ARTICLE

An evaluation of the inclusion of spatial thinking in undergraduate Geography modules: A case study of selected South African universities

Sanet Carow and Rudi Pretorius
Department of Geography, University of South Africa, Preller Street, Muckleneuk Ridge, Pretoria South Africa

sanetpc@unisa.ac.za https://orcid.org/0000-0003-0799-5779
pretorw@unisa.ac.za https://orcid.org/0000-0002-0269-2173

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ABSTRACT

This research reflects on the nature of spatial thinking featured in a selection of undergraduate Geography modules at South African universities and explores ways to enhance its role. The research has three objectives: to identify Geography modules that include spatial thinking in their curricula, to determine whether the lecturers of these modules consider the concept of spatial thinking when developing new modules, and to evaluate the spatiality of the outcomes of the selected modules by assessing it against the taxonomy of spatial thinking. Generally, the spatiality of the module outcomes and the integration level of the three spatial thinking components into the participating departments' modules proved to be limited. The three components of spatial thinking refer to cognitive levels, the use of concepts of space and the use of representation tools. Not one of the departments offering these modules was observed to set a clear developmental path to foster the development of students' spatial thinking skills from their first to the third year of study. When developing Geography modules, more attention should be given to incorporating spatial thinking into the curriculum. Every effort should be made at the departmental level to ensure students' spatial thinking skills are adequately developed during their studies.

Keywords: Spatial thinking, Module outcomes, Geography teaching, Undergraduate, South African universities

INTRODUCTION

The ability to think spatially is an essential skill that should be developed in Geography modules to improve academic achievement, prepare graduates to exploit employment opportunities better and increase the likelihood of a successful career (Goodchild & Janelle, 2010; Bednarz, 2019). In addition, spatial thinking can address challenges often experienced by students and lecturers, such as closing the gaps in gender inequality (Newcombe & Stieff, 2012) and bridging differences in students' educational backgrounds (Bednarz, 2019). Students with well-developed spatial thinking skills possess higher-order thinking skills that contribute to closing achievement gaps in topics presented in Science, Technology, Engineering, and Mathematics (STEM) (Uttal & Cohen, 2012; Bednarz, 2019). By including spatial thinking in Geography curricula, some of the challenges experienced by students, such as applying knowledge and experiences in an unfamiliar environment, will be reduced, thus supporting students to complete their studies successfully and to perform efficiently in the workplace (Bednarz, 2019). For this research, spatial thinking is defined as the application of spatial concepts, processes of reasoning and representation tools to conceptualise and solve geographical problems (NRC, 2006). Although various researchers call for the inclusion of spatial thinking in Geography curricula (Metoyer and Bednarz, 2017; Bednarz, 2019; Nursa'Ban et al., 2020), it is reported that this essential thinking tool remains under-represented in undergraduate Geography curricula at South African universities (Pretorius, 2017).

Jo & Bednarz (2016) developed a taxonomy of spatial thinking that can be used to determine the spatiality of assessment questions. Various research projects on spatial thinking have been conducted at the secondary and tertiary education levels in a number of countries. In such cases, the taxonomy of spatial thinking by Jo & Bednarz (2009) has been used, for example, in Rwanda (Tomaszewski et al., 2015), Brazil (Duarte, 2018) and Indonesia (Ridha et al., 2019) to evaluate the spatiality of questions posed in Geography textbooks. Scholz et al. (2014) also evaluated the spatiality of the questions posed in popular World Geography textbooks against the taxonomy of spatial thinking. However, the authors could find no evidence that the taxonomy of spatial thinking developed by Jo & Bednarz (2009) has been used to determine the spatiality of module outcomes. Only a few of the mentioned research projects were conducted in Africa (Tomaszewski et al., 2015; Flynn, 2018), and none on spatial thinking in South Africa specifically. In addition, most of these research projects focus on filling the gap in incorporating spatial thinking into the school curriculum, classroom activities, and technologies focused on developing spatial thinking, while only a few consider the tertiary context. Furthermore, the authors found no reference to the importance of planning for the inclusion of spatial thinking in Geography curricula. Therefore, evidence is supplied in this paper in support of the notion that spatial thinking should be considered as part of the curriculum from the planning stage of developing a Geography module and the definition of its outcomes.

This paper aims to determine the extent and nature of incorporating spatial thinking into the outcomes of undergraduate Geography modules at selected South African universities. Geography is inherently interdisciplinary (Bearman et al., 2016) and studies, amongst others, human-environment interactions that have a strong spatial component (Turner, 2002). It is, therefore, essential that lecturers plan for the inclusion of spatial thinking in the Geography curriculum from the planning stage of developing modules with a spatial nature. The paper has three objectives. The first is to identify undergraduate Geography modules offered at South African universities that could potentially include spatial thinking. The second is to determine which factors the lecturers of these modules consider essential when developing new modules and to what extent spatial thinking forms part of this process. The third is to determine the spatiality of the outcomes of the identified modules by assessing it against the taxonomy of spatial thinking, as developed by Jo & Bednarz (2009).

The research results reported in this paper point towards ways to foster students' spatial thinking skills and emphasise the importance of using Geospatial tools (GSTs) in Geography teaching. The paper reviews some pertinent themes in the literature on the topic, and explains the methodology applied in conducting the research. This is followed by a discussion of the results, while some recommendations conclude the paper.

INTEGRATING SPATIAL THINKING IN GEOGRAPHY

Spatial thinking finds natural application within Geography since it is the only discipline in which many theories and methods have a spatial component (Lobben & Lawrence, 2015). Research has shown that Geography is one of the most effective disciplines for fostering and developing students' spatial thinking skills (Verma & Estaville, 2018). However, the effectiveness of teaching spatial thinking depends on whether the education system, which includes the practices adopted by the lecturer, the curricula (including the module outcomes) and the textbooks and assessments, supports the development of students' spatial thinking skills (Duarte, 2018).

Geography could potentially equip students with three powerful ways of thinking: spatial thinking, geographic thinking and geospatial thinking (Bednarz, 2019). Bednarz (2019) describes the three types of thinking as the 'secret powers' of a geographer. These powers are considered 'secret' because ignorance and misunderstanding generally cloud the nature of Geography as a discipline (Bednarz, 2019). This research focuses on the 'secret power' of spatial thinking.

Developing spatial thinking skills through teaching practices

Based on the definition of spatial thinking, Geography teaching should focus on developing spatial concepts, developing reasoning skills at a high cognitive level and incorporating representation tools. One of the primary focuses when teaching Geography should be to enable graduates to think spatially (Silviariza et al., 2021). To achieve this, Geography education should go beyond the mere memorisation of facts (NRC, 2006; Jo & Bednarz, 2011; Ishikawa, 2013) and strive to incorporate applications within the field of Geography (Bednarz, 2019). Geography education should, therefore, be application-driven and progress from engagement with basic background knowledge to reasoning at a high cognitive level (Ishikawa, 2013).

To enable Geography teaching to attain a high cognitive level, teaching should involve not only problem-based learning (PBL) but also spatial problem-based learning (SPBL) (Silviariza et al., 2021). Like spatial thinking, SPBL requires applying spatial thinking skills at a high cognitive level and presents an opportunity to foster and develop Geography students' skills (Charcharos et al., 2016; Verma & Estaville, 2018). To achieve success, students should constantly be challenged to exploit their spatial thinking skills (Bednarz & Bednarz, 2008). Teaching practices to develop these skills should, therefore, include specific guidance to establish a "spatial habit of mind" (SHOM) (Bednarz & Bednarz, 2008).

From the preceding discussion on spatial thinking, it can be deduced that Geography teaching at the university level should be conducted (NRC, 2006; Jo & Bednarz, 2011; Ishikawa, 2013; Bednarz, 2019) at a high cognitive level (Charcharos et al., 2016), should involve SPBL (Silviariza et al., 2021) and should aim to develop a SHOM (Bednarz & Bednarz, 2008). However, spatial thinking should not be regarded as an "add-on" to study material or an afterthought but as an essential part of interpreting the curriculum (Nursa'Ban et al., 2020). It needs to be emphasised that spatial thinking is a personal skill and that, as a result, and regardless of the tools used, the spatial thinking capabilities of students will be developed only on condition that they are explicitly guided to personalise these skills (Walkington et al., 2018). Spatial thinking can be personalised if the coursework encourages students to make choices, be creative in geographical investigations, and fully engage with their study area (Walkington et al., 2018).

Tools for teaching spatial thinking – making a case for technology

Various tools can advance students' spatial thinking skills. These tools include analogue maps (Collins, 2018), global positioning systems (GPS) (Flynn, 2018), geographic information systems (GIS), graphs, models and flowcharts, globes (NRC, 2006), digital globes (Collins, 2018) and even hand gestures (NRC, 2006; Ormand et al., 2017). Although the use of analogue maps has been proven to be an effective method to foster specific spatial thinking capabilities in students (Collins, 2018), the teaching of spatial thinking, supported by GSTs, forms the foundation of an innovative Geography curriculum (Bednarz, 2007; Madsen & Rump, 2012). In addition, the inclusion of GSTs in Geography teaching improves students' employability (Moolman & Donaldson, 2016).

Spatial thinking forms a cornerstone of Geography teaching, and GIS has become the tool for developing spatial thinking skills (Liu et al., 2010). Using GIS in Geography teaching is known to strengthen students' spatial capabilities, such as pattern recognition, spatial description and visualisation, and their use of spatial tools and concepts (Kim & Bednarz, 2013a; Ishikawa, 2016; Bearman et al., 2016; Ghaffari et al., 2018). In addition, students with a knowledge of the application of GIS are better equipped to use spatial concepts to describe, compare and analyse data, evaluate a problem in context, and develop an informed understanding of data reliability (Kim & Bednarz, 2013a) These capabilities are all essential characteristics of a spatial thinker (NRC, 2006). Kim & Bednarz (2013b) also found that GIS students generally have higher-order thinking skills and an enhanced SHOM than students who have not completed GIS courses. Activities within GIS learning contribute toward fostering habits of recognising spatial patterns, using spatial vocabulary, and an enhanced understanding of the importance of visualising (Kim & Bednarz, 2013b).

Despite the benefits of developing spatial thinking skills by including GIS in Geography teaching, the incorrect use of GSTs in teaching could, in fact, hinder the development of students' spatial thinking skills. Lecturers should avoid following a buttonology (Fombuena, 2017) or a step-by-step approach (Pye, 2014 in Bearman et al., 2016) when teaching GIS software. A student should not only know which buttons to press and understand the logic of the software programme but also be aware of the implications of their decisions for the outputs they plan to produce (Fombuena, 2017). Even more importantly, GSTs should extend students' spatial thinking capabilities by applying geographic inquiry processes (Bearman et al., 2016) and expanding their understanding of spatial concepts (Metoyer & Bednarz, 2017). GSTs and spatial thinking are crucial in the modern world; therefore, university lecturers should equip themselves to teach Geography with the aid of GSTs (Collins, 2018).

METHODOLOGY

This research focuses on Geography modules offered at public universities in South Africa at the first, second and third-year levels. In South Africa, each module holds a credit count indicating the amount of time (also referred to as notional hours) a student should typically spend on completing a module successfully (one credit = 10 notional hours). Therefore, an average student should spend 120 notional hours completing a module with a credit count of 12, including all study time and all assessments. Those specific Geography departments and modules that participated in this research were identified through purposive sampling to ensure that only modules that would make a meaningful contribution to the research were selected. The data for this research was obtained in 2021, confirmed correct, and analysed in 2022.

Identifying Geography modules that might include spatial thinking

To achieve the first objective of this research, the first step was to obtain a list of all public universities in South Africa from the websites of the Department of Higher Education and Training (DHET, 2023) and Unirank (UniRank, 2023). Each university's website was scrutinised to determine whether it offered Geography modules. The information on the universities' websites was assumed to be accurate and updated. The name of the university, the name of the department offering Geography and all the Geography modules offered per year of study were recorded in a spreadsheet. Geography is offered by 16 of the 26 public universities in South Africa. To ensure anonymity, the name of each university and the code for each Geography module offered were replaced with the same letter, followed by the numbers 1, 2 and 3, with each numeral representing the year of study for each specific module. A module would be considered part of a mainstream subject provided it was generally offered to all students for enrolment as a compulsory or elective subject. Once it was established that a university offered Geography as a mainstream subject, a further search was conducted to establish whether the module descriptions were available on the university's website. Only the 16 departments indicating that they were Geography departments were considered for this research. Therefore, departments reflecting only Environmental Science in their name (without overlapping or combined with Geography) were omitted. Some of the departments considered to form part of this research were those that offered Geography and Environmental Science in an integrated way. However, this research did not consider Geography modules explicitly offered as part of only an education study programme (e.g., for teacher training) as these are not generally available to mainstream students.

The module descriptions on the university websites were scrutinised to identify phrases indicating that spatial thinking might be included in the modules. Phrases that were considered included references to identifying information required to solve challenges, solving problems in unfamiliar contexts, working in teams, and those mentioning the use of technology (Jo & Bednarz, 2011; Bednarz, 2019). References to 'working on different scales', 'using maps or images', or an 'applied component of spatiality' in the module descriptions were also considered as qualifiers for inclusion in this research (Lee and Bednarz, 2012; Bearman et al., 2016; Collins, 2018). Some modules listed their learning outcomes as part of the module description. If the outcomes were available on the internet, one module per study year was identified to constitute part of this research. However, if the module outcomes were unavailable online, two modules per study year that might include spatial thinking were identified for further investigation.

If the module outcomes were unavailable on the university website, the relevant departmental heads were requested to provide access to the necessary module/departmental documents containing this information. After examining the module descriptions, eight Geography departments were invited to participate in the research. The heads of the identified departments were contacted to confirm their availability to participate in this research. Permission was also obtained from these heads of departments to further engage with the lecturers of the identified modules through online interviews (Ethics clearance was obtained to engage with human participants: REC Reference number: 2019/CAES_HREC/184.)

Considerations by lecturers when developing modules

The data to achieve the second objective of this research was obtained from interviews with the lecturers offering the identified Geography modules. For the purposes of the original research, the interviews were intensive and covered multiple topics, but for this paper, only a selection of the relevant questions and responses were considered.

The selected questions are presented in Figure 1. Questions 1 to 4 were posed to gain insight into the teaching experience of each of the lecturers and to provide background information on the module they were teaching. Question 5 focused on gaining insight into the lecturers' thought processes and considerations when developing a module and was an open-ended question. The interviews were recorded and transcribed by a professional language practitioner.

Section 1: Background questions

(1) How long have you been teaching this module?

(2) Do you or have you taught any other Geography modules?

(3) How often do you review/update/revise the modules you offer?

(4) When did you last develop this module or any other one from scratch?

Section 2: Module Development

(5) If you were to develop this module or a similar module from scratch, what would be the thought process that you would follow?

Figure 1: Relevant questions from the interview guide

The answers to the open-ended questions were analysed using ATLAS.ti as a qualitative research tool to identify the key concepts that the lecturers considered relevant in developing a module. As the next step, the key concepts were classified into main concepts. The interview responses from the lecturers for each department were then evaluated against the main concepts to determine overlaps in concepts generally considered when planning for developing a new module. The omission of concepts was also noted.

The spatiality of module outcomes

The third objective was achieved by determining the spatiality of the outcomes for each of the selected modules using the spatial thinking taxonomy developed by Jo & Bednarz (2009). The taxonomy of spatial thinking is based on three components: concepts of space, representation tools and processes of reasoning. As shown in Figure 2, the taxonomy of spatial thinking is a three-dimensional model consisting of a set of cubes. Each cube is assigned a distinct number according to whether spatial concepts are incorporated in the study material, whether a representation tool is used (or not), and which reasoning processes are involved. Thus, the numerical value assigned to each cube represents the degree of spatiality inherent to each inquiry (Jo & Bednarz, 2009). (A greater numerical value would indicate a higher level of spatial thinking.) Cubes with values of 10 to 12, 16 to 18 and 22 to 23 represent all three components of spatial thinking and would, therefore, directly contribute to developing students' spatial thinking skills.

For this research, the taxonomy of spatial thinking, as described in the original research by Jo & Bednarz (2009), was used and applied. As such, it allowed for comparative studies to be conducted.

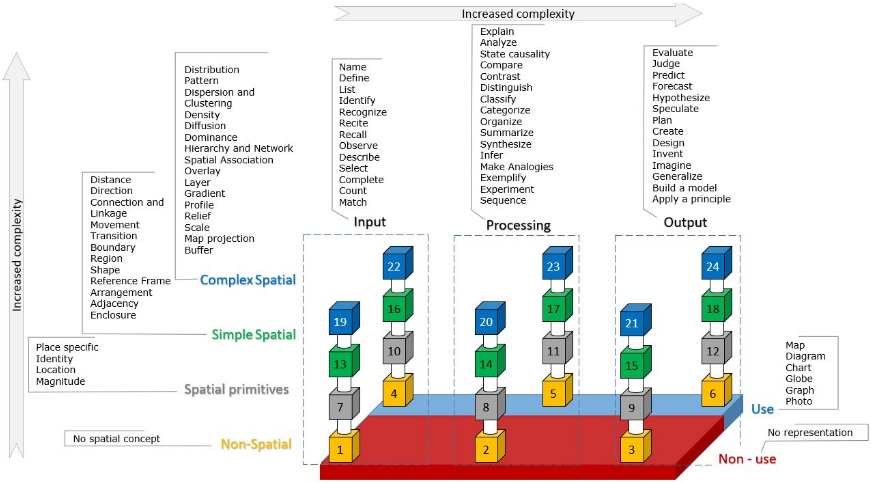


Figure 2. The taxonomy of spatial thinking (adapted from Jo & Bednarz, 2009)

Although the taxonomy of spatial thinking is a known and tested instrument, the interpretation of the spatiality of the module outcomes was partially based on the experiences and subjective views of the authors. Since a comparison is required between module outcomes, which are formulated in general terms, and the taxonomy of spatial thinking, which is formulated in terms of specific geographic processes and terminology, an element of subjectivity was therefore at stake.

RESULTS AND DISCUSSION

This research focuses on Geography modules offered at the first to third-year level at the 26 public universities in South Africa. The review of the websites concluded that 16 Geography departments in the 26 public universities in South Africa offer almost 190 Geography modules that would allow a student to study towards an undergraduate qualification in Geography or enrol for a Geography module. Of these modules, 43 are offered at the first-year level, 62 at the second-year level and 85 at the third-year level.

Identification of relevant Geography departments and modules

As the first step, the descriptions of Geography modules on the websites of South African universities were scrutinised to identify phrases indicating that spatial thinking might form part of the module content and/or outcomes. In this way, eight Geography departments were identified and invited to participate in the research, although two departments declined the invitation. Since purposive sampling was used to identify these departments, no alternative departments were contacted since they would not have made a significant contribution as participants to this research. Although the initial aim was to identify only one module per year of study for a department to be part of this research, a number of the departments that agreed to participate offered additional modules to include in the research. Incorporating these additional modules raised the initial number of 18 modules to 21.

Almost half (48%) of the 21 identified modules selected for this research had an application field in Human Geography, followed by those with application fields in Physical Geography (24%) and Geospatial Applications (19%); additionally, others were adopting an integrated approach to both Human and Physical Geography (9%). The reason why most of the selected modules focused on Human Geography may be attributed to the form of expression used to describe them and/or their outcomes. Modules in Human Geography often include phrases such as 'facing challenges on a global and local scale' and 'solving problems using a team approach'. In contrast, Physical Geography modules often refer to processes on a local scale, such as rock weathering or erosion, with little to no direct reference to any form of spatiality, indicating that spatial thinking may not be included in these modules. It is worth noting that very few Geography modules at South African universities follow an integrated approach (Pretorius, 2017). As such, the percentage of these modules forming part of this research study comprised only nine percent (9%) of the chosen modules. Only four of the 21 modules (19%) referred to developing students' critical, spatial, geographic or thinking skills. Although this was interesting to note, the lack of any reference to spatial thinking in the module outcomes should not necessarily be considered a matter of concern as spatial thinking *per se* should be integrated into the teaching and learning process and not be regarded as an add-on in the curriculum (NRC, 2006). It would, therefore, not be necessary to mention spatial thinking explicitly in the module outcomes. A word cloud of the keywords used in the module descriptions was generated to demonstrate the spatial thinking keywords. Figure 3 presents the word cloud of the keywords used in the descriptions and/or outcomes of the identified modules and indicates that spatial thinking may be included in these modules. The word cloud (Figure 3) indicates that the most frequently used spatial thinking indicators in the identified modules' descriptions and/or outcomes include 'problems', 'solve', 'scale(s)', 'interpretations', 'apply' and 'patterns'.

Figure 3: Spatial thinking keywords from module descriptions (generated using worditout.com)

Considerations by lecturers when developing modules

The results reported in this section of the paper are based on the interviews with the 20 lecturers responsible for the teaching and/or development of the identified modules. Background questions (questions 1-4, see Figure 1) were posed to determine the lecturers' experience level in teaching Geography and module development. The results indicated that the lecturers responsible for the identified modules have extensive experience teaching Geography at the tertiary level, with their experience varying from three to 40 years. Most (80%) of the 20 lecturers have had ten or more years of experience teaching Geography at a higher education institution. Contributing further to their teaching experience, most lecturers (79%) indicated they were teaching more than one Geography module. Most of the lecturers (84%) had taught the modules forming part of this research for more than five years, highlighting the extent of their experience in teaching Geography, specifically in the identified Geography modules.

Regarding the development of modules, almost 70% of the lecturers had developed a module from scratch during 2021 and 2022, while the remaining 30% indicated that they had no experience in this respect. Despite this shortfall, they all elaborated enthusiastically on the processes they would follow to develop a module. The key concepts considered by the lecturers in creating a module from scratch were identified from the interview data using ATLAS.ti and classified into five main themes: Geography and Geography-focused themes, Geography tools, a problem-solving approach, and themes around the workplace, students and institutional requirements. To ensure that the researcher remained neutral during the interview process and would not influence or lead the interviewees in a specific direction, the main concepts were not pre-empted but identified only after the interviews had taken place. Figure 4 provides a graphical presentation of the main concepts considered by the lecturers when developing a module from scratch. Although there were some overlaps in the key concepts considered by the lecturers, each of them followed their unique approach to a certain extent. The most often referred-to key concept was 'students' followed by 'student employability' within the South African industry. All lecturers indicated that they consider their students' needs, experience and interests when developing new modules. This confirms that the lecturers have a student-centred approach. All lecturers strongly emphasised a problem-solving approach and included real-world challenges and the local context. This confirms that the lecturers follow a PBL approach when conveying module content to students.

The main concepts provide direct and indirect indications as to whether the lecturers consider the concept of spatial thinking when developing their modules. From the literature, it can be deduced that references made to main concepts as a problem-solving approach (Silviariza et al., 2021), the use of Geography tools, such as GSTs, maps or globes (NRC, 2006) and spatial thinking can be regarded as indicators that spatial thinking has been considered from the outset in the development of modules. References to main concepts that might indirectly lead to developing students' spatial thinking skills include those to "workplace readiness" and "the real world".

Lecturers from only two departments referred directly to spatial thinking as an essential concept when developing a module, while lecturers from two other departments strongly emphasised the inclusion of Geography tools. Lecturers from three departments did not refer to including Geography tools at all. It must be kept in mind that spatial thinking can be developed only through the inclusion of concepts of space, representation tools and reference to processes of reasoning. The limited number of lecturers who were found to emphasise incorporating Geography tools in developing a module is, therefore, a matter of concern. It is also worrisome that lecturers from only two departments referred directly to spatial thinking. The responses to the interviews made it clear that although each lecturer had specific issues to consider with respect to module development, new modules are generally conceived and planned on a departmental level but developed by individual lecturers.

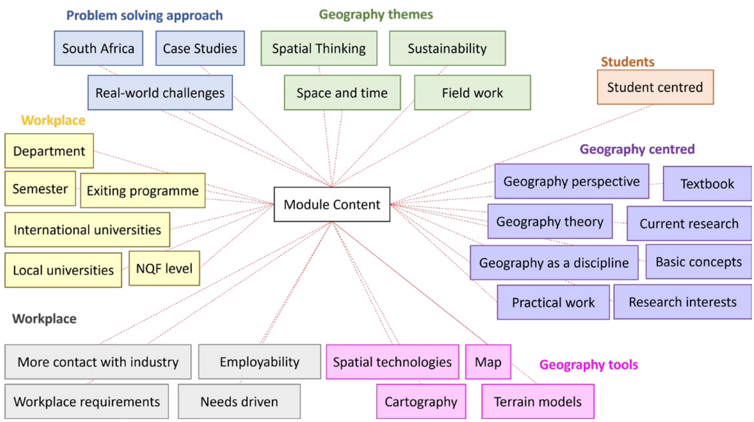


Figure 4: Thematic analysis of the interviews to determine key concepts considered by the lecturers when developing modules

Assessment of module outcomes against the taxonomy of spatial thinking

The module outcomes were first evaluated against the components of spatial thinking, namely the cognitive level, the concept of space and the use of a representation tool. The results of the assessment of each component are discussed individually in the sections that follow. In evaluating the outcomes against the taxonomy of spatial thinking, it was acknowledged that module outcomes are often written in general terms. In contrast, the taxonomy of spatial thinking is an exact method in terms of its description of geographic processes and the use of terminology. While assessing the module outcomes against the taxonomy of spatial thinking, it was kept in mind that the module outcomes demonstrate an exit level that should be reached after a teaching semester. A total of 107 outcomes emanating from 21 modules were evaluated against the taxonomy of spatial thinking. Table 1 summarises the number of modules and outcomes per department.

Table 1: Number of outcomes per department

Department	Number of modules	Number of outcomes
Department A	4	19
Department B	3	6
Department E	4	18
Department F	3	12
Department H	3	15
Department J	4	37
Total	21	107

Cognitive level

The expectation was that the module outcomes would increase in complexity from the first to the third study year. Figure 5 summarises the results of the evaluation of the cognitive levels at which the module outcomes were defined. Three departments (A, F and H) are used as examples to showcase the type of results obtained. The three examples showcase modules that include outcomes on a high cognitive level in all the study years (Department A), modules with an increase in the cognitive level (Department F) and modules that do not include a high cognitive level in any of the study years and the output cognitive level that decreases in the third year of study.

The illustrated results of the assessment of the module outcomes in terms of cognitive level reveal that outcomes on the input level vary from 0% (F.1 and H.1) in the first year of study to 50% (H.2 and H.3) in the second and third years of study, while the outcomes on the processing level vary from 0% (A.2) in the second year of study to 75% (F.1) in the first year of study. The outcomes on the output level vary from 0% (F.1 and H.1) in the first year of study to 83% (A.3) in the third year of study.

The three pie diagrams are presented in Figure 5 for each selected department to demonstrate the cognitive levels of the outcomes discussed in the previous paragraph from the first to the third year of study. These diagrams illustrate an increase in the complexity of the cognitive level (Department A), a positive alternative to a rise in the complexity of the cognitive level (Department F) and no increase in the complexity of the cognitive level (Department H).

Two of the illustrated departments, namely A and F, indicated an increase in the cognitive level of module outcomes from the first to the third year of study. The module outcomes defined on the output level of Department A increased from 50% in the first year to 86% in the second year, with a slight decrease of three percent (3%) in the third year of study. Although it appears that these modules do indeed reach the desired level of complexity, the outcomes of module A.2, which are currently only on an input and output level, should be redefined to include the processing level as well.

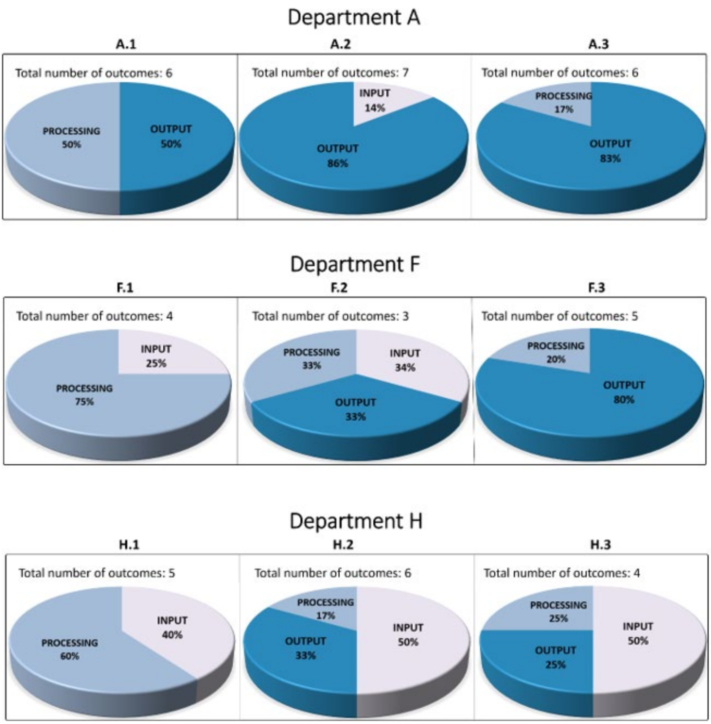


Figure 5: Percentage of module outcomes per cognitive level for Departments A, F and H, arranged per year of study

In the case of Department F, there are no module outcomes on an output level in the first year, 33% in the second year and 80% in the third year of study. The module outcomes on an output level reflect a clear increase from the first to the second year, although there are no outcomes on an output level in the first year, which is, therefore, not at an acceptable cognitive level. Since spatial thinking can be taught at any age and level, some of the outcomes of module F.1 on the processing level should be redefined on an output level.

In the case of Department H, the cognitive level does not demonstrate increased complexity from the first to the third year of study. The input level reaches a high percentage for all the years of study, with 40% in the first year and 50% in each of the second and third years of study. The module outcomes should be redefined to reflect an increase on the output cognitive level for all years of study to, for example, require students to predict, hypothesise or forecast changes when given a specific scenario. Module outcomes that do not reach the highest cognitive level might not develop students' spatial thinking skills.

Concepts of space

The classification of the concepts of space is based on four levels: non-spatial, spatial primitives, simple spatial and complex spatial (refer to Figure 2 for the spatial concepts on each level). For Geography modules, it could be expected that the proportion of complex spatial concepts of space in module outcomes should be high and increase from the first year to the third year of study. Since the module outcomes demonstrate an exit level that a student should achieve at the end of a teaching semester, it could be expected that the inclusion of non-spatial concepts should be limited. Figure 5 provides examples of how the various concepts of space are incorporated into the module outcomes of three participating departments. The pie diagrams demonstrate an increasing use of spatial concepts and complex spatial concepts from the first to third year for Department F, but with a large proportion of the modules presenting with a non-spatial component for Department A, while the outcomes show a decline in the use of complex spatial concepts of space from the first to third year for Department H.

The overall results illustrated in Figure 6 indicate that the non-spatial concepts of space vary from 0% (F.1, F.2 and F.3) to 57% (A.2). Spatial primitive concepts of space are included in 50% of the outcomes of H.3. The use of simple spatial concepts of space in the module outcomes varies from 17% (A.1) to 50% (F.1). It is encouraging that all the modules include complex concepts of space, although not always in increasing proportions from the first to the third year of study. The proportion of module outcomes that include complex spatial concepts of space varies from 25% (H.3) to 100% (F.3).

Since Geography is a discipline focused on investigating phenomena in space and time, the aim should be to include only complex spatial concepts in the third year of study. However, as shown in Figure 6, Departments A and H have high proportions of outcomes on a non-spatial level in this year of study. Some of these outcomes, therefore, need to be redefined to include concepts of space at a higher level of complexity to ensure that students' spatial thinking skills are adequately developed. On the other hand, Department F demonstrates a clear developmental path in terms of incorporating complex spatial concepts of space and attained a 100% rating for complex spatial concepts in the third year of study. For Department F, the outcomes that include complex spatial concepts of space increased from 50% in the first year to 67% in the second year and 100% in the third year of study. Departments A and H, therefore, need to reconfigure their module outcomes to include a larger percentage of complex concepts of space to achieve a level of progression from the first to the third year of study.

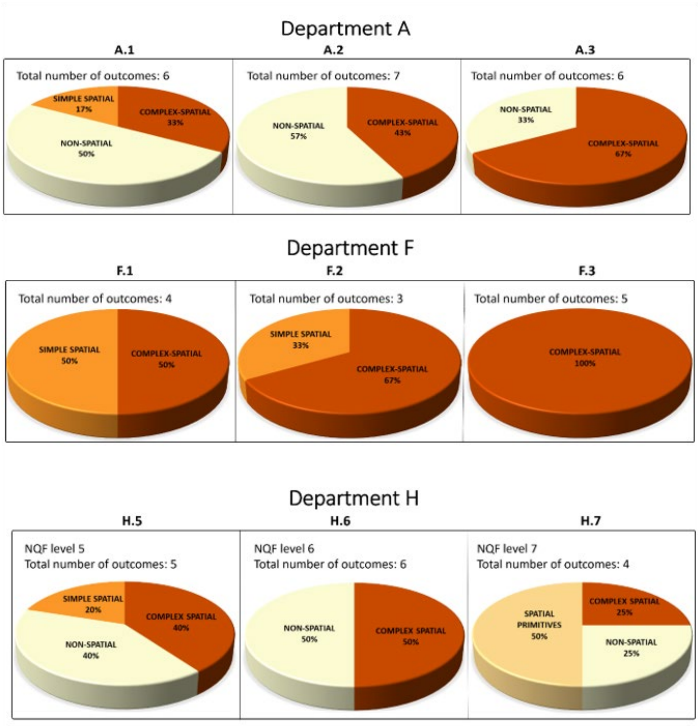


Figure 6: Percentage of module outcomes per concept of space for Departments A, F and H, arranged per year of study

Representation tools

Since Geography is a visual and creative discipline (De Jager, 2014), one would expect to find a high usage of visual materials such as globes, graphs, videos and maps in various forms in the teaching/learning environment. Including representation tools to develop students' spatial thinking skills would, therefore, be essential.

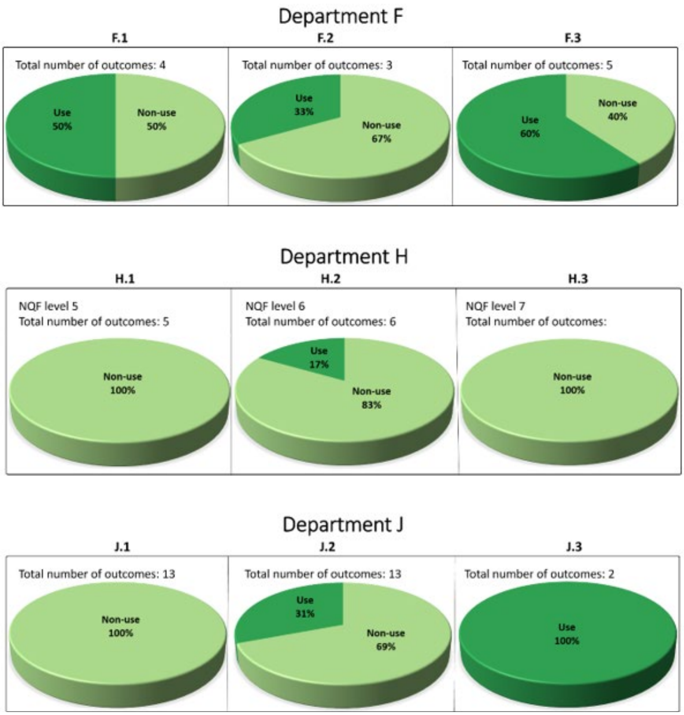


Figure 7: Percentage of module outcomes that include a representation tool for Departments F, H and J, arranged per year of study

The general finding concerning all the departments that participated in this study is that the inclusion of representation tools in the module content is erratic. Figure 7 demonstrates the results for three departments (F, J and H) as examples. This includes modules with outcomes ranging from those with no representation tool at all (e.g., H.1, H.3 and J.1) to those including representation tools in all outcomes (J.3). Department F includes the use of a representation tool in all the years of study; however, the percentage varies from 50% in the first year, 33% in the second year to 60% in the third year of study.

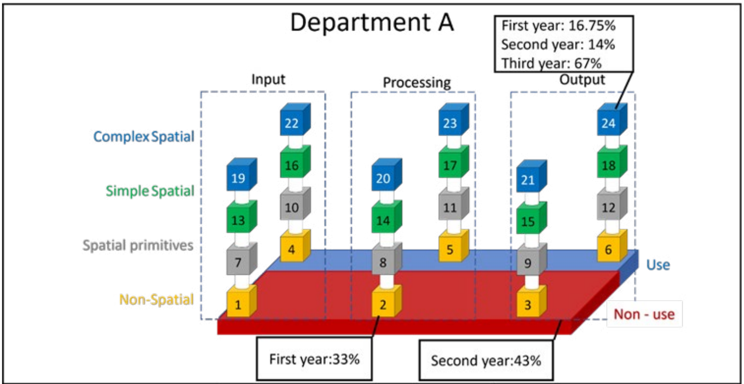
The relatively high prevalence of the non-use of a representation tool in the outcomes observed in Figure 6 is a matter of concern. Since the use of representation tools is essential for developing the spatial thinking abilities of students, it should feature as a significant proportion of most of the module outcomes on all study levels. However, the only module that incorporated a 100% usage of a representation tool in its outcomes was the module in the third year of study (J.3), focusing on Geospatial Applications.

Integration of indicators in the taxonomy of spatial thinking

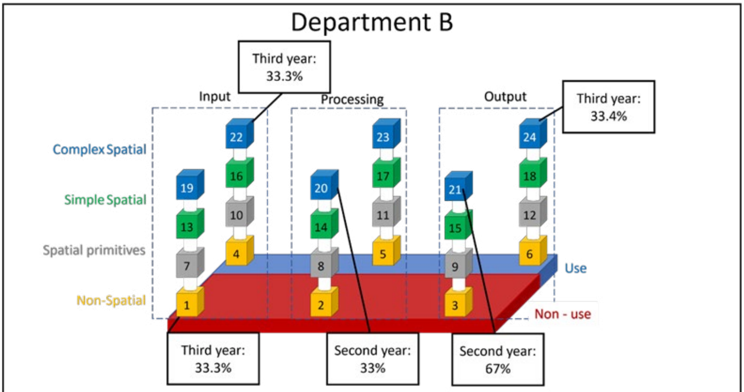
The indicators of spatial thinking, namely the cognitive level, concepts of space, and representation tools, are combined in the taxonomy of spatial thinking (Jo & Bednarz, 2009) and can be used to indicate the spatiality of module outcomes. The results emanating from the assessment of the module outcomes against the taxonomy of spatial thinking should be interpreted cautiously because the number of outcomes per department varied greatly (see Table 1). In addition, this research assumed that an equal number of credits would be attributed to teaching each outcome, which might not always have been the case. The results should also not be used to compare the respective departments against each other but rather to determine how spatial thinking has been included in the curricula and whether there is an increase in spatiality from the first year to the third year of study. Figure 8 summarises the results of evaluating the outcomes of the 21 selected modules for the six identified Geography departments against the taxonomy of spatial thinking. The results of all the departments that formed part of the research are indicated in the figure.

Analysis of Figure 8 shows that the spatiality of the module outcomes varied vastly: from a cell value of one (lowest spatiality) to 24 (highest spatiality), while the integration of the three components of spatial thinking varied from 0% (B.2, E.2, H.1, and H.3) to 100% (J.3). A matter for concern is that only 24% of all the modules in all three study years sufficiently integrated the three components of spatial thinking and that only 13% of the outcomes in the first and second years of study included all three components of spatial thinking. The corresponding percentage in the third year of study was 56%. Only the outcomes of Departments A and F attained high spatiality ratings of 23 and 24, respectively, in all three years of study – although, in some instances, the percentage of the outcomes reaching a high level of spatiality remained low.

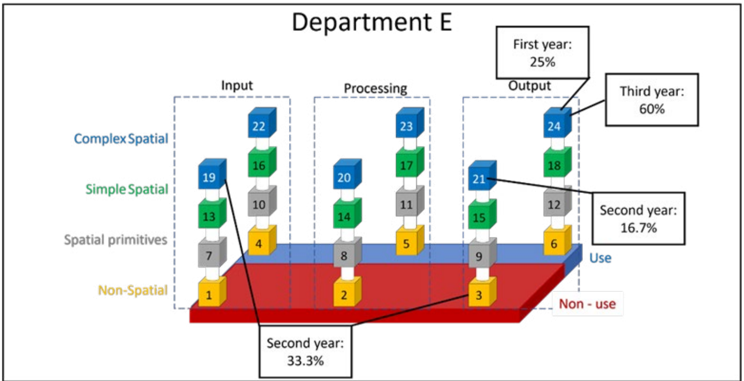
The results indicate that a low percentage of the modules per department fully integrated the three components of spatial thinking in their outcomes. Only one module (see Figure 8, Department J) focusing on Geospatial Applications presented with an integration level of 100%. The integration of the three components of spatial thinking then dropped significantly to 67% (A.3 and B.3) and is much lower for the remaining modules. Four of the six departments (B, E, H and J) had at least one module that did not integrate the three components of spatial thinking into their outcomes (B.2, E.2, H.1 and J.1).



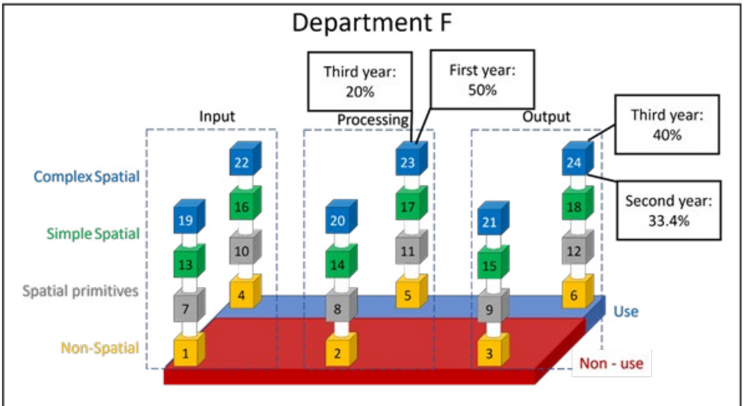
A.1			A.2			A.3		
Integrated = 16.75% N = 6			Integrated = 14% N = 7			Integrated =67% N = 6		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
2	33%	2	1	14%	1	2	16.5%	1
3	16.75%	1	3	43%	3	3	16.5%	1
14	16.75%	1	21	29%	2	24	67%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



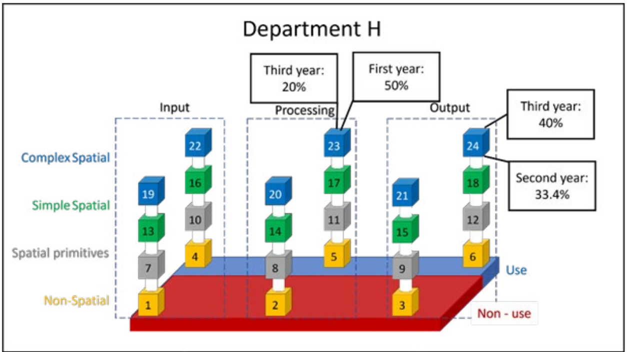
B.1			B.2			B.3		
Integrated = N =			Integrated = 0% N = 3			Integrated =67% N = 3		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
Not available			20	33%	1	1	33.3%	1
			21	67%	2	22	33.3%	1
						24	33.4%	1



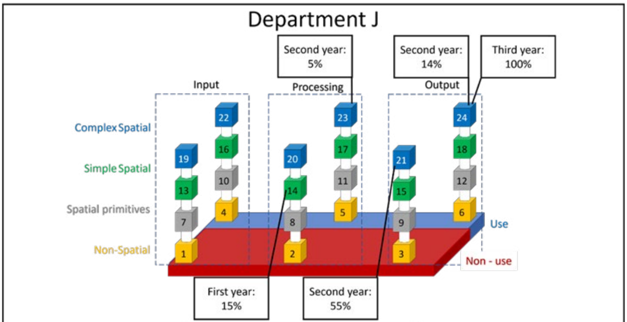
E.1			E.2			E.3		
Integrated = 25% N = 4			Integrated = 0% N = 6			Integrated =60% N = 5		
Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes	Spatiality	Percentage	Number of outcomes
3	25%	1	3	33.3%	2	1	20%	1
19	25%	1	19	33.3%	2	20	20%	1
21	25%	1	20	16.7%	1	24	60%	3
24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



F.1			F.2			F.3		
Integrated = 50% N = 4			Integrated = 33.4% N = 3			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



H.1			H.2			H.3		
Integrated = 0% N = 5			Integrated = 20% N = 6			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.1			J.2			J.3		
Integrated = 0% N = 13			Integrated = 19% N = 22			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 8: Evaluation of the module outcomes against the taxonomy of spatial thinking (For clarity, only some of the spatialities are indicated on the graphs. Spatiality in red text refers to integrating all the components of spatial thinking)

Analysis of Figure 8 shows that too many outcomes included low cell values such as one, two and three on the taxonomy of spatial thinking (e.g., the modules of Departments A and H) From this, it can be deduced that none of the departments participating in the research demonstrated a level of spatiality in the selected modules that could foster students' spatial thinking skills. The demonstrated low cell values will not contribute to developing students' spatial thinking skills. The low integration of the three components of spatial thinking into the module outcomes indicates that, based on the module outcomes, there is little prospect that the students' spatial thinking skills will be developed. The results of this research suggest that the modules demonstrating the highest level of integration (67% and 100%) of the three components of spatial thinking are those focusing on geospatial applications (modules B.3 and J.3). Since module outcomes define the preferred exit level a student should achieve at the end of a teaching semester, and research has confirmed that spatial thinking could be learnt at any level or age (NRC, 2006; Newcombe & Stieff, 2012), it could be expected that, regardless of the year of study, each of the modules should reach a high level of spatiality (cell value = 24, 23 or 18) on the taxonomy of spatial thinking.

CONCLUSIONS

This research aimed to determine the extent and nature of incorporating spatial thinking into the module outcomes of undergraduate Geography modules at selected South African universities. This research confirms that despite the benefits of including spatial thinking in Geography curricula, this concept has not been significantly incorporated into Geography module outcomes at the South African universities considered in this research.

The lecturers of the modules from the six departments participating in this research demonstrated specific considerations when developing modules, but in most instances, the concept of spatial thinking was not considered at all or not in a direct way. Planning for including spatial thinking in modules with a strong spatial component is essential; otherwise, students' spatial thinking skills may not develop adequately. The inclusion of spatial thinking into Geography curricula should be considered from the module's planning phase and reflected in the module outcomes. This research indicates that the cognitive level at which module outcomes are formulated needs to be redefined at a higher output level in all study years. Although there is room for improvement when defining the module outcomes, the fact that some modules indeed showcase the application of complex spatial concepts is encouraging. Incorporating visualisation tools such as GSTs that needed to be mastered by the students should also be considered and reflected in the module outcomes. The lack of representation tools contributed significantly to the low level of integration of the three components of spatial thinking into the module outcomes. It could be argued that using representation tools (e.g., GSTs) should form an intrinsic part of many Geography modules on any level to integrate the three components of spatial thinking successfully.

The inclusion of spatial thinking, as featured in the module outcomes, was found to be erratic. Furthermore, concerning the respective study years, none of the identified modules for the selected Geography departments demonstrated development towards any clear spatial thinking patterns or a high level of integration of the three components of spatial thinking into the module outcomes, especially in the third year of study. This research shows that the module outcomes were mostly developed in relative isolation and without due attention given to the level of spatiality at which the other modules in each respective department are offered. To set a clear developmental path for spatial thinking in the module outcomes, departments should make a concerted effort to develop some modules oriented towards spatial thinking.

This research is a first step towards determining the inclusion of and contributing to improving spatial thinking in undergraduate Geography modules at South African universities. It focused on what lecturers consider important in developing modules and in determining the spatiality of their module outcomes. This presents the groundwork for fostering students' spatial thinking skills. Further research could include the methods university lecturers could apply to successfully convey module content to their students while fostering their spatial thinking and, most importantly, the spatiality of their instruction methods and assessments.

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