representation tools. This research found that in most instances, assessment questions are pitched at a low cognitive level that does not foster the development of students' spatial thinking skills. Lecturers should also ensure that concepts of space are used at an appropriate level when they formulate questions, and their answers should be assessed accordingly. Assessment questions often encourage students to consider sentence structure and grammar instead of focusing on the correct spatial concepts and geographical terminology when answering such questions. The correct use of spatial concepts will further contribute to the development of a SHOM. Where possible/appropriate, representation tools should be used when formulating assessment questions. Students should also be encouraged to use representation tools such as graphs, flow charts and maps whenever possible in their responses to assessment questions and should be graded accordingly (i.e., penalised should the question lend itself to the application of such tools, but which they then decide not to use).

This research identified that the overall level of integration of the three components of spatial thinking in the assessment questions under scrutiny was low. It is recommended that an effort be made to increase the spatiality of assessment questions in the case of both formative and summative assessments. This should also be the case for modules focusing on Geospatial applications, for which the level of integration of the three components of spatial thinking is not always necessarily as high as one would expect it to be.

Better alignment between the spatiality of assessment practices, the module outcomes and the way in which the module content is conveyed to students should be sought. This research found that the spatiality of assessment questions demonstrates no clear developmental path for the students from NQF Level 5 to NQF Level 7. This issue should be discussed on a departmental level to facilitate the alignment of all modules with a spatial focus to ensure that a developmental path is laid down, not only within the modules but also for the students to progress through the respective NQF levels. In fact, the taxonomy of spatial thinking could be used as a guideline to align this developmental path.

Assessment questions could also be based on the STAT and which can be used to identify the strengths and weaknesses in students' spatial thinking abilities. Lecturers could develop teaching material and additional exercises to address such weaknesses in the students' spatial thinking skills and to further improve their spatial thinking abilities. The results of this research concur with those of Beets (2007), who calls for a reflection on assessment practices in South African Geography teaching – and proves the necessity of considering the spatiality of assessment questions within the South African context.

8.2.4 Recommendation 4: A strategy for improving spatial thinking

Geography lecturers should become experts in developing students' spatial thinking skills ─ to equip them to think creatively and critically about their communities and the world. Lecturers should be allowed to convey Geography content according to their personal teaching preferences but, from the outset, they should include spatial thinking when designing Geography curricula, formulating outcomes and developing modules and assessment questions. These practices can be achieved by implementing the strategy for developing spatial thinking skills as proposed in this thesis. The successful implementation of the strategy to improve spatial thinking in undergraduate Geography depends on a concerted effort at departmental level and a positive disposition prevailing among lecturers regarding the incorporation of spatial thinking in their teaching.

The respective spatialities of the curriculum, module outcomes, module development, and the ways in which module content and assessment questions are conveyed, must be effectively aligned. If this alignment is not maintained at an appropriate level of spatiality, the spatial thinking skills of students may not develop adequately. To ensure the successful implementation of the strategy to improve these skills, the taxonomy of spatial thinking and the STAT should be used to inform the teaching and assessment processes.

It is recommended that departments of Geography attend to and commit to improving students' spatial thinking skills through appropriate Geography teaching. Geography teaching methods should be reviewed according to the strategy proposed in this thesis to improve spatial thinking in undergraduate Geography and thus foster students' spatial thinking skills.

Using the strategy for improving spatial thinking will ensure that students are appropriately equipped to become credible spatial citizens and make informed decisions through the critical use of GSTs.

8.3 Limitations of this research

This section highlights the limitations of this research. However, owing to the lack of research in spatial thinking on the African content and within the South African context, the contributions made by this research to the field of spatial thinking by far outweigh the limitations.

Some of the module descriptions of the participating Geography departments were not available on their web pages. Since the module descriptions on these web pages were initially scrutinised to gauge whether spatial thinking could potentially be included in curricula, it is possible that departments that could have made a significant contribution to the research might have been overlooked. Despite this possible oversight, enough departments eventually participated in this research to ensure that sufficient information could be collected to obtain a comprehensive view of practices in departments to support the development of the strategy for the improvement of spatial thinking in undergraduate Geography. Since some of the Geography departments offered more modules than were required for inclusion in the research, those specific modules that would contribute most effectively to the research could then be selected. This further minimised the possibility of excluding modules that could make a valuable contribution.

This research assumed that all module outcomes have an equal number of notional hours. This may not be an accurate reflection of reality, however. Nevertheless, regardless of the notional hours per individual module outcome, a high level of spatiality for the module outcomes per NQF level should be expected, with an increase from NQF Level 5 to NQF Level 7.

In some instances, it can be argued that the evaluation of module outcomes and assessment questions was subjective and based on the researcher's experience. However, the methodological framework allowed for an outside subjective perspective based on experience, and in this context, a different researcher may have had different views or experiences in teaching Geography and its related fields. Nevertheless, it is envisaged that the results obtained by a different researcher would not differ significantly from the results of this research as the instruments used to collect the information have been tested, are reliable and imply that researchers would follow the same procedures and consider the same variables, thus increasing the probability of similar results.

The role of other subjects that students might be registered for such as the Arts, Dance, Mathematics, Physics and Computer Science, and that might influence their spatial thinking skills were not considered. Other variables that may influence individuals' spatial thinking skills, such as socio-economic background, cultural background, demographic attributes, ethnicity, travel experiences and language, were also not considered. Since only a few researchers are currently focusing on the field of spatial thinking, the influence of these disciplines and variables has not yet been determined and has also not yet been considered by other researchers.

Yet another limitation of this research concerns the inclusion of questions for both the formative and the summative assessments. The information received from the participating lecturers in respect of the assessment questions was inconsistent for three reasons. Some lecturers did not have a full record of assessment questions for the three years covered by this research (2019-2021). Furthermore, the number of formative assessments and how they are conducted differed between departments and even within the same department. Also, one lecturer did not submit any assessment questions. However, a large number of assessment questions (2 231) were included in this research and evaluated against the taxonomy of spatial thinking. Thus, valuable information on the *status quo*, as well as overall trends, could be obtained.

The response by students to the STAT was low. Thus, the results cannot be regarded as representative of the Geography departments that formed part of this research; neither can they be considered as representative of all Geography departments at South African universities. However, the results could be used to successfully demonstrate how the STAT makes it possible to identify weaknesses in students' spatial thinking abilities and to formulate strategies to address these weaknesses.

This research focuses on Geography departments at South African universities, and as such, no international benchmarking was conducted. However, very few research articles focus on spatial thinking on the African continent, and even fewer are available for the South African context specifically. This thesis thus provides a benchmark for further research on spatial thinking at university level in South Africa and the rest of Africa and for comparative studies on the international front.

8.4 Reflections on the significance of this research

This research recognises the importance of spatial thinking and supports its inclusion as part of the undergraduate Geography curriculum at tertiary institutions, as promulgated by various researchers (National Research Council, 2006; Lee & Bednarz, 2012; Bearman et al., 2016; Jo et al., 2016; Collins, 2018a; Collins, 2018b; Walkington et al., 2018; Bednarz, 2019). Almost 20 years ago, the National Research Council (2006) observed that spatial thinking at educational institutions in the USA in general is 'under taught and under recognised'. This research confirmed that spatial thinking has still not been sufficiently incorporated into the Geography modules that formed part of this research.

As mentioned in Chapter 1 of this thesis, those researchers interested in the field of spatial thinking are few and far between and generally include only a small number of specialised individuals who could contribute to creating opportunities for further research in this field (National Research Council, 2006; Bednarz & Bednarz, 2008; Jo & Bednarz, 2009; Verma, 2015). To the knowledge of this researcher, none of the mentioned researchers is from the African continent or, specifically, from South Africa. The absence of researchers from Africa that are working on spatial thinking might partially be the reason why only a few African research projects on this topic have been conducted and reported upon thus far, with none from South Africa. This research fills this gap in that it focuses on Geography Departments at South African universities.

This research has further contributed to the field of spatial thinking by determining the *status quo* regarding the level of inclusion of spatial thinking in undergraduate Geography at selected Geography departments in South Africa. The findings of this research confirmed that undergraduate modules of participating Geography departments at South African universities have fallen short in their quest to teach spatiality and improve the development of spatial thinking. The shortfall in including spatial thinking in undergraduate Geography has also been reported in international studies conducted in countries such as the USA, Indonesia and Ethiopia. Therefore, this research has made a unique contribution to the teaching and learning of Geography in that it has proposed a strategy to improve spatial thinking in undergraduate Geography modules.

8.5 Further research

Despite the proven importance of spatial thinking, scholars who are interested and active in this field of research are few. The literature review for this research indicated that most of the published material on this topic focuses on universities in the USA, with only a few publications on school learners or undergraduate students from Africa. Furthermore, the literature review for this thesis showed that research on spatial thinking within the South African context is largely lacking. As such, South Africa offers ample opportunities for further research on this topic. Such research could include comparative studies to find common ground and compare the challenges experienced in South Africa with those experienced by international universities and other universities in Africa.

Most of the recently published research on this topic focuses on best practices for teaching spatial thinking and setting up assessments, while students' preferences in terms of how they learn spatial thinking are largely ignored. More research is therefore needed to determine the perceptions of undergraduate students as to their preferred types of teaching practices and assessment methods for the incorporation of spatial thinking into their learning ethos. To stay in line with developments within those industries employing Geography graduates, further research on this topic should, therefore, also contribute to improving students' employability.

While some of the published research in other countries touches on the association between aspects of spatial thinking and factors such as race, gender, and the rural or urban background of students/learners, more research on this topic is needed in countries such as South Africa and other African countries experiencing spatial and social-economic disparities. For example, Tomaszewski et al. (2015) found a significant difference between the spatial thinking skills of learners from rural and urban schools in Rwanda. More such research is needed to identify such differences and to design and implement appropriate teaching strategies that will foster the spatial thinking skills of school learners and undergraduate students in Geography. No publications could be found on research pertaining to the association between students' spatial thinking skills and their cultural background, demographic attributes, ethnicity, socio-economic background, travel experiences, language, and academic background (Verma & Estaville, 2018).

A more extensive research project to gauge the spatial thinking abilities of undergraduate Geography students at all South African universities should be conducted. Such a research project should include a significant number of students to ensure that the results are representative of students enrolled for Geography modules at South African universities.

The proposed developmental path within assessments should be further investigated to determine whether it would be best to increase the levels of spatiality within each formative and summative assessment or whether there should be a gradual increase in the level of spatiality of assessment questions as the semester progresses. It is also essential to distinguish between the levels of spatiality of formative and summative assessments to ensure that there is indeed an increase in the spatiality of the questions included in the summative assessments.

This research provides the foundation for similar research at school level to develop appropriate strategies for the development of the spatial thinking skills of primary and secondary school learners. Such research could also be extended to include those individuals currently employed in the geospatial and geographically aligned industries. It could be expected that such employees should have well-developed spatial thinking abilities. However, it would be interesting to determine whether there are any associations between their fields of expertise, such as programming, spatial analysis, systems development, etc., their level of appointment, their number of years of experience and their spatial thinking abilities.

8.6 Reflection on using the AQAL model as a theoretical framework

The AQAL model is grounded in Integral Theory and provides a framework for a holistic approach to conducting this research. Integral Theory has previously been successfully implemented and used in an educational context by Davis (2019b), Murray (2009) and Pretorius (2017). This research confirms the relevance of the AQAL model of Integral Theory for application within the educational context.

This research was based on qualitative and quantitative data. Three of the quadrants of the AQAL model informed the methodology used in the research. The first quadrant is the UR quadrant of the AQAL model. It allows for an objective view and the collection of information using developed instruments, such as the taxonomy of spatial thinking, the disposition questionnaire and the STAT. In fact, the practical value of the AQAL model was demonstrated when it became clear that the evaluation of the module outcomes and assessment questions against the taxonomy of spatial thinking was not always a well-defined process.

The interpretation of the spatiality of some module outcomes and assessment questions was partially based on the subjective view of the researcher and thus located in the UL quadrant of the AQAL model. However, this was complemented by the objective methodology followed in the UR quadrant, where most of the collected data could be statistically analysed and the results used to inform the strategy for improving spatial thinking.

The UL quadrant of the AQAL allows for the incorporation of the subjective views of the participants in this research, as well as those the researcher. As such, they provide added depth to the level of analysis and the value and impact of the results. Interviews were conducted with the lecturers to obtain insights into the ways in which they convey geographical content to their students. Through a subjective view, these participants shared their experiences and personal preferences when conveying Geography content to students. The interviews were conducted from the inside perspective of the lecturer.

The UL quadrant also allowed the researcher to interpret the responses to the interviews and to use ATLAS TI to analyse the information, further based on her experience as a tertiary educator from an outside perspective.

The third quadrant of the AQAL model that informed the methodology for this research is the LL quadrant, where an inter-subjective view is at stake, with participants providing their views on the proposed strategy in the context of a group session. All the results obtained through the analysis of the collected information were fed into the strategy for improving spatial thinking. Focus group discussions were then conducted to obtain mutual resonance and finalise the proposed strategy.

For the purposes of this research, the respective NQF levels are represented in terms of the respective levels of the AQAL model. The taxonomy of spatial thinking is represented by the lines of the AQAL model which also demonstrate the respective levels of complexity. The disposition of the lecturers with respect to the inclusion of spatial thinking in their teaching are represented by the respective states of the AQAL model, while the application field of modules is consistent and representative of the different types of applications. By incorporating all levels, all lines and the full range of elemental types, the AQAL model was instrumental in ensuring that this research reached the required level of profundity and was inclusive of all relevant perspectives.

8.7 Conclusion

The findings of this research correspond with those of Goodchild and Janelle (2010), who expounded on the fact that spatial thinking should be accorded the same level of interest in education as reading, writing and numerical skills. In the case of Geography, in addition to the other skills mentioned, emphasis should be placed on the teaching and learning of spatial thinking.

Research on spatial thinking is limited, especially on the African continent and specifically in South Africa. The extensive literature review conducted for this research makes it clear that only a few researchers are contributing to this critical field of Geography.

This research determined that spatial thinking is mainly lacking in the selected Geography modules of the participating departments. This thesis aimed to address this shortcoming in Geography teaching and learning by developing a strategy for improving spatial thinking in undergraduate modules. The aim of the research was achieved by incorporating the results obtained through the three objectives into a strategy for improving spatial thinking in undergraduate Geography at South African universities.

Through the achievement of the objectives, this research proved that while spatial thinking is included in the teaching of Geography modules, integrating the three components of spatial thinking is mainly lacking in the module outcomes, especially when the revision, redevelopment or development of new modules and assessment questions is considered. The integration of the three components of spatial thinking is limited, primarily owing to the lack of incorporating representation tools.

This thesis calls for universities to implement the strategy for improved spatial thinking as part of undergraduate Geography curricula and recommit to teaching spatial thinking to undergraduate students. In doing so, students will be empowered to become worthy spatial citizens and to make informed decisions in an ever-changing world.

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Annexure A – Ethics approval

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 28/11/2023

Dear Ms Carow

NHREC Registration # : REC-170616-051
REC Reference # : 2019/CAES_HREC/184
Name : Ms S Carow
Student #: 66140463

Decision: Ethics Approval Confirmation after Fourth Review from 01/12/2019 to 30/11/2024

Researcher(s): Ms S Carow
sanetpc@unisa.ac.za

Supervisor (s): Prof R Pretorius
pretorw@unisa.ac.za; 011-471-3680

Working title of research:

A strategy for the improvement of spatial thinking in undergraduate Geography at South African universities

Qualification: PhD Geography

Thank you for the submission of your yearly progress report to the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is confirmed to continue for the originally approved period, subject to submission of yearly progress reports. **Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

Due date for next progress report: 30 November 2024
The progress report form can be downloaded from the college ethics webpage:
https://www.unisa.ac.za/sites/corporate/default/Colleges/Agriculture-&-Environmental-Sciences/Research/Research-Ethics

*The **minimal risk application** was originally **reviewed** by the UNISA-CAES Health Research Ethics Committee on 28 November 2019 in compliance with the Unisa Policy on*

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Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **2019/CAES_HREC/184** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

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Annexure B – Interview guide

PARTICIPANT INFORMATION SHEET

Ethics Clearance reference number: REC-170616-051
Research Permission reference number: 2019/CAES_HREC/184

<Insert date>

Title: A model for the improvement of spatial thinking in undergraduate Geography at South African universities

Dear Prospective Participant

My name is Sanet Carow and I am doing research under the supervision of Prof. Rudi Pretorius, of the Department of Geography, towards a PhD in Geography at the University of South Africa. We invite you to participate in a study entitled: "A model for the improvement of spatial thinking in undergraduate modules at South African universities".

I am conducting this research to determine the manner in which spatial thinking is included in Geography modules in undergraduate studies at South African universities.
Since you are a Geography lecturer at a South African university, you are invited to participate in this study. The module that you offer has been perused, and initial research indicated that spatial thinking may be incorporated in the module that you offer. This interview forms part of a more extensive study that includes eight other South African universities. Your contact details were obtained from the chair of your department.

This study involves interviews with Geography lecturers and will be based on questions identified and informed by a literature review on spatial thinking. These questions will help me determine your disposition towards teaching spatial thinking, personal experiences in presenting this module in a specific way and the methods you are using to convey the module content to your students. The interview should not take longer than 45 to 60 minutes.

Participating in this study is voluntary, and you are under no obligation to consent to participate. If you decide to participate, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and need not provide a reason.

Participation in the interview will contribute towards a model for the improvement of spatial thinking in undergraduate modules at South African universities.

We do not foresee that you will experience any negative consequences by completing this survey. The researchers undertake to keep any information provided herein confidential, not to allow it out of our possession, and to report on the findings from the participating group's perspective and not from the perspective of the individual. The names of the universities participating in this study will not be divulged.

Your answers may be reviewed by officials, namely members of the Research Ethics Review Committee, who are responsible for ensuring that the research is conducted properly. Otherwise, unless you give permission for other people to see the records that identify you, these will be available only to those people working on the research. Information collected during this project may be used for other peer-reviewed articles or for conference proceedings.

The researcher will store hard copies and electronic copies of your answers for a period of five years in a locked cupboard/filing cabinet in her office for future research or academic purposes; electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to a further Research Ethics Review and, if applicable, approval. After five years, all hard copies will be shredded, and the electronic copies of information will be deleted from the computer's hard drive.

You will not be reimbursed or receive any incentives for your participation in this survey.

This study has received written approval from the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. If you so wish, a copy of the approval letter can be obtained from the researcher.

If you would like to be informed of the final research findings, please contact Sanet Carow on 011 471 2011 or email sanetpc@unisa.ac.za. The results are accessible until 2024.

Should you require any further information or would like to contact the researcher about any aspect of this study, please contact Sanet Carow on 011 471 2011 or email sanetpc@unisa.ac.za. Should you have concerns about the way in which the research has been conducted, you may contact Prof. Rudi Pretorius on 011 471 3680 or email pretorw@unisa.ac.za, if you have any ethical concerns, please contact the research ethics chairperson of the CAES General Ethics Review Committee

Thank you for taking the time to read this information sheet and for participating in this study.

Sanet Carow

Interview with lecturers

University: ____________________

Module: ____________________

NQF level: ____________________

Section 1: Background questions

1. How long have you been teaching this module?

2. Do you or did you teach any other Geography modules?

3. How often do you review/update/revise the modules that you offer?

4. When last did you develop this module or any other module from scratch?

5. If you were to develop this module or a similar module from scratch, what would be the thought process that you would follow?

Section 2: Indirect questions to determine whether spatial thinking is included in the course content or when presenting lectures

6. Which methods do you use to convey the content of this module to students?

   a. If you use a PowerPoint presentation to convey the content of this module to students, do you make the PowerPoint presentations available to the students?

7. What do you mainly use in your method of presentation when you convey the content of this module to your students?

1. Globes	
2. Graphs	
3. GIS	
4. Maps	
5. Sketches	
6. Diagrams	
7. Flow charts	
8. Images	
9. Models	
10. Virtual Globes	
11. Other	

12. If none of the above tools is incorporated, give reasons why you do not make use of such tools?

13. If you prefer to use a blackboard, what would you typically write/draw on the board?

1. Illustrations/sketches of systems	

2. Graphs	
3. Key words	
4. Flow charts	
5. Other	

- Illustrations/sketches of systems
- Key words
- Graphs
- Flow charts

14. Would you say that your teaching of this module is mainly factual or based on scenarios?

a. If scenarios are used, how many scenarios would you typically use to explain the content to students?

b. If you use scenarios to explain the course content to students, do you encourage students to participate in the discussion or is the scenario discussed by only yourself?

c. Do you use a real-world scenario or a fictional scenario?

d. Do you lead the students to come up with solutions for the specific scenarios or are you the main one proposing the solutions yourself?

e. Do you think your students find it difficult to apply knowledge in different scenarios?

f. Give a reason for your answer.

15. If you use scenarios in your teaching, do you try to teach the students a problem-solving approach?

    a. If yes, do you teach them specific steps for problem-solving?

16. Do you explain the content of this module using different geographic scales (e.g. the local scale, the provincial scale, the global scale), or do you make the students aware of geographic scales in a geographic environment?

17. Is this module in line with the latest technologies used by the experts in your knowledge domain?

a. Name three of the latest technologies used by the experts in your knowledge domain. Do you use any of these technologies in your teaching and learning?

b. Do you use any technologies that are outdated?

c. Is there a specific reason why you still use these technologies?

Section 4: Direct questions to determine whether spatial thinking is included in the course content or when presenting lectures

18. Are you familiar with the concept of spatial thinking?

19. What do you consider to be spatial thinking?

Annexure C - Disposition towards spatial thinking

UNISA university of south africa

Survey on spatial thinking

Dear Prospective Participant,

Ethics Clearance reference number: REC-170616-051
Research Permission reference number: 2019/CAES_HREC/184

You are invited to participate in a survey conducted by Sanet Carow, under the supervision of Prof Rudi Pretorius of the Department of Geography, towards a PhD degree at the University of South Africa.

The survey form that you have received has been designed to promote the study of spatial thinking abilities in students at South African universities. You were selected to participate in this survey because you are a lecturer on NQF level 5, 6 or 7 and initial research indicated that spatial thinking is included in the module that you offer. By completing this survey, you agree that the information you provide may be used for research purposes, including its dissemination through peer-reviewed publications and conference proceedings.

It is anticipated that the information we gain from this survey will help us to determine the spatial thinking abilities of students at South African universities. You are, however, under no obligation to complete the survey and you can withdraw from the study prior to submitting the survey. The survey has been designed to be anonymous, meaning that we will have no way of connecting the information that you provide to you specifically. Consequently, based on the anonymous nature of the study, you will not be able to withdraw from the study once you have clicked the "send" button.

If you choose to participate in this survey, it will take up no more than 10 minutes of your time. You will not benefit from your participation as an individual. However, it is envisioned that the findings of this study will contribute towards a model for the improvement of spatial thinking in undergraduate Geography modules in South African universities.
We do not foresee that you will experience any negative consequences by completing this survey. The researchers undertake to keep any information provided herein confidential, not to allow it out of their possession, and to report on the findings from the perspective of the participating group and not from the perspective of the individual.

The records will be kept for five years for audit purposes where after they will be permanently destroyed. The electronic survey will be permanently deleted from the hard drives of all the involved computers. You will not be reimbursed or receive any incentives for your participation in this survey.

The research was reviewed and approved by the CAES General Ethics Review Committee. The primary researcher, Mrs Sanet Carow, can be contacted during office hours at 011 47 2071. The study leader, Prof. Rudi Pretorius, can be contacted during office hours at 011 471 3680. You can report any serious unethical behaviour to the University's Toll-free Hotline number at 0800 86 96 93.

By advancing to the next page, you are making a decision to participate or not. You are at liberty to withdraw from the study at any time prior to clicking the "send" button.

1. I have read and understood the above and therefore:

- ◯ Give consent to participate in this survey.
- ◯ I am not interested in participating in this survey.

Next

Page 1 of 3

UNISA

Survey on spatial thinking

...

* Required

Section 1

2. Please indicate your answer on the Likert scale provided *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	I do not know
I believe that spatial thinking skills can be taught	○	○	○	○	○	○
I believe that thinking skills should be taught.	○	○	○	○	○	○
Developing students' thinking skills is my highest priority goal.	○	○	○	○	○	○
I feel satisfied when students remember exactly what I have said.	○	○	○	○	○	○
I frequently challenge students through questions and tasks.	○	○	○	○	○	○
I show students how I think through a problem rather than just providing a final answer.	○	○	○	○	○	○
I ask students to provide explanations and reasons to support their answers.	○	○	○	○	○	○
I know what spatial thinking is.	○	○	○	○	○	○
I believe that spatial thinking is powerful.	○	○	○	○	○	○
I believe that spatial thinking is integral to everyday life and the workplace.	○	○	○	○	○	○
I believe that spatial thinking is a skill that is innate (natural, inborn).	○	○	○	○	○	○
I believe that spatial thinking skills can be taught.	○	○	○	○	○	○

I believe that spatial thinking should be taught at the tertiary level.	○	○	○	○	○	○
I believe that geography is a collection of factual information.	○	○	○	○	○	○
I believe that geography is best learned by rote memorization of facts.	○	○	○	○	○	○
I believe that asking questions and solving problems is important in geography.	○	○	○	○	○	○
I believe that geography is the study of spatial aspects of human existence.	○	○	○	○	○	○
I believe that understanding spatial patterns and processes is essential in learning geography.	○	○	○	○	○	○
I believe that spatial thinking is an essential part of learning geography.	○	○	○	○	○	○

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UNISA

Survey on spatial thinking

* Required

Section 2

3. Question *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree	I don'tknow
I believe that knowing spatial concepts is essential in learning geography.	○	○	○	○	○	○
I explicitly teach the concept of location.	○	○	○	○	○	○
I explicitly teach the concepts of place and region.	○	○	○	○	○	○
I explicitly teach concepts of distance and direction.	○	○	○	○	○	○
I explicitly teach the concept of scale.	○	○	○	○	○	○
I explicitly teach the concept of overlay.	○	○	○	○	○	○
I explicitly teach the concepts of distribution and pattern.	○	○	○	○	○	○
I explicitly teach the concept of map projection.	○	○	○	○	○	○
I explicitly teach the concept of density.	○	○	○	○	○	○
I explicitly teach the concept of diffusion.	○	○	○	○	○	○
I explicitly teach the concept of spatial correlation.	○	○	○	○	○	○
I believe that using and creating spatial representations, such as maps, diagrams, and graphs, are essential for spatial thinking.	○	○	○	○	○	○
I believe that using and creating spatial representations are essential for learning geography.	○	○	○	○	○	○

I believe that students can readily interpret spatial representations without a guided practice.	○	○	○	○	○	○
I demonstrate to students how to reason using maps, diagrams, and graphs.	○	○	○	○	○	○
I frequently ask students to create their own spatial representations.	○	○	○	○	○	○
I believe that geospatial technologies, such as geographic information systems (GIS) and global positioning systems (GPS), are powerful tools for spatial thinking.	○	○	○	○	○	○
I believe that geospatial technologies are a powerful tool for learning geography.	○	○	○	○	○	○
I am familiar with the educational uses of geospatial technologies.	○	○	○	○	○	○
I demonstrate to students how geospatial technologies can be used to solve problems and make decisions.	○	○	○	○	○	○

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Submit

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Annexure D – Example questions from the spatial thinking ability test

UNISA university of south africa

Spatial thinking ability

Ethics Clearance reference number: REC-170616-051
Research Permission reference number: 2019/CAES_HREC/184

A model for the improvement of spatial thinking in undergraduate Geography at South African universities

Dear Prospective Participant,

You are invited to participate in a survey conducted by Sanet Carow, under the supervision of Prof Rudi Pretorius of the Department of Geography, towards a PhD degree at the University of South Africa.

The survey form that you are about to complete has been designed to determine students' spatial thinking abilities at South African universities. You were selected to participate in this survey because you are an NQF level 5 (first year), 6 (second year) or 7 (third year) student. By completing this survey, you agree that the information you provide may be used for research purposes, including its dissemination through peer-reviewed publications and conference proceedings. It is anticipated that the information we gain from this survey will help us determine students' spatial thinking abilities at South African universities.

However, you are under no obligation to complete the survey, and you can withdraw from the study prior to submitting the survey. The survey has been designed to be anonymous, meaning that we will have no way of connecting the information you provide specifically. Consequently, based on the study's anonymous nature, you will not be able to withdraw from the study once you have clicked the "send" button.

If you choose to participate in this survey, it will take up no more than 40 minutes of your time. You will not benefit from your participation as an individual. However, it is envisioned that this study's findings will contribute towards a model for the improvement of spatial thinking in undergraduate Geography modules in South African universities.
We do not foresee that you will experience any negative consequences by completing this survey. The researchers undertake to keep any information provided herein confidential, not to allow it out of their possession, and to report on the findings from the perspective of the participating group and not from the perspective of the individual.

The records will be kept for five years for audit purposes, where after they will be permanently destroyed. The electronic survey will be permanently deleted from the hard drives of all the involved computers. You will not be reimbursed or receive any incentives for your participation in this survey.

The research was reviewed and approved by the CAES General Ethics Review Committee. The primary researcher, Mrs Sanet Carow, can be contacted during office hours at 011 47 2071. The study leader, Prof. Rudi Pretorius, can be contacted during office hours at 011 471 3680. Alternatively, you can report any serious unethical behaviour to the University's Toll-free Hotline number at 0800 86 96 93.

By advancing to the next page, you are making a decision to participate or not. You are at liberty to withdraw from the study at any time prior to clicking the "send" button.

...

* Required

1

I have read and understood the above and therefore: *

○ Give consent to take part in this study

○ I am not interested in participating in this survey.

Next

UNISA

Spatial thinking ability

* Required

Tell us a little bit about yourself...

2

Gender

◯ Male

◯ Female

3

Do you plan or are in process of completing Geography module(s) to a third-year level *

◯ Yes

◯ No

◯ Maybe

4

Have you ever taken a Cartography or Geographic Information System (GIS), Remote sensing or Map reading course? *

◯ Yes

◯ No

5

I am currently studying Geography on a *

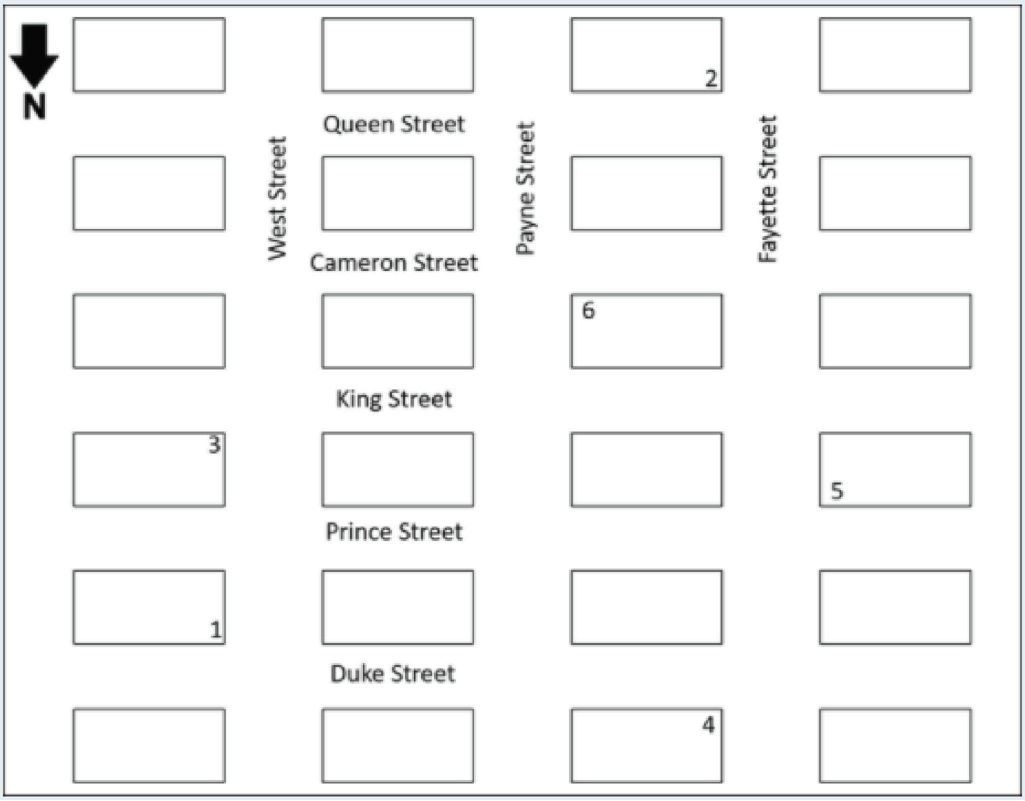
◯ first year level

◯ second year level

◯ third year level

Back   Next

Directions: Answer the questions on the basis of the street map below.



6

If you are located at point 1 and travel north one block, then turn west and travel three blocks and then turn south and travel two blocks, you will be closest to point:

- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6

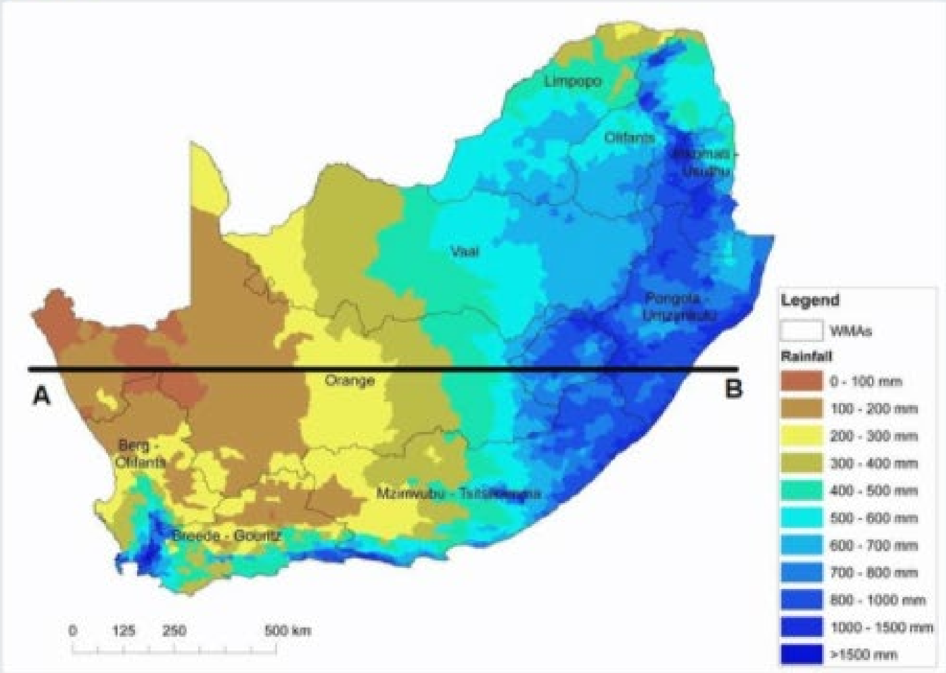
7

If you are located at point 1 and travel west one block, then turn left and travel three, then turn west and travel one block, and then turn right and travel four blocks, you will be closest to point:

- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

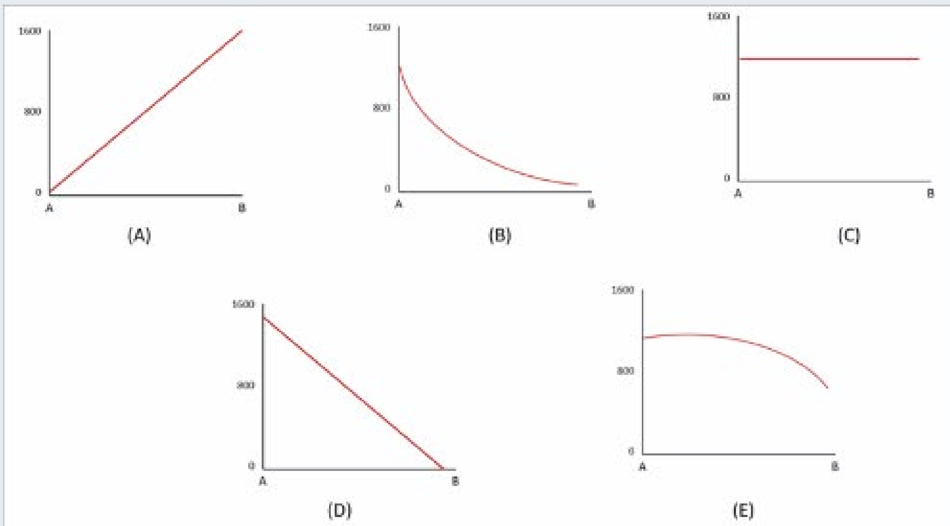
Direction: The map below shows annual precipitation of South Africa

Source:
https://www.researchgate.net/publication/321970658_Spatial_inequality_in_water_access_and_water_use_in_South_Africa



8

If you draw a graph showing the change in South Africa's annual rainfall between A and B, the line will be best represented by Graph :



- ◯ (A)
- ◯ (B)
- ◯ (C)
- ◯ (D)
- ◯ (E)

Annexure E – Permission to use STAT

Dear Sanet,

Please find the attached for two equivalent formats of the STAT and keys and hope that these will be helpful for your studies.

Best regards,

Jongwon

이종원, 교수
이화여자대학교 사회과교육과 지리교육전공
Jongwon Lee, PhD
Professor
Dept. of Social Studies Education (Geography)
Ewha Womans University, Seoul, South Korea
jongwonlee@ewha.ac.kr
Secretary, Commission on Geographical Education, IGU

On Tue, May 28, 2019 at 4:10 PM Sanet, Carow <sanetpc@unisa.ac.za> wrote:

Dear Dr Lee,

The article by yourself and Bednarz (2012), Components of Spatial Thinking: Evidence from a Spatial Thinking Ability Test, refers.

I am a lecturer at the University of South Africa (Unisa) at the Department of Geography. I am starting my PhD studies this year. The preliminary title for my study is: A model for the improved facilitation of critical spatial thinking in undergraduate Geography at South African universities.

To this end I would like to obtain permission to use the spatial thinking ability test developed by you and Prof Bednarz. I would also like to replace some of the questions with South African or African examples.

Will you be able to assist me in this regard or kindly direct to a person who will be able to assist?

Much appreciated

Best regards,

Sanet Carow

Lecturer

Department of Geography

University of South Africa

Annexure F - Outline of feedback sessions

PARTICIPANT INFORMATION SHEET

Ethics Clearance reference number: REC-170616-051
Research Permission reference number: 2019/CAES_HREC/184

<date>

A model for the improvement of spatial thinking in undergraduate Geography at South African universities

Dear Prospective Participant

My name is Sanet Carow and I am doing research under the supervision of Prof. Rudi Pretorius, of the Department of Geography, towards a PhD in Geography at the University of South Africa. We are inviting you to participate in a study entitled: “A model for the improvement of spatial thinking in undergraduate modules at South African universities”.

The purpose of this focus group is to provide you with feedback and the results of the abovementioned study. You have been invited to take part in this focus group since you previously took part in this study and provided me with the necessary documentation in the form of study material to collect invaluable information for this study.

Your involvement in this focus group is required for further feedback regarding the proposed model for the improvement of spatial thinking in undergraduate Geography at South African universities. Your feedback in this regard will enable me to adjust and rationalise the proposed model for the improvement of spatial thinking.

The study involves a focus group that will discuss the proposed model for the improvement of spatial thinking. During the focus group I will present the various identified models to you and you will be asked to identify possible pitfalls, challenges and short coming and to indicate your preferred model. The focus group should not take longer than 2 hours.

Participating in this focus group is voluntary and you are under no obligation to consent to participate. If you do decide to participate, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and need not provide a reason.

We do not foresee that you will experience any negative consequences by taking part in this focus group. The researchers undertake to keep any information provided herein confidential, not to allow it out of our possession, and to report on the findings from the perspective of the participating group and not from the perspective of the individual. The names of the universities participating in this study will not be divulged.

Your answers may be reviewed by officials, namely members of the Research Ethics Review Committee, who are responsible for ensuring that the research is conducted properly. Otherwise, unless you give permission for other people to see the records that identify you, these will be available only to those people working on the study. Information collected during this project may be used for other peer-reviewed articles or for conference proceedings.

Hard copies and electronic copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet in her office for future research or academic purposes; electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to a further Research Ethics Review and, if applicable, approval. After five years, all hard copies will be shredded, and the electronic copies of information will be deleted from the hard drive of the computer.

You will not be reimbursed or receive any incentives for your participation in this survey.

This study has received written approval from the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. If you so wish, a copy of the approval letter can be obtained from the researcher.

If you would like to be informed of the final research findings, please contact Sanet Carow on 011 471 2011 or email sanetpc@unisa.ac.za. The findings are accessible until 2024.

Should you require any further information or would like to contact the researcher about any aspect of this study, please contact Sanet Carow on 011 471 2011 or email sanetpc@unisa.ac.za. Should you have concerns about the way in which the research has been conducted, you may contact Prof. Rudi Pretorius on 011 471 3680 or email pretorw@unisa.ac.za, if you have any ethical concerns, please contact the research ethics chairperson of the CAES General Ethics Review Committee

Thank you for taking the time to read this information sheet and for participating in this study.

Sanet Carow

Feedback sessions

09:00 Welcome

09:10 – 09:20 Short introduction and background to the study

09:20 – 10:00 Presentation of research:

Summary of results obtained from the research

Discussion of challenges identified in developing the model

Present draft model or alternative models to lecturers.

10:30 – 11: 00 Feedback sessions

11:00 Closing

Annexure G – Inclusion of spatial thinking when conveying module content

University	Experience	Experience in teaching the Module	Other modules	Last updated	New module	Representation tools	Spatial language	Cognitive level
A	10	10	2	Annually	5 years	Yes	Layers, visually present data	Based on Bloom's taxonomy, models
	21	16	5	Annually	1	Yes	Scale, space and time, projections, visualisations, spatial analysis, Interpretation of data, spatial thinking	Predictions, model
	14	10	3	Annually	2 years	Yes	Spatial data, projections, distribution, spatial thinking, spatial issues, scale and data, data quality and applicability	Models
	13	4	5	Annually	3 years	Yes	Distribution	Application
B	32	17	3	Annually	5 years	Yes	Spatial technology, spatial literacy, Projections, scale, networks, stream ordering, patterns	Predictions, models
	9	9	4	Annually	1 year	Yes	Spatial relationships, spatial injustice	Apply concepts
	27	27	3	Annually	1 year	Yes	Projections, models, distribution, Buffers, Dissolve	Apply

University	Experience	Experience in teaching the Module	Other modules	Last updated	New module	Representation tools	Spatial language	Cognitive level
E	20	3	3	Annually	1 year	Yes		Comparisons, apply principles.
	40	10	3	Annually	1 year	Yes	Space and time	Comparisons, apply principles
	16	6	3	Annually	1 year			Comparisons
	31	29	3	Annually	5 Years	Yes	Small scale and large scale	
F	36	17	1	Annually	1 year	Yes	Spatiality Virtual field trips, location, scale, adjacency	Comparisons, interpretation
	9	9	1	Annually	0	Yes	Linkages, connections, spatial analysis	Comparisons,
	34	7	1	Annually	5 years	Yes	Apply models and concepts	
H	3	3		Annually	0	Yes		Applications, synthesise
	31	13	3	3 years	2 years	Yes	Distribution, hotspots relationships, correlation	Applications
	22	20	2	Annually	10 years	Yes	Planning	Hypothesise, imagine
J	31	17	4	Annually	0	Yes	Scales, predictions	Applications, Hypothesise
	30	2	0	0	0	Yes	global networks, spatial integration, spatial inequalities	Hypothesise, Compare
	9	9		Annually	7 years	Yes	Terrain analysis, buffering, projections	Hypothesise, imagine

University	Globes	Graphs	Geospatial software	Maps	Sketches	Diagrams	Flow charts	Images	Models	Virtual Globes	Other	Tools	Blackboard/ E-board	Scenario
A	1	1	Not on NQF Level 5	1	1	1	1	1	1	1	Transparencies to introduce layering	Yes	Seldom	Combination
	1	1	1	1	1	1	1	1	1	1	Radar, Python	yes	Illustrations /Sketches	Combination
	0	1	1	1	1	1	1	1	1	1	Videos	yes	No	Combination
	0	1	1	1	1	1	1	1	1	1	Podcasts, Videos	Yes	Illustrations/ Sketches	Combination
B	1	1	1	1	1	1	1	1	1	1	Tennis balls, videos	Yes	Illustrations/S ketches	Combination
	0	1	1	1	1	1	1	1	0	0	Videos	Yes	Keyword/ diagrams	Combination
	1	1	1	1	1	1	1	1	1	1	Videos	Yes	Illustrations/S ketches	Combination
E	0	1	0	1	1	1	1	1	0	0	Videos	Yes		Case studies
	1	1	0	1	1	1	1	1	0	1	Videos	Yes	Diagrams/ sketches	Combination
	0	0	0	0	0	0	0	1	0	0		Yes	Diagrams/ keywords	Scenario
	1	1	1	1	1	1	1	1	1	0	Videos	Yes	Hovercam	Scenario
F	0	1	0	1	1	1	1	1	0	0	Videos, podcasts, Atlas	Yes	No	Yes
	0	1	0	0	1	1	1	1	0	0	Videos	Yes	Yes	Combination
	0	1	0	1	1	1	0	1	1	0	Videos	Yes	n/a	n/a

University	Globes	Graphs	Geospatial software	Maps	Sketches	Diagrams	Flow charts	Images	Models	Virtual Globes	Other	Tools	Blackboard/ E-board	Scenario
H	1	1	0	1	1	1	1	1	1	0	videos	Yes	Yes	Combination
	1	1	0	1	1	1	1	1	0	0	videos	Yes	Sketches/ keywords	Scenario
	0	1	0	1	1	1	1	1	1	0	Videos	Yes	Keywords	Scenarios
University J	1	1	0	1	1	1	1	1	1	1	Videos	Yes	not really	Scenarios
		1		1	1	1	1	1	1		Videos	Yes	All	Scenarios
	1	1	1	1	1	1	1	1	1	1	Videos	Yes	Sketches/ diagrams	Combination

University	Number of Scenarios	PBL vs SPBL	Problem-solving approach	Steps	Application abilities of students	Scale	Technologies	Outdated
A	1	SPBL	One of the major skills a Geographer should have	Teach to think		Yes	Yes	Yes - for comparison perpuses
	1	SPBL	Allow students to present views - no right or wrong answer	Yes - positive response from students	Attempt but feel it is not successful	Yes, in terms of place and time	Yes	Yes - paper maps
	> 1	SPBL	Engagement of students. Lead towards solutions, facilitate problem solving	Yes - think spatially. Consider the spatial problem; identify what data they need to solve this thing; and come up with a methodology and approach whereby they can solve it.	Yes, but needs refinement.	Yes	Yes	Yes
	>1	SPBL	Yes. Guiding towards a solution	Lead towards a solution	Improvement from lower to higher levels	Emphasis on different scales	Yes	Yes - but aware of it
B	>1	SPBL	Yes	Yes	Challenge with the interpretation of numeracy, spatial literacy and graphicacy	Yes	Yes	Yes
	>1	SPBL	Yes	Yes	Improvement throughout the semester	Yes	No	Yes

University	Number of Scenarios	PBL vs SPBL	Problem-solving approach	Steps	Application abilities of students	Scale	Technologies	Outdated
	1	SPBL	Yes	Yes	Very difficult - they cannot join the dots. But some improvement in higher levels	Yes	Yes	Yes
E	>1	SPBL	Yes	Yes	Improvement from lower to higher levels	Yes	Yes	Yes
	>1		Yes	Yes	Sometimes	Yes	Theory	Yes
	>1	SPBL	Lead towards	No	Yes, for the most part	Yes	Theory	
	>1	SPBL	Yes	Yes	Yes	Yes	Yes/No	Yes
F	>1	SPBL	Yes	Yes	Remains a problem but it gets easier	Yes	Yes	Yes
	>1	SPBL	Yes	Yes	Difficult to apply and relate problems to the environment	Yes	No	No
	>1	SPBL	Yes	No	Very difficult	Yes	No	Yes
H	>1		Yes	Yes	Some improvement	Yes	Yes	Yes
		SPBL	Yes	No	Students can apply knowledge	Yes	Yes	Yes
	<1	SPBL	Yes	No	Increasing challenge from second to third year.	Yes	Yes	Yes

University	Number of Scenarios	PBL vs SPBL	Problem-solving approach	Steps	Application abilities of students	Scale	Technologies	Outdated
J	>1	SPBL	Yes	Yes	Improvement	Yes	No	Applications, Hypothesise
	>1	SPBL	Yes	Yes	Challenging	Yes	No	Hypothesise, Compare
	>1	SPBL	Yes	Yes	Yes, comes with improved confidence	Yes	Yes	Hypothesise, imagine

Annexure H - Results from the spatial thinking ability test

Table 1: Percentage of correct answers per NQF level

	NQF Level 5	NQF Level 6	NQF Level 7
Q1	42.0000	31.0000	22.0000
Q2	48.0000	37.0000	27.0000
Q3	73.0000	53.0000	29.0000
Q4	36.0000	27.0000	15.0000
Q5	47.0000	34.0000	17.0000
Q6	62.0000	52.0000	29.0000
Q7	23.0000	20.0000	14.0000
Q8	42.0000	38.0000	19.0000
Q9	12.0000	13.0000	16.0000
Q10	40.0000	34.0000	20.0000
Q11	17.0000	11.0000	10.0000
Q12	17.0000	7.0000	6.0000
Q13	47.0000	38.0000	33.0000
Q14	23.0000	25.0000	19.0000
Q15	71.0000	51.0000	29.0000
Q16	40.0000	31.0000	28.0000
Average	40.0000	31.3750	20.8125
Minimum	73.0000	53.0000	33.0000
Maximum	12.0000	7.0000	6.0000
n	92.0000	68.0000	40.0000

Table 2: Percentage of correct answers per Gender

	Female	**Male**
Q1	49%	46%
Q2	54%	59%
Q3	77%	78%
Q4	41%	37%
Q5	43%	59%
Q6	70%	73%
Q7	26%	32%
Q8	40%	62%
Q9	21%	20%
Q10	47%	48%
Q11	21%	16%
Q12	12%	18%
Q13	60%	57%
Q14	32%	35%
Q15	70%	83%
Q16	49%	51%

Average	44%	48%
Min	12%	16%
Max	77%	83%
n	117	82