Catchment and River Management in Graduate Teacher Education:

A Case Study of Student Teacher Learning and Teaching in the Upper uThukela Valley, KwaZulu-Natal

by

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Abstract

This study developed as a progressive focus on a design research process towards the inclusion of new environmental knowledge in teacher education. It is centred on the clarification of pedagogical content knowledge for the teaching of catchment and river management in Geography teacher education. The study was developed as a design research case study with three phases or iterations of experiential engagement and data collection during the teaching of Postgraduate Certificate in Education students at the University of KwaZulu-Natal where I lecture Geography Education. The study's iterative design was developed around pedagogical content knowledge refinement with curriculum knowledge analysis (phase 1) that was followed by lecture delivery and analysis (phase 2) and analysis of student engagement during fieldwork, and on teaching practice in rural classroom contexts (phase 3). Data and insights were generated across the successive stages of knowledge differentiation and teaching and learning interactions over time, and included reflection with students involved in the lectures, fieldwork and teaching practice programme. The analytical work covered a review of trajectories in new environmental knowledge, social-ecological systems, sustainability competencies, practice architecture and fieldwork pedagogy. This was done using three research lenses, namely social-ecological systems, social learning and practice architectures. All the design research and review processes served to develop, clarify and refine pedagogical content knowledge for sustainability-oriented teacher education. Thus the study conformed to the tenets of design-based research that was centred on clarification and review of pedagogical content knowledge that was carried into phases two and three. Research was focused at the nexus of pedagogical content knowledge and sustainability concerns that is necessary for the teaching of catchment and river basin management within a social-ecological systems perspective for integrated water resources management in South Africa and globally. The findings informed an illustrative model on how the research was carried out. Six design research insights and principles conclude the study and encapsulate the contribution it makes to new knowledge on how teacher education practice can be progressively aligned with new content knowledge teaching and the teaching of sustainability concerns. Specific findings in the form of six research insights indicated that the fieldwork-based teaching practice experience proved a successful learning crucible to develop sustainability competences. The cohort of student teachers passed their fieldwork teaching practice despite inadequate covering of foundational concepts in school and university. The teaching of a catchment management strategy case study was valuable in all three phases of

research. A multi-contextual teaching and learning environment was successfully negotiated and navigated by the student teachers. The present Curriculum and Assessment Policy Statement does not speak to the reality on the ground, particularly in deep rural environments. A compulsory virtual Geography teacher training experience is recommended. Lastly, varied and broad responses to the noted multi-contextual challenges are needed in order to prepare and equip student teachers for the demands of the new environmental knowledge in the curriculum. Based on the groundwork provided by this study, there is scope for further research especially regarding the varied and broad responses to this new environmental knowledge in the curriculum.

Declaration of Originality

This thesis is entirely my own work and where I have used the work of other scholars, this has been referenced throughout.

The thesis has not been submitted for a degree at any other university.

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Ethical Clearance

This thesis has prior and ongoing clearance from the Rhodes University Ethical Standards Committee (ethics application sent on 25 November 2015). Letters of informed consent were faxed (they were also emailed on 23 June 2016) to the heads of School A and School C high schools on 4 May 2016, and emailed to the head of School B High on 11 May 2016. Letters of informed consent were given to the students who participated. A full briefing of the project was given to the students on 3 May 2016. Care has been taken to render anonymous any school or student mentioned in the study (see 3.2.2 for further elaboration on the ethics process).

List of Acronyms

CAPS	Curriculum and Assessment Policy Statement
CM	Catchment Management
CMS	Catchment Management Strategy
CRM	Catchment and River Management
FET	Further Education and Training
IWRM	Integrated Water Resource Management
KZN	KwaZulu-Natal
PIWM	Participatory Integrated Water Management
SES	Social Ecological System
TSPCK	Topic-Specific Pedagogical Content Knowledge

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1.1 Introduction

1.1.1. Overview

This study developed as a formative design research process centred on clarifying the inclusion of new environmental knowledge in teacher education. It set out to clarify topic-specific pedagogical content knowledge for the teaching of catchment and river management in Geography teacher education. The case study was designed as an iterative process with three phases of data generation and analysis that were undertaken during the teaching of Postgraduate Certificate in Education students at the University of KwaZulu-Natal where I lecture Geography Education. The research process unfolded in three successive phases to both develop and clarify topic-specific pedagogical content knowledge with a small group of student teachers. The iterative design work involved:

- Preliminary curriculum knowledge and exam performance analysis to design the formative course (phase 1),
- Delivery and analysis of the formative lecture series to enable student teachers to develop topic-specific pedagogical content knowledge and competences (phase 2),
- Analysis of student teacher teaching practice engagement during fieldwork and in rural classroom contexts (phase 3).

My role thus included that of a researcher, a lecturer, and an assessor/ researcher. Data were generated and reviewed within and across the successive stages of knowledge differentiation, and teaching and learning interactions over time. The research process included reflection with students as emerging professionals involved in the lectures, fieldwork and teaching practice programme. The successive stages of design analysis covered trajectories in new environmental knowledge, social-ecological systems, sustainability competencies, fieldwork pedagogy and a review of practice architecture in play in the rural education setting of the study. These successive focus areas served to develop, clarify and refine topic-specific pedagogical content knowledge for sustainability-oriented teacher education. The study was informed by the tenets of design-based research, in that topic-specific pedagogical content knowledge for both phases two and three was tested and analysed in a rural catchment Geography teaching and learning setting. Research at the nexus of topic-specific pedagogical

content knowledge and sustainability concerns is necessary for the teaching of catchment and river basin management within a social-ecological systems perspective for integrated water resources management in South Africa and globally. Thus, the study contributes to the realisation of some of the sustainable development goals, especially Goal 4 (Quality Education) and Goal 6 (Clean Water and Sanitation). The study aimed to contribute new knowledge on how teacher education practice can be progressively aligned with new content knowledge teaching and the teaching of sustainability concerns. The outcomes of the study are informing the design of a course text and pedagogy for postgraduate teachers of Geography.

1.1.2 Field of the research

The field of this research can be described as follows: Environmental Education, Catchment and River Basin Management (CRM), Curriculum and Assessment Policy Statement (CAPS), Further Education and Training (FET), Social Ecological Systems, Sustainability Competencies, Fieldwork, Topic-Specific Pedagogical Content Knowledge, Disciplinary Subject Knowledge, Design-Based Research.

1.1.3 Context of the research

The research study emerged from a publication entitled *Teaching Water* (Khan, Dickinson and Heath, 2014) that I worked on with two colleagues in 2014 for the Fundisa [Teaching] for Change Programme.[1] The joint writing of this teacher education text raised uncertainties and questions to which, at the time, we had little more than speculative answers.

The Fundisa for Change programme is a national network co-ordinated by the Environmental Learning Research Centre at Rhodes University, in which my university, the University of KwaZulu-Natal (UKZN), participates. I am a Geography Education lecturer at UKZN and participated in the Fundisa for Change programme between 2013 and 2015. Moreover, I have a long history in engaging with catchment management concerns in the KwaZulu-Natal area, both as a lecturer and as an active member of the Mountain Club of South Africa as well as a corporate member of the South African Planning Institute. The publication that I developed with colleagues for the Fundisa for Change programme sought to support teachers and subject advisors at the Further Education and Training (FET) level in South Africa to access new environmental knowledge and improve their teaching and assessment practice (i.e.

[1] The Fundisa for Change Programme is a national teacher education initiative that focuses on transformative environmental learning through teacher education (www.fundisaforchange.co.za).

develop their pedagogical content knowledge [Shulman, 1986, see below]) on river catchments and water issues. This was in line with the requirements of the Curriculum and Assessment Policy Statement Further Education and Training Geography curriculum requirements (South Africa. Department of Basic Education (DBE), 2011).

The Fundisa for Change programme is responding to the issue that teachers do not always have the requisite knowledge and have not been trained to teach a significant part of the new [environmental] curriculum knowledge that is contained in the Curriculum and Assessment Policy Statement (www.fundisaforchange.co.za). In the case of this study, which focusses on knowledge of catchment and river basin management, such knowledge is often also new to teacher educators, and historically it has not been well covered in earlier versions of educational policy such as Curriculum 2005: Lifelong Learning for the 21st Century (South Africa. Department of Education (DoE), 1997) or the National Curriculum Statement (South Africa. DoE, 2003). The articulation of more carefully framed knowledge of catchment and river basin management in the Curriculum and Assessment Policy Statement curriculum has national import, in that it will directly inform South African teaching practice, but teachers need to be adequately prepared to teach this new knowledge, as argued in the Fundisa for Change programme. This has also been proposed more broadly by the Department of Higher Education and Training which is putting in place new teacher education policy to focus more on the teaching of subject and disciplinary knowledge (Lotz-Sisitka, 2011; South Africa. Department of Higher Education and Training, 2011). Internationally, the study has the potential to contribute to the growing field of catchment management and how we teach this in relation to current water concerns with emphasis on the pedagogical processes of teaching such knowledge.

It is necessary to explain to international readers the progression and shifts of the South African secondary school curriculum. Since the advent of full participatory democracy in South Africa in 1994, there have been three major changes in the school curriculum. The first curriculum to serve the entire South African school population was introduced in 1995 (the National Assembly Training and Education Department curriculum), followed by the National Curriculum Statement (NCS) in 2003 and the Curriculum Assessment and Policy Statement (CAPS) in 2011. The first major shift was therefore in 1995 as this was the first time a unified curriculum had been constructed for all South African children, regardless of ethnicity. The second shift was in 2003 with the NCS, which was underpinned by Outcomes Based Education pedagogy. This was rather thin in content and was succeeded in 2011 by

the CAPS, which is a content-rich document. Therefore, with regard to Geography education and teacher education in South Africa, there have been many changes in the curricula over the past 26 years, some commendable, but others somewhat rushed and not always well thought through. This is particularly true in terms of curriculum history and changes restoring an emphasis on content knowledge, as can be seen between 2003 and 2011.

In terms of the context of this research, various critical sustainability issues facing the province of KwaZulu-Natal need to be considered. The issues mentioned in the Global Change Grand Challenge National Research Plan which comprise "ecosystem degradation, global warming, declining fossil fuel reserves, resource depletion, waste accumulation, inequality, rapid urbanisation, and food insecurity" all feature prominently in this province (South Africa. Department of Science and Technology, 2010, p.10). Food insecurity, which is driven by poverty, is furthermore linked to the study published by Nemai Consulting (2012) (see below in 1.1.4). As mentioned below, water and sanitation are critical issues in this province (Stephen, 2003. Another issue bedevilling sustainability in the province is gender inequality, especially in rural areas (Ndimande, 2001).

These sustainability issues also affect the three schools featured in the study. The schools fall within the Upper uThukela Location, part of the former KwaZulu homeland (Pearce, 2006, p. 348). The schools are directly affected by their rural setting (see Figure 3.2), sparse and minimal infrastructure and a history of poor education results. Teachers and learners thus need to negotiate and navigate critical sustainability issues in a multi-contextual school environment. This is also discussed in section 2.5.3.

After many years of indecision, the then Minister of the Department of Water and Sanitation promulgated the country's nine water management areas on 16 September 2016, and announced that a catchment management agency would be established for each, in terms of the National Water Act, 1998. The Pongola-Mtamvuna water management area is thus defined by the following parameters: "Major rivers include the Pongola, Mhlatuze, Mfolozi, Mkuze, Thukela, Mvoti, Umgeni, Umkomazi, Umzimkulu and Mtamvuna; Tertiary drainage regions W11 to W13, W20, W31 to W32, W41, W45, and the portions of W42, W43, W44, W57 and W70 falling within the boundary of the RSA; Primary drainage regions V and U; Tertiary drainage regions T40, T51 and T52" (South Africa. Department of Water and Sanitation, 2016, p.169). The last six named rivers flow off the Drakensberg or its foothills

and have catchments with varying levels of degradation and erosion. This water management area is a vast, diverse and challenging to manage.

1.1.4 New educational theory and consequences to the study

Geography occupies a somewhat diluted and contested place in the South African school curriculum (see 2.5). From Grades 4 to 9, Geography is offered as part of Social Sciences, and is compulsory. Typically half of the year is given to Geography and the other half to History. The aim of the combined subject is to offer History and Geography in as integrated a way as possible, and to offer a broad and non-specific education in the two subjects. From Grades 10 to 12, Geography is a dedicated Further Education and Training (FET) subject and is voluntary. The aim of FET Geography is to provide specific knowledge of the subject and prepare the learner for post-school study.

This study has been informed by an increasing concern for a Geography course to work more explicitly with pedagogical content knowledge as part of a process of disciplinary literacy or disciplinary subject knowledge. This was clearly seen during the fieldwork of this project: how different forms of knowledge intersected, overlaid and even sometimes did not intermesh well as a coherent multi-disciplinary field for Geographical studies. Lotz-Sisitka (2011, p.32), writing about a national case study on teacher professional development with three pilot studies, stated that “the pilots, however, recognise that teaching is a complex practice in which a variety of different forms of knowledge intersect, and the pilots therefore also investigated pedagogical content knowledge, and the relationship between knowledge, and teaching practice, i.e. knowledge-practices of teachers in training (in-service and pre-services)”. Given that phase three of the data collection was conducted during a teaching practice period, this is a salient point that informed the development of the study as an iterative process of design research for and with student teachers in the field of Geography education.

Powell (2018) noted that both content (substantive) and language use (syntactic) of the discipline have to be understood and applied by students, for the development of sound pedagogical content knowledge. Understanding one without the other will not be enough.

Shulman and Shulman (2004) show an important representation of the types of capital (moral, curricular, technical and venture) that are placed around the contexts of individual

and institution (where reflection is essential), community and policy/ resources. It is clear that for a well-functioning educational environment, these types of capital have to work optimally and together, and that a reflective process, plus synergy, is necessary between and across the individual, community and policy/resources. The authors clearly outlined the importance of how teaching and learning is supported by the provisioning of resources. This was noted during the fieldwork data collection phase, in particular, that was influenced by content knowledge developed during lectures and in the design of the fieldwork tasks that required foundational knowledge of and competence in mapwork, for example. The literature outlines five possible clusters of effective teaching attributes, namely cognitive, dispositional, motivational, performance and reflective clusters (Shulman and Shulman, 2004). These clusters are essential to the functioning of a well performing school and were used to inform and review the successive phases of the design research process..

Moreover, it was clear from perusing socio-economic indicators, sourced primarily from a study authored by Nemai Consulting (2012) for the Okhahlamba Local Municipality, that the area in which the schools are situated is characterised by poverty and welfare dependency. The local municipality is classified as “most vulnerable” (Nemai Consulting, 2012) and the poverty rate in 2010 was 78.1% (ibid.). The level of education was also cause for concern with only 15% of inhabitants reaching Grade 12 (ibid.). Only 4% of inhabitants are classified as “middle income” while 60% have “no income” (ibid.). This socio-economic background was essential to understanding the individual, community and policy/ resources prisms posited by Shulman and Shulman (2004) (the four types of capital especially the venture and technical).

Carney and Indrisano (2013) wrote about the importance of not only pedagogical content knowledge but also of disciplinary literacy, i.e. understanding the particular literacy of a subject or discipline, and socio-cultural perspectives on learning. The latter is concerned with how literacy processes are influenced by a community’s values, practices, attitudes, beliefs and objectives (ibid., p.43). These five attributes also informed the study as they were clearly evident in the educational landscape, land management practices, cultural belief system and other human settlement patterns in the upper uThukela area.

A paper by Lane and Coutts (2012) explored how secondary school pupils in Australia have alternative notions when it comes to scientific concepts and geographical concepts like scale

and spatial distribution. The authors described five essential attributes or perspectives of physical Geography, namely place, location, spatial distribution, interaction and interdependence (Lane and Coutts, 2012). Of interest for this study is that it appeared that alternative notions shaped common disciplinary misconceptions amongst Geography graduates during the data collection exercise (see Chapter Six). It also appeared, from the data collected during phase 3, that the five student teachers (who are Geography graduates) had problems conceptualising these physical Geography attributes and expressing them when teaching their learners. The writers also explained the importance of coherence across disciplinary subject knowledge and pedagogical content knowledge for Geography teachers.

Falk (2006), in an interview with Lee Shulman, wrote about 'signature pedagogies'. For this study I focused on catchment and river management, and mountain-oriented education as signature pedagogies in Geography, which derive both from my theoretical training in the field and my recreational pursuits in mountain catchments. I endeavoured to train teachers in the deepest way possible so that they developed a sense of consciousness for the mountains and its rivers. The pedagogy was both site-oriented and community-oriented.

1.1.5 Diagnostics and learning attainment

An overview of the South African Geography curriculum has been provided above in section 1.1.4. With regard to the examination process, at the end of the Further Education and Training phase, candidates write the National Senior Certificate (NSC) examination which is primarily based on Grade 12 content but is also informed by the preceding years (Grades 10 and 11). The NSC examination can be achieved with Matriculation Exemption (university entrance) or without it (which allows entrance to apprenticeships and educational institutions other than research universities).

The performance data from the nationwide school-leaving examinations can reveal challenges and issues for the teaching and learning of catchment and river management. The assessment standard for geomorphology in the Curriculum and Assessment Policy Statement (for the trial and end-of-year examinations) (under which Catchment and River Basin Management falls) comprises a *"short objective type question for 15 marks to cover content on Climate and Weather and Geomorphology"*, and another 30-mark question on geomorphology. These questions appear in both questions one and two in Section A of the exam. Learners must answer any three questions (from questions one to four), therefore it is

essential for them to answer at least one physical Geography question, which falls in both questions one and two (South Africa. DBE, 2011, p.58).

There was no explicit indication of problems with the catchment and river management section (which falls under the Theory Paper [Paper One]), in terms of the recent examination diagnostic report for the National Senior Certificate Geography Examination published by the Department of Basic Education in 2015). However, there was a general problem with conceptual thinking in terms of Physical Geography, and the diagnostic report states that the average marks per questions one and two (see above) (Physical Geography) for 2014 were 36 and 33, which compare poorly with questions three and four (Human Geography) where the average marks were 55 and 48 (South Africa. DBE, 2015). Thus, there is 19% and 15% difference between answering questions in either human or physical Geography.

Furthermore, in the 2015 diagnostic report, the following problems were reported with respect to spatial and map literacy: “d. candidates struggled to identify human-made features on the orthophoto map” and “e. candidates struggled to identify natural features on the orthophoto map” (South Africa, DBE, 2015, p.77). This has implications for the realisation of systems thinking and social-ecological system expertise on the part of candidates who opt to study to become student teachers.

Regarding the 2019 diagnostic report, it was mentioned that “most candidates do not have a sound knowledge of basic geographic concepts and therefore would not be able to answer questions of a high cognitive demand” (South Africa. DBE, 2019, p. 104). The diagnostic question analysis for Paper One showed average percentages of 50 for Question 1 (Climate and Weather and Geomorphology), 42 for Question 2 (Climate and Weather and Geomorphology), 46 for Question 3 (Rural and Urban settlements, and Economic Activities of South Africa, and 55 for Question 4 (Rural and Urban settlements, and Economic Activities of South Africa (South Africa. DBE, 2019). Thus there is an average percentage of 46 for the physical Geography questions (one and two), and 51 for the human Geography questions (three and four), showing a still significant difference in performance between physical and human Geography. However, this is not as pronounced as in 2015. An average percentage of 53 is given for catchment and river management compared to, say, 93 (the highest) for rural and urban settlements in Graph 6.3.2 (Average Marks per Subquestion as a Percentage in Paper 1) . The lowest percentage is 24 for river capture (South Africa. DBE, 2019). With respect to Paper Two (Mapwork), a highly significant percentage of 15 was

calculated for “fluvial feature interpretation” (see Graph 6.5.2 [Average Marks per Subquestion as a Percentage in Paper 2]). This was the lowest percentage recorded; the highest (67) was for statistical analysis (South Africa. DBE, 2019). In summary, “middle- to higher-order questions continue to be a great challenge to the candidates” and “the correct understanding and interpretation of map scale is required” (South Africa. DBE, 2019, p. 116-117). It is clear that candidates are still struggling with cognitive challenges and understanding scale.

Under “General Suggestions for Improvement”, the authors state the following (this has currency for how new environmental knowledge, including catchment and river management, is integrated in the CAPS curriculum [see also 1.1.7]):

> (e) Teachers must ensure that learners know all the geographical concepts and definitions required….
> (f) When a geographical problem is studied, learners should study the causes and effects, both negative and positive impacts, as well as possible solutions or sustainable strategies to be implemented….
> (g) Geography is a dynamic subject and new information on numerous topics is updated regularly…Teachers are therefore encouraged to collect resources on an ongoing basis and to be aware of current events that should be taught in Grade 12.
> (h) Teachers are encouraged to set source-based questions in class assignments, tests and examinations. They should use relevant and recent resources from the internet and avoid using sources that appear only in textbooks and are familiar to learners. Teachers should focus on the interpretation of diagrams, sketches, photographs, cartoons and graphical data (South Africa. DBE, 2019, p. 105-106).

This apposite advice will allow the introduction of new environmental knowledge from a secondary school level, and this will aid understanding at tertiary level.

Wilmot and Dube (2015) explained that Geography is still the fifth most popular school subject in the Eastern Cape Province (which is similar to KwaZulu-Natal in its deep rurality). However, there was a low level of achievement in the subject in the province (only 0, 5% candidates scored 80% and above in the 2013 matriculation examination). They identified the following issues: there is a wide difference between schools, problems with learning in the subject diagnostic report, and that poor subject knowledge of teachers is prominent. These

issues are also more widely reflected across the country in other subjects as shown in the Department of Basic Education diagnostic reports for the year 2015.

1.1.6 Water resource management issues of the day in South Africa – State of the Rivers

Knowledge of the conditions of South African rivers and catchment basins is essential for understanding the topic of the pedagogical research undertaken in this study. The South African National Biodiversity Institute's (SANBI) report (2005) identified that 80% of the country's rivers are "threatened" and of these, 44% are "critically threatened". It is clear too from the SANBI (2012) report that our rivers are under pressure**.** According to the 2012 report, only one third (33%) of the country's rivers are in "good ecological condition" (p.24). Furthermore, according to the report, there is an "uneven spread" of threat regarding rivers, and the few big rivers are "hard working". "Of the country's river ecosystem types, only 14% are well protected, one third are poorly protected, and half have no protection at all" (ibid., p.25). The Department of Water Affairs and Forestry (2013) has also published technical reports on the major and even minor river systems throughout the country. These reports outline the key and pressing challenges and issues facing the sustainability and well-being of South Africa's waters. Critically, pollutants continue to affect our rivers and reservoirs (with eutrophication being very prominent), and this is accelerating (Oberholster and Ashton, 2008). The document (*A CSIR perspective on water in South Africa-2010*) outlines the many threats facing water supply in the country. The document ends with these words:

> If we fail to radically improve our water quality management approaches and treatment technologies, we will face an inevitable outcome: a gradual decline in the volume of water available per person, progressive worsening of water quality, loss of biological integrity in our aquatic ecosystems, and continually rising costs associated with treating water for people to drink. Ultimately, this will prevent us from achieving social and economic growth and eliminating poverty. (Council for Scientific and Industrial Research, 2010, p. 65)

1.1.7 New environmental knowledge in the Curriculum and Assessment Policy Statement - Catchment and river management

From the abovementioned literature and findings for informing and framing the three-phase research process, it was clear that there was a need for new environmental knowledge on catchments and catchment management to be learned and for teachers to be supported to engage with such knowledge in the teaching of Geography. This has implications from both

epistemological (the nature of knowledge) and ontological (the underlying experiential dimensions) perspectives. This new environmental knowledge on catchments and catchment management is underpinned by government policy, research and the latest water and land management theory. At a teacher education level, there is a need for catchment and river management theory, and practice, to be studied and understood by student teachers attempting to teach the Curriculum and Assessment Policy Statement document in relation to the context and life experiences of learners. One cannot teach the Geography curriculum without understanding catchment and river management – this includes developing one's own notes and techniques for teaching sections of the curriculum that include knowledge of water and integrated water resources management, including catchment and river management (some of which are outlined above; water concerns are also integrated into different levels and phase of the curriculum). South Africa's present and/or impending water crisis is based on the fact that all of South Africa's water resources are already allocated, our rivers are being severely degraded, catchment management agencies are poorly or not functioning effectively, and South Africa faces additional water scarcity challenges under impending conditions of climate change which introduces uncertainty, and further complexity into the integrated water resource management system of thinking/ practice in South Africa (South African National Biodiversity Institute, 2005).

1.1.8 Global Change Grand Challenge National Research Plan (water quality and access)

The Global Change Grand Challenge National Research Plan, published by the Department of Science and Technology (2010, p.10) explicitly framed "water security for South Africa" as a key new knowledge area, framing it as a key knowledge challenge for South Africa under the wider framework of "Adapting the way we live". The Department of Science and Technology (2015) noted that the intersection of various climate, ecological, social, economic and global change concerns present a "polycrisis" that is characterised by complexity, and the need for substantive social learning-centred responses. This document emphasised the need to

> develop knowledge, skills, competences, values and practices that take account of the fact that the natural systems interact indivisibly with human systems, and that both now, and in the future, South Africans, like others on the African continent, and in all places around the world, will need to learn to cope with and respond to a multi-faceted polycrisis constituted by interacting forces that arise when ecosystem

> degradation, global warming, declining fossil fuel reserves, resource depletion, waste accumulation, inequality, rapid urbanisation, and food insecurity interact. (Department of Science and Technology, 2010, p.10)

The Global Change Grand Challenge National Research Plan stated further that a "complex system of non-linear interacting factors incorporating time-lags and spatial heterogeneity is unlikely to change in a smooth and predictable fashion when nudged in a particular direction…it is not known where the thresholds for sudden changes in future lie, since the global environmental crisis at the beginning of the 21st century is in many respects unprecedented" (Department of Science and Technology, 2010, p.10).

1.1.9 Social-ecological systems

An understanding of social-ecological systems was and still is imperative for teachers embarking on teaching about water security, and catchment and river management in the Curriculum and Assessment Policy Statement curriculum. Complexity, actors, change, scale, place and space are all integral to social-ecological systems (Norberg and Cumming, 2008) as well as to disciplinary subject knowledge. In our Fundisa-for-Change teacher education publication *Teaching Water*, we wrote about the need for systems and science thinking when teaching and learning about water: "Due to the need to understand water and water issues in a more holistic, socio-ecological way, teaching water will require that you have strong foundational knowledge of water and concepts that deal with water, water management and water choices" (Khan et al., 2014, pp.11-12).

1.1.10 Complexity theory

An understanding of complexity theory, which is allied to social-ecological systems, is essential to understand and conceptualise the 'polycrisis' facing the world. Norberg and Cumming (2008, p.279) wrote that "complexity theory provides a transdisciplinary, value-neutral body of ideas that together can be used to understand a wide range of macroscopic properties of the seemingly insurmountable complexity of the world in which we live", and also pointed out that the "challenge we face in securing development toward a sustainable future is to comprehend the integrated nature of the world we live in, the feedbacks and responses within the social-ecological system and the multilevel cause and effect relationships that govern its dynamics" (ibid., p.289).

Spatial variation is another key concept within the theory, and the authors suggested that local area knowledge and indigenous knowledge systems are important for getting all communities involved – as Norberg and Cumming (2008, p.290) pointed out "this includes biodiversity as well as the diversity of local ecological knowledge, institutional diversity and cultural diversity" (ibid., p.290).

A study of social-ecological system and all the factors that impinge on it is not complete without considering sustainability competencies. This is because understanding and activating a social-ecological system (which operates at different scales, levels and time frames) will depend on properly developed sustainability competences. Students were trained to identify and harness shaping or problem-solving competencies as per Wiek, Withycombe and Redman's (2011, pp.207-211) set of core interrelated competencies, namely "systems thinking competence, anticipatory competence, normative competence, strategic competence and interpersonal competence".

1.1.11 Integrated water resource management

As can be seen, integrated water catchment management is the new conceptual guiding framework for catchment and river management. However, the theory of integrated water catchment management in South Africa is often fundamentally different to the practice, in relation to the apparent functioning of its catchment management agencies. This calls for careful critical engagement with such concepts in teaching and pedagogy, and for supporting teachers-in-training to develop practically oriented critical understandings of such concepts, hence my growing interest in the clarification of both foundational knowledge and its relationship with fieldwork as a critical teaching and learning tool.

1.1.12 Argument for pedagogy and to re-emphasise fieldwork

From the abovementioned literature and findings for informing and framing the three-phase design research process, there was thus a clear need for clarifying pedagogy, encompassing topic-specific pedagogical content knowledge and disciplinary subject knowledge, to deal with the multi-faceted crisis facing water management in South Africa. The situation is worsening and thus urgent steps need to be taken in the next ten years. Geography education cannot be fully developed as a coherent and relevant field without a clear commitment to fieldwork (which is directly related to key sustainability competencies especially development of an understanding of social-ecological systems perspective as these are

experienced and found *in situ*). There is also the need to work towards the attainment of the sustainable development goals. This study has direct relevance to the following goals: four (Quality Education), six (Clean Water and Sanitation), eleven (Sustainable Cities and Communities), fourteen (Life below Water) and fifteen (Life on Land) (United Nations, 2015). Sustainable Development Goal four has particular relevance and applicability to the general aims of education for sustainable development in South Africa.

This study is furthermore a step towards improving or revitalising Geography teacher education through a social-ecological systems framework and pedagogy. This is where Geography education is becoming aligned with environmental education, whereby not only the content is taught but also methods on how to address the problem. A careful analysis of data was done to develop theory from the key trajectories and issues in the data. Topic-specific pedagogical content knowledge was built and developed through the course I taught. I was cognisant of the different roles I occupied during the three phases, and how these roles would have influenced data collection. A large part of the research process concerned generating data to deepen thinking about teacher education in rurality. The literature review was developed to explore how content knowledge and fieldwork are an essential component in developing new pedagogies for catchment and river management, but such fieldwork activities and practices need to be imbued with an understanding of complexity thinking and social-ecological systems thinking, spatial variation, integrated and adaptive forms of management, and critical engagement with the realities of theory and practice as these relate to catchment and river management. This study sought to examine how teacher education can support the development of this scope of knowledge and competence for teaching catchment and river management.

1.2 Content Focus Area and Problem Statement

1.2.1 Content

This study covers the following content: Environmental Education, Catchment and River Basin Management, Curriculum and Assessment Policy Statement, Further Education and Training.

1.2.2 Problem statement for framing the design research process

As argued above, the researcher identified a need to investigate, clarify and model a Geography pedagogy for the teaching of new environmental knowledge on catchment and river management in teacher education. The case study framing of an iterative research process was used to explore an approach that was inclusive of social-ecological systems, complexity, fieldwork practice and sustainable competence development. This broad, practical and open-ended design research approach was necessary if teachers were to be adequately prepared for teaching catchment and river management within a wider integrated water resource management framework that takes full account of the nature and complexity of catchment and river management in South Africa. This nature and complexity are, furthermore, becoming more apparent due to the prevalence of longer and more critical droughts across the country. These droughts in turn are leading to increased degradation of catchment basins, especially in the eastern half of the country.

1.3 The Framing of Formative Research Questions

To frame the study as an iterative process covering a content knowledge curriculum review, a lecture series and supervised teaching practice in a rural mountain catchment, the overarching question developed to guide the research process was:

> **How can a teacher education programme on catchment and river management be designed that is Curriculum and Assessment Policy Statement Geography-aligned and that reflects a complex social-ecological systems perspective?**

The following questions were developed to guide the design process:

- How did student teacher engagement with new environmental knowledge and fieldwork practices develop competencies that reflect grasping of a complex social-ecological systems perspective?
- What opportunities and challenges need to be addressed for teacher education and student teacher practitioners to develop such an approach?

1.4 Overview of Chapters

Chapter One

This chapter has covered an introduction to the study which encompassed the framing of an iterative design research process, a review of the critical context behind the study (including the key trajectories and issues derived from data), and the development of the problem statement informing the study. From the problem statement, the research questions served to frame an iterative research process of course design, implementation and review on teaching practice. Thus an introductory context was provided for the specific study and the chapter ends with an overview of chapters.

Chapter Two

This chapter is a literature review that covers the main lessons and tenets of catchment and river management which have been derived from the key theorists informing the study. Attention is given to the emerging field of montology, especially its links with catchment and river management and integrated water resource management. The latter and Geography teacher education (including pedagogical content knowledge and disciplinary subject knowledge) are also covered with the emphasis on Geography fieldwork. The key issues and trends relating to the curricula were also considered, and this serves to clarify the scope of the problem informing the study and in need of clarification through a design research process.

Chapter Three

The research methodology scopes the case study research process around catchment and river management pedagogy. In Chapter Three, this was developed to include a curriculum review, the development of the introductory lecture series and the design of the supervised teaching practice session with student teachers that followed at three schools in the upper uThukela basin, KwaZulu-Natal. Three iterative phases of the research process had the researcher undertaking a triple role. The first was that of a researcher, the second that of a lecturer delivering materials (both the content of catchment and river management, and how to teach this in an issue-based approach relevant to future sustainability) to students, and the third that of an assessor/ researcher.

The first phase was based on an analysis of what is actually in the curriculum (especially the difference between the theory within the curriculum and the reality of South African education). Regarding theory, this referred to the implicit knowledge and how it has been constituted and developed in relation to new environmental knowledge and catchment and

river management practices. Apropos the reality of South African education, attention is drawn to the state of Geography education and fieldwork in all schools, with particular attention on the conditions in rural high schools settings where many of the University of KwaZulu-Natal Postgraduate Certificate in Education graduates would have been teaching. Here data were generated through an analysis of curriculum documents to frame the proposed graduate teacher education programme, phase two. In phase two, the course delivery, content and activities of the lectures were fully documented along with student responses (through the use of questionnaires informing the student record). In this, design-based research aided in the analysis of how this phase informed the students. The third phase comprised taking the lecture-informed students into the field to work with the materials in a fieldwork context of meaning-making and lesson development. The teaching programmes prepared by the students were presented to learners at three high schools. The use of the materials and lessons on teaching practice was also tracked and assessed. Here data were generated through peer-on-peer observation sheets and focus group discussions with the teams of students developing materials and lesson plans, and through the formal assessment of assignments and presentations (design-based research). All this formed data for the study.

Chapter Four

The opening curriculum analysis covered the three national school curricula used in South Africa between 1994 and 2018. It showed the pleasing emphasis on social-ecological systems in the 1995 National Assembly Training and Education Department syllabus but also covered how this focus was lost to vagueness in the 2003 curriculum. Very little elaboration and clarity on catchment and river management left teachers vague and undecided about what exactly to teach, leading to the Physical Geography dynamics of catchment and river management being barely covered. However, in the 2011 syllabus, attention and elaboration were given to catchment and river management, detailing exactly what needed to be taught, and the necessary time and resources to do this properly. In this chapter, the diagnostic report on the National Senior Certificate Geography examinations was also covered. This showed how well (or not) the current curriculum was delivering in terms of examination results.

Chapter Five

This phase of the research covered the seven lectures, over and above the first part of the Postgraduate Certificate in Education course (which comprised lectures on an introduction to Geography teaching, spatial awareness, mapwork and fieldwork), that were given to the volunteer students at the Pietermaritzburg campus in 2016. The first two lectures of the

dedicated course covered the introduction to catchment and river management, and participatory integrated water management, and its reality in South Africa. Other lectures encompassed catchment management strategies, and the importance of the Maluti/Drakensberg water system. The last three lectures covered teaching and learning resources for catchment and river management, and social-ecological systems and sustainability competencies. The meaning-making in the lecture room was analysed and how this was carried into lesson planning by the student teachers. Questionnaires were given out at the end of each lecture and the answers have generated useful data. Constructive discussions were held in class regarding the lecture material.

Chapter Six

This phase of study was concerned with the students in the field. Here data were generated by use of formal assessments and the students' own assessment materials during teaching practice, reflective reports done by the students after consultation with their tutor (self), and audiovisual taping, by means of a smartphone camera. Students followed the formal assessment form used in Teaching Practice, and were assessed on this. After the lesson, a one-on-one consultation with the student enabled discussion of the lesson. Afterwards, students wrote a reflection report on their lesson. Lessons were also videotaped. Enablements and constraints were identified from the analysis of the students' work in the field. Disjunctures were discerned across what the students had been exposed to in lectures and their ultimate knowledge engagement practices in the field. The disjunctures explored were ascribed to a number of factors (both educational and socio-economic) that impacted on, but also enabled, student teacher performance. A number of key trajectories of issues were identified and tracked.

Chapter Seven

The synthesis of the iterative progressions in the design research process essentially covered the development of pedagogical content knowledge, including disciplinary subject knowledge in the teacher education classroom, and during fieldwork. Design-based research involved analysing how phases informed each other and the programme. Constructive work was done during fieldwork and to a lesser extent in the Teacher Education classroom, and out of this useful data were generated. It was found that much more attention needs to be paid to pedagogical content knowledge, especially in our assumptions that Geography graduates are adequately equipped and skilled to teach all facets of the Curriculum and Assessment Policy Statement curriculum. A number of analytical insights were generated, from the three phases

of the research: the curriculum analysis, the series of lectures, and the fieldwork experience. These phases fed into and informed the subsequent phases. The analytical statements or insights show the reality versus the ideal as evidenced by the literature. The research questions were thus answered, with the key finding that pedagogical competence in all aspects of the Curriculum and Assessment Policy Statement curriculum, especially the catchment and river management, and fieldwork imperatives, remain a challenge and that more work is needed across the lines of discontinuity uncovered in the study,

The analytical insights were then listed and probed for how these came into being and might be moderated in a revised course text. These were further unpacked using the methodology and the collected data chapters. The narrative encapsulates lessons learnt, trends noted and themes identified. Of specific interest was the problem of translating and contextualising between Chapter Five (the series of lectures) and Chapter Six (fieldwork and teaching practice). Recommendations, developed from the design work, followed in the form of design principles. These were critical for structuring and conceptualising a proposed Geography Teacher Education resource book on teaching catchment and river management within a rural South African context.

Chapter Two
Literature Review

2.1 Introduction

The structure of this literature review is to show firstly the crisis facing rivers, and therefore catchment and river management in South Africa. The pedagogy of catchment and river management is also covered. Secondly, there is a significant focus on pedagogical content knowledge and how it has been transformed into topic-specific pedagogical content knowledge. Lastly, the reality of both South African secondary education and tertiary education is covered, as far as it pertains to the subject focus of this study. This proceeded to the knowledge focus.

2.2 New Focus on Issues such as Integrated Water Resources Management (IWRM) and Catchment and River Management (CRM)

There is a growing body of research into watershed or catchment management worldwide but this is mostly European- or North American-centred, with some interesting research coming out of Asia, especially the foothills of the Himalaya (Bandyopadhyay et al., 1997; Hamilton and Bruijnzeel, 1997; Hamilton and McMillan, 2004; Achet and Fleming, 2006). Recently, the Dushanbe Forum of Mountain Countries in Asia (Mountain Partnership, 2015) reiterated the importance of integrated water management. South Africa too has an emerging tradition of integrated water resources management with most such research being supported by the Water Research Commission and by new policy developments that have established participatory structures for integrated catchment management under the National Water Act of 1998 (Lotz-Sisitka and Burt, 2006). The literature referred to within this section is the most recent I have been able to obtain. Not much literature concerning IWRM and CRM has been published in the last six years (2015-2021) and the few articles that have been are not directly relevant or applicable to this section.

Catchment management has been earmarked as the most important method of land management (Easter and Dixon, 1986; World Meteorological Organisation, 1994; Bandyopadhyay et al., 1997; Davies and Day, 1998) and a number of models of catchment management have been identified in the literature. These have relevance to this study, in particular with systems thinking and complexity theory imperatives (Hufschmidt, 1986; Gregersen et al., 1988; Ives, Messerli and Rhodes, 1997; Falkenmark, 2004). Easter and

Dixon (1986) maintained that water management cannot be undertaken successfully without a commitment to interdisciplinarity, a trend that is also observable in South African water sciences (Rogers, Le Roux and Biggs, 2000). Catchment and river management practices inherently contain a need for interdisciplinary fieldwork techniques and the development of sustainability competencies. These emerge in and through engagement with the complex social-ecological systems thinking necessary for catchment management (Rogers et al., 2000; United Nations Educational, Scientific and Cultural Organisation, 2010; Wiek et al., 2011, Project WET Foundation, 2014). This has implications for pedagogy, which I discuss in more detail below.

There are numerous publications and programmes that are beginning to provide useful pedagogical guidance informed by complex social-ecological systems thinking. For example, the United Nations Educational, Scientific and Cultural Organisation (2010) provides useful practical guidance on mountain water management systems. This has relevance to mountain-oriented education, a key feature of this thesis. An Australian initiative, Streamwatch, has many useful pedagogical and other suggestions on how to take care of streams and rivers (Streamwatch, 2012). In South Africa, the Mini-Stream Assessment Scoring System (mini-SASS) programme has developed social learning pedagogies that enable adaptive catchment management via citizen science (Vallabh et al., 2016).

Watershed or catchment management is also one of the cornerstones of the new science of montology, a body of work that is not well known in South Africa. Mountains generally belong in the peripheral and even politically marginalised areas of South Africa, and knowledge and techniques to manage them are not well known, or ignored. Mountains are significant in that they form the upper reaches of all catchments, and are therefore a key feature of catchment management.

Catchment and river management has also moved through phases in South African history, from when governments thought they could dam every valley to innovative but problematic inter-basin transfers, to the new emphasis on participatory integrated watershed management (Macleod, Scholefield and Hogarth, 2007). The emphasis on participatory integrated watershed management has led to South Africa promulgating catchment management agencies but these are either not working optimally or not at all (Versfeld, 1995; Ashton, 2000; Malzbender et al., 2005). This has implications for the teaching of catchment and river management because teachers in local areas should work with, indeed take guidance from, catchment management agencies but as the literature points out, the promulgated authorities

that should be in the lead are not working properly. Lotz-Sisitka and Burt (2006) argued that a key issue affecting the effective functioning of catchment management agencies in South Africa is a lack of attention to social learning, and the agency of people in the catchment. They offer a strong rationale for giving more attention to catchment management education at all levels in South African society, including in the formal schooling system.

There have, however, been some positive steps regarding catchment and river management in South Africa. Zunckel (2003) has shown how community involvement in the Mnweni area has helped combat *donga* or gully erosion by the building of gabions. There is also increasing clarity and valuing of the importance of the potential of ecosystems services that emerge from and in the Drakensberg area, which stretches from the north eastern Cape to the Royal Natal National Park areas (Maloti Drakensberg Transfrontier Park, 2007). These ecosystem services are essential for national development, water security and the well-being of people and enterprises in the catchment and downstream.

Regarding the teaching of the importance of managing drainage basins and catchment areas, as well as the impact of people on these areas, materials and theory developed by Swiss mountain geographers, together with their Ethiopian counterparts, proved useful in their African Highlands Initiative. In the late 1980s a team of Swiss mountain experts started getting involved in the East African highlands as a study area. They saw the area as needing interventionist tools. Many of the comments they made about the Ethiopian highlands can be seen as relevant for some parts of the Drakensberg, especially those under communal tenure, like the Mnweni. They discussed the human-environment system as well as erosion in African mountains extensively (Messerli and Ives, 1990). They included an 'African Mountain Model', based on the "biosphere, climate and soil" as points of departure (Messerli and Ives, 1990, p.13). Bernd Wiese (1990) also wrote about changing socio-economic conditions in African mountain areas and the fact that decision-makers should keep in mind long term perspectives and international best practice. Wiese's article contains excellent conceptual diagrams of maximising agricultural potential and minimizing soil erosion in mountain foothill environments, all aligned to altitude and gradient. Some of these diagrams also usefully include the local vernacular.

In addition, Hans Hurni's model, showing "intervention levels and activities in sustainable mountain development and resource management," (Ives et al., 1997, p.461) has proved to be influential. This model is an integrated and participatory theory that could advise a future

integrated catchment and river management model for the Drakensberg region. It is useful in that it stems directly from the work of the Swiss experts in the African Highlands Initiative, and it is nuanced and multi-faceted. Mountains are such delicate and involved systems that it is not enough to have good policy; what is needed is systemic and integrated processes that work together to either produce success or failure. This model shows five spatial levels, from the local to the global, namely "land, household, community, national and international", as well as all the processes that could respectively occur between them. These processes are "agricultural calendar, community land-use plans, inter-household collaboration, social organisation, national land-use plans, market development, participatory watershed management, extension systems, environmental conventions and treaties, and environmental and economic agreements" (Ives et al., 1997, p.461). Hurni (1997, p.211) has written that a "'multi-level stakeholder approach to sustainable land management' has been developed for finding feasible, acceptable, viable and ecologically sound solutions at local scales".

2.3 Integrated Water Resource Management and Geography Teacher Education

This academic nexus has to consider two knowledge areas, namely the growing field of mountain-oriented education (MOE) and hydrological/ catchment/ watershed theory attuned to education.

There are many references explaining and detailing the importance of the hydrological cycle in a watershed (for example, Figure 15.1 in Warshall, P., 1980 in Hamilton and Bruijnzeel, 1997). This has to be the point of departure in hydrology education.

The conference paper by Petersen (2007) is influential as it details the reasons for watershed or catchment education, as well as useful ideas for educational methodology. Petersen emphasised three methods for watershed education (lecture, field trip and seminar) in his conference presentation. There is a strong ecological and holistic focus in these three methods or modes of delivery, which creates sound methodology, as evidenced below:

> The lecture component will address watersheds as natural systems, and their importance to water resources, economic viability, ecological health, and other relevant aspects of sustainable development … the field trip will concern study of watershed environments and impacts, giving consideration to issues, problems and management … the seminar will involve discussing and applying information learned

> thus far, on critical review of existing materials, and on the presentation of student-produced lesson plans developed for as specific learning environment. (Petersen, 2007, p.179)

The example of watersheds and their interconnected nature to Science and Geography is well illustrated in this quote: “Watersheds provide excellent examples of natural /environmental systems as they function at the interface that integrates the hydrosphere, atmosphere, lithosphere, and biosphere” (Petersen, 2007, p.180). Petersen furthermore explained the far-reaching effects of disturbances to the integrity of a catchment or watershed as a physical/ natural system in the following statements:

> The environmental processes and components of a watershed are interrelated, and can be examined in the context of a local/regional subsystem of the hydrologic cycle. Problems in one part of the watershed system are likely to cause problems elsewhere, and watershed problems can also affect groundwater resources. … watersheds are open systems, and the main throughput is water, which is continually affected by the quality of inflow and the physical-human geographic conditions over which the water flows. (Petersen, 2007, p.181)

The author, moreover, showed the interrelated and holistic background of a geographical education, and its application to catchment management. In this Petersen stresses the need to *do* Geography and that geographic inquiry means accruing as much information as possible to understand and do something about a geographic problem (Petersen, 2007, p.182).

Useful literature is also emerging from the Alpine regions of Europe. Mountain-oriented education arguably has its origins there and, besides being a sporting playground, the Alps is an expansive educational laboratory. Mountain-oriented education (MOE) covers criteria, which are attuned to Geography and sustainable development, such as “global change, educational potential, educational tasks, teaching principles, educational interest” (YOUrALPS, 2017, p.10). The same publication lists a number of cogent learning objectives in a graphical illustration of learning objectives derived from 18 interviews. These learning objectives are focused around two central objectives, namely “discovering region/ surroundings” and “entrepreneurship”. Located around the former are sub-objectives such as “promotion of nature appreciation, authentical/ individual experiences” and around the latter, ones like “developing motor skills” and “knowledge transfer and acquisition.” Sub-objectives

like “personal development” and “(education for) sustainable development and lifestyle” are posited between the two central objectives (YOUrALPS, 2017, p.30).

Elfin and Sheaffer (2006, p.33) have explained how educationally useful a watershed or catchment can be to link theory and ground realities. In this “watershed-based education” allows for “sustainability approaches” such as managing “ecosystem-based models” which are then integrated within “geographic education.”

The two authors (ibid., 2006, p.36) further stress that:

> Stressing the watershed as a framework for geographic education reinforces geographic theory with sociospatial reality. Stoddart (1986) writes that ‘organism and ecosystem are of interest as alternative approaches to a central theme in geographical inquiry: that of the relationship of man and environment in area.’

Considering that the data collection of this study endeavoured to test the sociospatial reality with the theory on the catchment or watershed, this is a significant quote.

The use of Geographic Information Systems comprises a strong methodological tool to investigate, analyse and document the dynamics of a watershed or catchment. Geographic Information Systems for watershed investigations has included finding out about urban sprawl, *inter alia,* in a catchment (Bodzin and Anastasio, 2006). The relevance of Geographic Information Systems and even traditional mapwork to catchment management is wide-ranging, and it is difficult to conceive of managing a catchment without recourse to, and expertise in, geospatial information.

Borden et al. (2007, p.94) have written on a watershed studies (focusing on the Union River watershed) programme at an American college. What is of interest is the interdisciplinary nature of the programme, with a strong emphasis on sustainability competences and social ecological systems.

> With support from town officials … the goals of the project were: 1. to develop watershed studies as an area of concentration within the College of the Atlantic’s curriculum; 2. to build community capacity for participatory regional planning and for community watershed education; and 3. to create an electronic network for GIS data sharing and interactive modelling for community land use planning. The Watershed Curriculum – the operating premises behind the college’s work on this project were threefold: (1) hands-on learning – a pedagogical belief that a curriculum that enables

> students to apply knowledge to real problems can provide superior training for the students; (2) service-learning – a commitment to use the talent and resources available at the college to benefit the people in the surrounding communities; and (3) human ecological focus – the planning, work, and analysis should be ecologically based.

The courses of this programme cover a mix of both human and physical Geography and there is an emphasis on employable skills such as modelling and planning. Courses included, inter alia, the "human ecology" of the local river, "watershed community planning and decision making," "river conservation", "river ecology environmental education" and "introduction to a watershed approach to land use planning" (Borden, 2007, p.95).

A master's degree level integrated water resource management course is offered by a Swedish agricultural university (Krasny et al., 2009). This course appears to be strongly skills-driven and management-rich.

> In line with the paradigm shift taking place in water resources management in Europe … the Swedish University of Agricultural Sciences adopted Integrated Water Resource Management (IWRM) as the theme for a two-year master's degree programme starting in 2007. As a management practice, IWRM focuses on combining technologies, institutional strategies, and processes needed to facilitate the sustainable management of watersheds, rivers, and coastal waters in the face of conflicting demands. (Krasny et al., 2009, p.43)

Thompson et al. (2012), writing on integrating student-centred approaches into the pedagogy of catchment hydrology, have expounded on the importance of pedagogical content knowledge. Their key lesson was to vary teaching and pedagogical content knowledge to reflect the way that people learn.

The noteworthy importance of field experience and data has been shown in the abstract to the paper published by MacDonald (1993). It is clear that without field experience and field-derived data, the wrong conclusions will be drawn, and that the reality of space and time will be missed. No amount or level of trust in models will be able to replace data derived from thorough and holistic field experience. This is borne out in this quote:

> Recent assessments have emphasized the lack of a field and laboratory component in hydrologic education at the university level. Consequences of this lack include: (1) an unwarranted faith in published data; (2) lack of appreciation for the spatial and

> temporal variability of most hydrologic processes; (3) lack of appreciation for the difficulty of collecting good quality field data; (4) an inability to design and execute projects to collect field data; (5) a lack of field experience which can be applied when confronted with different problems or new environments; (6) an inability to evaluate published materials or models against the field reality; (7) an excessive reliance on, and trust in, theoretical or conceptual models; and (8) reduced potential for lifelong learning through observation and analysis. Field courses need not be costly or difficult, but the instructor must be willing to adapt to the uncertainty and problems associated with field measurements. (MacDonald, 1993, p.357)

This is also buttressed by this statement: "Learning is the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, cited in Krakowka, 2012, p.236). To elaborate, the creation of knowledge is generated through passing through Kolb's four learning stages (1984), namely Active Experimentation (planning before the fieldtrip), Concrete Experience (doing during the fieldtrip), Reflective Observation (observing and reflecting on the fieldtrip), and Abstract Conceptualization (thinking about the fieldtrip and key lessons learnt) (Krakowka, 2012).

In catchment or watershed education, there is a need for a strong Physical Geography component, which is sometimes lacking in the students' schooling. However, this issue is not confined to South Africa only. Bednarz, Petersen and Bednarz (2017) wrote that "precollegiate geography in the US currently emphasizes human rather than physical factors, and gives only a modest inclusion of sustainability issues (Petersen, 2007, p.179).

Many learners in KwaZulu-Natal and South Africa have little idea of where the water out of a tap comes from. While children may know the edge of the coast or the main transport routes within a province, very few know the courses of the major rivers and the critical high lying areas that are the water factories or headwaters. This mis-conceptualisation is not, however, confined only to South Africa and KwaZulu-Natal; it is also prevalent in the United States:

> Research conducted with elementary and middle school students shows that they do not usually think about water in dynamic, cyclical systems … they show little awareness of connections between water in one location and water in other locations … Students also have a variety of conceptions about watersheds…but rarely view watersheds as connected through the processes of evaporation, condensation,

> precipitation, and infiltration to groundwater, atmospheric, and biotic systems … (Gunckel et al., 2012, p.845)

2.4 Theory on Pedagogical Content Knowledge

Shulman (1986) proposed that pedagogical content knowledge is a special combination of content and pedagogy that is required in teaching. Other researchers (Borko, 2004; Shanahan and Shanahan, 2008) have argued that engagement with pedagogical content knowledge is important for content area teaching experts, and in this study, it is important for teacher education. Solis (2009) argued that there is a lack of research on content teaching in a range of contexts including countries such as the USA, the Netherlands, Britain and Australia. In South Africa this lack of research extends to teacher education, where there is a paucity of research on how teacher education practice influences content area teaching, a gap that this study worked into. Solis noted that, in Shulman's view, the key to distinguishing the knowledge base of teaching rests at the intersection of content and pedagogy, the core interest in the developing phases of the study. Shulman (1986) proposed several key elements of pedagogical content knowledge including (1) knowledge of representations of subject matter (content knowledge); (2) understanding of students' conceptions of the subject and the learning and teaching implications that were associated with the specific subject matter; and (3) general pedagogical knowledge (or teaching strategies). Solis (2009) also pointed out other elements that Shulman included to complete what he called the knowledge base for teaching: (4) curriculum knowledge; (5) knowledge of educational contexts; and (6) knowledge of the purposes of education. Carney and Indrisano (2013) also explained what domain (the breadth of knowledge), topic (depth of knowledge relative to concepts) and tacit (unexamined or unconscious) knowledges are.

According to Solis (2009), this conception of pedagogical content knowledge has been expanded over time to include a focus on the linguistic and cultural characteristics of a diverse student population. As can be seen from the design of this study, these elements of pedagogical content knowledge were considered throughout. Comprehending the substantive and syntactic components of the discipline is essential, as stated in a recent publication on pedagogical content knowledge:

> Returning to Shulman's conceptualization of pedagogical content knowledge, it seems clear that a key component of the development of pedagogical content knowledge is

> firm and grounded understanding of the 'substantive' and 'syntactic' structures of the discipline from whence the school curriculum was forged … (Powell, 2018, p.258)

Jing-Jing (2014, p.412) has described how Gudmundsdottir and Shulman (1987) "divided PCK [pedagogical content knowledge] into three categories, which were (1) knowledge of the central topics, concepts, and areas of the subject matter…(2) knowledge of the different ways topics can be taught, and the pros and cons of each approach…(3) knowledge of students' preconceptions and misconceptions about the topics they learn".

Jing-Jing (2014, pp.412-413), writing about pedagogical content knowledge components in the form of nature, principle and trend, also cited Grossman's explanation of pedagogical content knowledge, which proved to be highly influential:

> In her clarification, the construct of PCK includes four central components: (1) conception of teaching purposes- knowledge and beliefs about the purposes for teaching a subject at different grade levels; (2) knowledge of students, including students' misunderstanding, conceptions, and misconceptions of particular topics in a subject matter; (3) curricular knowledge, which includes knowledge of curriculum materials… and knowledge about both the horizontal and vertical curricula for a subject; as well as (4) knowledge of instructional strategies and representations for teaching particular topics.

Jing-Jing (2014, p.415) also described how Andrews (2001) included "teacher language awareness" in pedagogical content knowledge. In this awareness, strategic competence, language competence, and knowledge of subject matter are important.

Moreover, it is clear that pedagogical content knowledge cannot be approached without understanding disciplinary literacy which is developed through literacy development and sociocultural perspectives on learning. "Disciplinary literacy pedagogical content knowledge is grounded in essential theories and perspectives that inform literacy teaching and learning, and thus includes an understanding of literacy development (Alexander and Jetton, 2000) and sociocultural perspectives on learning (Alvermann and Moje, 2013; Gee, 2004; Heath, 1983; Vygotsky, 1978)" (Carney and Indrisano, 2013, p.42). Linguistic and syntactic acquisition is thus as important as knowledge acquisition. A sociocultural perspective leads to understanding the ways literacy processes are embedded within a cultural context and are influenced by a community's values, practices, attitudes, beliefs, and objectives (Heath, 1983,

1991). These five elements constitute cultural capital, and it is clear that any intervention in a community will not succeed without first comprehending what the cultural capital is. Carney and Indrisano (2013, p.43) described the use of a "pervasive filter" and explained what it means to be initiated into the "discourse of a community." In this the two authors refer to how social and cultural contexts act as a filter for all incoming experiences and understandings.

It is evident from the writers that the reading process or the acquisition of literacy can never be discounted, and that it is no use concentrating on subject material without considering subject literacy. As Carney and Indrisano (2013, p.47) stated, "we suggest that it is this synergy of subject matter content knowledge, pedagogical content knowledge, and knowledge of the reading process that provides the intellectual foundation for the pedagogical content knowledge that informs the teaching of disciplinary literacy".

It is clear from Beverly Falk (2006, pp.75-76), in her interview with Lee Shulman, that more and more expert pedagogy for student teachers will have to result, in the form of "signature pedagogies." Shulman went on to explain that really deep and far-reaching ways are required to educate teachers: "One way of addressing it is to imagine, to the extent we can, what are the ways of educating teachers that are the most profound and intentionally deep ways? What would we want to expect from the person/persons to whom we would entrust the responsibility for designing, enacting, and redesigning programs for teachers?" (cited in Falk, 2006, pp.75-76). Essentially, Shulman was calling for a new professionalism for teacher educators, so that the status of the profession can be restored.

According to Gudmundsdottir and Shulman (2006), for teacher understanding to result, a compact based on content, pedagogy and learner characteristics must occur and in their study of novice teachers compared to experienced teachers, the role of potential mentors or master teachers was crucial (cited in Falk, 2006, p.69). Perry (2013, p.48) cited the framework proposed by Grossman, Schoenfeld and Lee (2005), which was based on a series of six inquiry-oriented questions: "The questions guide teachers in an investigation of the content knowledge, teacher orientations, student understanding, curriculum, assessment, and instructional strategies related to a specific subject". These questions were not meant to be definitively answered immediately but rather to serve as markers or guides over a career. Perry went on to say that the use of the framework "to synthesize the research that defines the

knowledge base and best practices in sustainability education provides a model of interdisciplinary teacher learning for integration into multicultural teacher education programs" (Perry, 2013, p.48).

Lane and Coutts (2012, p.221) stated that the proper remedy is to focus on both disciplinary or domain subject (topic-specific) knowledge and pedagogical content knowledge: "An essential first step in the development of pedagogy for improving geographical understanding is to ensure that teachers of Geography are adequately equipped in terms of both their *domain specific knowledge* and *pedagogical content knowledge (PCK)*". One cannot be approached or dealt with without the other receiving the same attention. In addition, "effective teachers of Geography require a deep knowledge of the scientific principles that underpin key concepts in the curriculum, an awareness of the common alternative conceptions students hold in these areas (PCK) and knowledge of evidence-based approaches for promoting conceptual change" (ibid., p.221). Spatial thinking is also connected to topic-specific pedagogical content knowledge. Jo and Bednarz (2009, p.6) shared a taxonomy of spatial thinking. This taxonomy contains three levels or components of spatial thinking, namely 'Complex-Spatial', 'Simple-Spatial' and 'Primitives'. Another level or component of 'Non-spatial' was also given. It appears to be impossible to conduct Geography as a discipline without referring to this taxonomy and all the geographical features and verbs that fall under this taxonomy. Golledge, Marsh and Battersby (2008) have also provided a framework for geospatial thinking. Their five-level scope and sequence of geospatial concepts ("Primitive, Simple, Difficult, Complicated, Complex") on page 294 provides a very accessible and clear framework of identifying and categorising geographical concepts. Every geographical phenomenon, concept and feature falls under one of these concept levels. It is necessary to understand all these different concepts and the associated geospatial thinking to be well versed in geographical pedagogical content knowledge.

Another feature of geographical pedagogical content knowledge is its relative fragility as a discipline amongst even well-qualified teachers. In the study conducted by Arenas-Martija et al. (2017) it was found that nine (according to the sample) Chilean secondary school teachers of the subject had fragile pedagogical content knowledge, and that the teachers considered Geography to be of "marginal knowledge in the school curriculum, although they also consider it relevant to the education of their pupils". Although the circumstances of the Chilean schooling system are different to South Africa's, there are parallels in this country of

the fragility of geographical knowledge, and of its disciplinary standing compared to the 'big three' subjects of English, Mathematics and Physical Science.

2.5 The Realities of South African Secondary Education

2.5.1 Teachers not consulted about curriculum changes, and attendant haste

There is no local Geography association in South Africa to represent Geography teachers in their dealings with government officials. An association such as the United Kingdom Geography Association would have been able to mobilise participants, conduct publicity via the media, and present a unified and authoritative voice to proposed changes in the curriculum, all of which did not happen amongst Geography teachers in South Africa before the National Curriculum Statement was implemented. Nel and Binns (1999, p.127) decried the lack of a local association in promoting the integrity of school Geography, and pointed out with respect to school sector geographers, "the perceived lack of interest and support which they receive from academic geographers". This was also short-sighted and self-defeating on the part of the particular academics as Geography at university level can only thrive on the basis of the success or performance of school Geography. This perceived lack of interest could also stem from the traditional condescension amongst academics regarding what happens at the school level, an attitude that is not enabling to either side.

Ballantyne (1999, p.75) also indicated the lack of consultation that occurred between the curriculum planners and the education community, regarding Curriculum 2005. He specifically used the phrase "top down" and stated that the process was "not transparent", and that it did not have "the support of geography teacher educators" (i.e. lecturers) (Ballantyne, 1999, p.76).

The pressure to produce, and the attendant hurriedness, of Curriculum 2005 has also been described by Nakabugo and Siebörger (2001, p.53). Bizarrely and counterintuitively, outcomes were foregrounded before any discussion of any other pedagogical structures. These authors noted that "a key feature of Curriculum 2005 was the decision (made before any substantial discussion had taken place) that the first aspects to be developed, before any other structures had been conceptualised, were the outcomes" (Nakabugo and Siebörger, 2001).

Wilmot and Dube (2015, p.2) have also heavily criticised the headlong rush to Curriculum 2005, without the necessary thinking through the desired changes, leading to "a feeling of despondency among many teachers".

2.5.2 Political transformation versus disciplinary integrity

Jansen (1999) has explored the rush that accompanied the curriculum changes in the latter half of the 1990s and the somewhat superficial (he points out the essential alterations that should have occurred) result of these changes. This can be explained in the less than total political victory that the African National Congress political party had in 1994, and that the changeover was the consequence of many compromises and constraints. "The haste with which the state pursued a superficial cleansing of the inherited curriculum is explained in terms of the political constraints, conflicts and compromises which accompanied the South African transition from apartheid" (Jansen, 1999, p.57).

Le Grange and Beets (2005, p.274) stated that "South Africa's choice to implement transformational OBE rather than traditional OBE involves a shift away from a discipline-based knowledge structure to integrated learning areas, presumably to address the country's socio-politico-economic needs (for a detailed discussion see Wilmot, 2005, p. 70)". This emphasis on the socio-political instead of the integrity of the discipline and its content would have fateful consequences for the status of the discipline.

Le Grange and Beets (2005, p.274) also pointed out

> for example, the principles on which the NCS for FET is based are the following: social transformation; outcomes-based education; high knowledge and high skills; integration and applied competence; progression; articulation and portability; human rights, inclusivity, environmental and social justice; valuing indigenous knowledge systems; credibility, quality and efficiency. To date no guidelines have been provided to show how these principles are to be integrated in learning programmes.

Of these principles, six could be classified as socio-cultural-political and the rest (seven) correctly belong to disciplinary knowledge and skills. There is nothing inherently wrong with these political aims, especially social and environmental justice, but not enough foregrounding was paid to the real disciplinary knowledge that was necessary for the subject in the 21st century. Nel and Binns (1999, p.119) also pointed to the apparent precariousness of Geography in the new curriculum structure, and cautioned that it will take "generations"

rather than years to transform South African society, as in all countries emerging from obsolescent periods. The need to protect the integrity of the discipline, as well as the transformative nature of Geography, has been emphasised by Nicolau and Davis (2002, p.19) in the millennial era:

> Geography as a discipline has a unique ability to enhance cross-cultural and national understanding and its essential focus on people-environment relationships make it an important discipline in the process of transforming South Africa to a new democracy…we believe the rest of the restructuring discipline should be encouraged. However, any changes that are made should ensure that the integrity of the discipline is protected at all costs.

According to Chisholm (2005, pp.198-199), "…the environmental lobby sought recognition of environmental issues across the curriculum. It emphasized the importance of the principle of the integratedness of knowledge by reference to the inter-relatedness of environmental, developmental, and educational issues. Through a Ministerial Advisor on Environment, this lobby sought to raise knowledge, skills, and awareness of sustainable development in all learning areas. And so, 'a healthy environment' became a key concept in the curriculum (DoE 2002a)." This was a pleasing and necessary component of systems thinking and the balance between Physical and Human Geography.

Van Harmelen (1999, p.80) claimed that school Geography for most learners is regarded as little more than "book knowledge", and that learning is "de-contextualised" and "largely dependent on the rote learning". The author also pleaded for the specific systems-thinking and physical/human geographies strengths of Geography: "the application of this systems approach in the geographical context of time, place and space…is an enabling framework for the identification both of the essential concepts that provide geography with its unique character and for their development as interconnected and contextual constructs" (ibid., p.81). Indeed, as aforementioned, it is a tragic and shortsighted mistake to treat Geography as a humanities subject – once one 'disconnects', 'de-sciences' and 'decontextualises' Geography, it is no longer a subject of integrity.

It has been shown that Physical Geography results are lower than those in Human Geography in the National Senior Certificate Geography examination. This issue, however, is not unique to South Africa. Lane and Coutts (2012, p.205), in a study on Australian secondary school students, showed that alternative notions regarding Physical Geography processes and

concepts (to do with tropical cyclone causes and processes) exist: “Results indicate that secondary school Geography students (*n* = 339) hold a range of alternative conceptions related to foundational scientific principles as well as the geographical concepts of location, scale, spatial distribution, interactions and interdependence”. The misconception of scale and spatial distribution in particular are germane to this study, and will be covered in Chapter Six. Physical Geography is far more scientific than Human Geography in its scope, conceptions and processes. Furthermore, it marries concepts such as place and location that are learnt in Human Geography to Science: “Physical Geography involves more than the study of scientific processes and principles. It also includes the uniquely geographical perspectives of place, location, spatial distribution, interaction and interdependence” (Lane and Coutts, 2012, p.206).

The lack of symmetry and disciplinary integrity regarding Physical and Human Geography started in the planning of Curriculum 2005 (C2005). There was a socio-political reason for this as disadvantaged pupils traditionally did much better in Human than Physical Geography (for which an understanding of Mathematics and Physical Science are necessary). A reason could have been to make the subject ‘easier’ and ‘more accessible’ to the vast majority of learners. However, if one dilutes the Physical Geography (this point has already been made above), one is left with more of a humanities subject than one in a science discipline, and this has had, tragic consequences for disciplinary integrity. The real strength of Geography is located in how it straddles the human and physical worlds. If the science is taken out of Geography, one is left with a subject that does not really exist. Ballantyne (1999, p.76) referred to the disquiet experienced by Geography teacher educators regarding Curriculum 2005 and the disjuncture between the teaching of physical and human Geography. Indeed, these educators wanted to know “how can you teach ‘human’ geography without referring to aspects of ‘physical’ geography?”

Regarding the Curriculum and Assessment Policy Statement (South Africa. DBE, 2011), there is much greater synergy between the Physical and Human Geographies and furthermore Wilmot and Dube (2015) write that an aim of the 2011 curriculum is to elaborate upon the ever-changing relationship between the physical and human environments or worlds. The concepts of dynamism and relationship between the two Geographies are thus critical in this document.

2.5.3 Status of teaching today including quality control

Wilmot and Dube (2015, pp.1-5) explained that Geography is still the fifth most popular school subject in the Eastern Cape Province (one of nine South African provinces, and with similarities to rural KwaZulu-Natal). However, there is a low level of achievement in the subject in the province (only 0, 5% candidates scored 80% and above in the 2013 matriculation examination). Issues they identified included the wide difference between schools, problems with learning in the subject diagnostic report, and that poor subject knowledge of teachers is prominent. These issues are also more widely reflected across the country in other subjects as shown in the Department of Basic Education diagnostic reports (South Africa. DBE, 2015).

Regarding continuity and progression in the curricula, Beets and Le Grange (2008, p.68) "conclude that elements of continuity and progression are evident in both the Human and Social Sciences document of Curriculum 2005 (C2005) and the Revised National Curriculum Statement (RNCS) for Social Sciences. However, several shortcomings concerning continuity and progression are evident in the documents, requiring teacher competence in both geographical and pedagogical knowledge", something which the authors state cannot be taken for granted. This comment is aligned to Human Social Sciences (not Further Education and Training Geography) but considering that Further Education and Training Geography is dependent on disciplinary knowledge taught during Social Sciences (which falls under the General Education and Training phase), it cannot be discounted.

Wilmot and Dube (2015, p.2) characterised the Curriculum and Assessment Policy Statement (South Africa. DBE, 2011) as representing "yet another attempt by the state to address the ongoing challenges of low-quality learning outcomes." There is indeed an element of incipient desperation on the part of the state to get the education system working and it is certainly hoped that the Curriculum and Assessment Policy Statement will prove to be viable and not a last ditch attempt by the state to evince reasonable educational outcomes.

There is a fairly extensive range of references dealing with the problems of mapwork interpretation in South African schools. Among the reasons for the underperformance in mapwork are historical, academic and linguistic. Schools (and by extension mapwork) in black areas were underfunded compared to their white counterparts (Innes, 2012). Innes and Vander Willigen (n.d., p.1), writing about a GIS-based programme to teach map analysis,

noticed that learners "taking Mathematics and Science along with Geography had a positive impact on spatial competence" and that "speaking a language at home that is different to the language of instruction … had a slightly negative impact on results".

Innes (2012, p.102) indicated that, "in a recent attempt at the collaborative writing of topographic map analysis exercises, 70% of the questions written by a group of 108 practicing (sic) senior geography teachers were rejected because they were inappropriate or the answers they had provided to their own questions were incorrect".

Ormrod and Cole (1996, p.37) have shown that in the United States there was a problem with content knowledge serving teachers. Furthermore, the authors speaking of United States' Geography teachers, explained the shortcomings of the teaching or pedagogy of Geography: "Geography is a discipline for which many teachers have little content knowledge or pedagogical content knowledge". These comments show that disciplinary content knowledge is as big a problem in the United States as it is in South Africa. It also points to a threat to the discipline, in that if a discipline does not have integrity of knowledge or content, it can be dismissed as a 'light' or weak discipline. Considering that social-ecological system theory is about considering both social and ecological factors and processes, this is very significant.

There is a vast difference between the examination results of the three main classes of schools in KwaZulu-Natal: private, ex-'Model C' plus ex-House of Delegates schools (i.e. formerly 'white' and 'Indian'), and ordinary state (including 'no fee' schools). The highest results are achieved by a tiny number of select, and geographically and materially privileged schools, not necessarily private, that are staffed by dedicated and well-qualified teachers. The situation for mainly African schools is unfortunately the polar opposite: "Poor leadership, low staff morale and high rates of absenteeism are common in many African schools. Some 46 percent of African teachers were under- or unqualified in 1994, compared with 29 percent of Coloured teachers and only 7 percent of Indians and 1 percent of whites" (cited in Lemon, 1999, p.96). This quotation, while dated, is regrettably still accurate. The focus should however not really be on the qualification but on rates of absenteeism (for both staff and pupils) and dedication.

Achievement rates in the National Senior Certificate and the income of one's parents are inextricably connected and this nexus has worsened since 1994. The political changes also led to major changes in the way schools were run, and a minority of former state schools were effectively privatised. There are schools in the greater Durban area that are charging

R41 000 annually per pupil, and the difference between results for those schools and the no-fee schools are enormous (*City Press*, 1 November 2015).

According to the *Independent Online* (31 December 2015), a number of KwaZulu-Natal schools were implicated in group copying in the National Senior Certificate examinations. Geography was mentioned as one of the subjects implicated.

2.5.4 Skills and fieldwork

Wilmot and Dube (2015, p.10) noted that while fieldwork is considered important in the literature, it is simply not happening in the schools they surveyed (in the Eastern Cape province); in fact, fieldwork is rarely undertaken in 'no fee-paying' schools. The authors cited Dube (2012) who found that "the barriers that hinder the fieldwork activities include 'financial constraints, shortages of time, a large workload, an examination-oriented system, large classes and an ambiguous policy message on fieldwork'". Raath and Golightly (2017) found that the use of the mini-stream assessment scoring system (mini-SASS) was appreciated by students at their university in a problem-based learning fieldwork exercise. Skills development and social skills were some of the positive results of the exercise.

2.5.5 Higher education curriculum issues in South Africa

It is clear that with the world on the cusp of the fourth industrial revolution, and the onset of artificial intelligence (AI), plus the sixth great extinction of species, the curriculum that students will have to follow will have to change drastically to meet these new challenges. Universities can no longer pretend or aim to be to be ivory towers; to ensure the survival and relevance of the university model, universities will have to work far closer with communities on real world problems. This is borne out in the following quote by the Council on Higher Education (2016, p.14):

> Beliefs about what higher education is for tend to shape higher education systems, determine institutional identities and influence what they do. The second major trend globally that affects all systems, is the fundamental shift in the way knowledge is defined and understood, and how this affects purpose. The change in the status of knowledge in this narrative has a direct implication in changing the role of the university as an autonomous institution that furthers the pursuit of what is understood to be truth to … or, on the other, an institution that is embedded in its communities and becoming more engaged with real-world problems and concerns in both its

> practices and its scholarship. The democratisation of knowledge has been enhanced through the rapid development in information and communications technology, different modes of delivery and different sites of production.

The study is also contingent on an understanding of interdisciplinarity, and the context of knowledge being in rapid flux, by the participating students and researcher, as can be seen below:

> A corollary of this view is that the skills indispensable to the furtherance and maintenance of the economic and social systems become core to the academic project … On the one hand, skills are needed to fulfil society's own need for internal cohesion … but to develop … teachers … to meet pragmatic ends … Simultaneously, discipline boundaries, where disciplines have traditionally been the organising precepts of knowledge domains, are becoming more porous, with interdisciplinary studies becoming more commonplace – particularly in professional areas where knowledge from across many disciplines is called for to solve particular problems. What counts as knowledge in in rapid flux, and this has major implications for how higher education is organised, for curriculum, for research and for teaching and learning. (Council for Higher Education, 2016, pp.14-15)

2.5.6 Geography *vis a vis* Environmental Education and Education for Sustainable Development

Geography and its curriculum are properly placed to teach sustainable development and by extension, watershed management or at least take the dominant role. The key knowledge traditions of Geography have been explained by Bednarz (2006, p.237) who located Geography centrally as a proper science: "American geographers have, from the beginning, characterized a major component of geography as the study of the man-land, human-environment, or environment-society relationships". Bednarz (2006, p.238) moreover has reiterated the centrality of Science to Geography:

> Turner's (2002, p.53) conception of the nature of geography, that 'from its modern foundation, geography has designated itself a science, and it prospers less when this role diminishes' is obviously not shared by all geographers. It should be noted, however, that he argues for a very broad interpretation of science, and he recognizes that geography embraces most ways of knowing.

Many subjects are potentially suited to teaching sustainable development. Bednarz (2006, p.239) has quoted Huckle's views, however, on the responsibility of Geography to cover most aspects of sustainable development teaching: "Geography has been given the major responsibility for delivering education for sustainable development".

Two quotes by Kyburz-Graber, Hofer and Wolfensberger (2006) and Lugg (2007) show the criticality of "real-life situations" generating relevant knowledge, and explain that there is a "crisis of education":

> Thus, the challenge for environmental education is to provide learning situations in which learners have the opportunity to explore, analyse and interpret human actions in real-life situations and to search for solutions with the participation of the people concerned. Meaningful starting points for socio-ecological environmental education are, therefore, not environmental impacts and general environmental topics … but real-life situations (socio-economic contexts) in which people are involved in their daily lives…. Environmental issues are treated as social-contextual constructions of the people involved. When learners interact with those constructions, they can generate local and socially relevant knowledge; they can reflect on values and value systems, explore conditions of action, and work on possibilities for individual and structural change. (Kyburz-Graber et al., 2006, p.104)

> The kind of education we need begins with the recognition that the crisis of global ecology is first and foremost a crisis of values, ideas, perspectives, and knowledge, which makes it a crisis *of* education, not one *in* education. (Orr, 2004, p.5 in Lugg, 2007, p.99)

Nine examples of knowledge and skills "that should be attained by sustainability-literate graduates" as posited by the Higher Education Academy (2006) and quoted in Lugg, 2007, pp.102-103) are: appreciation of discipline contexts, knowledge of sustainable development, problem solving skills, creative thinking, self-reflection, holding sustainability values, bridging gap between theory and practice, interdisciplinary teamwork, and change making. These are skills Geography teaches and that prepare learners for the world of work. "However, all authors qualify their claims by emphasizing the importance of spending *extended periods* in outdoors environments and of *careful facilitation* of the experiences" (ibid., p.105). "In arguing that direct experience of nature and natural processes can engender

a connection with the environment, Higgins and Kirk (2006) emphasize the sensory, affective and cognitive potential of the outdoor experience as a catalyst for SE….” (ibid., p.106).

2.5.7 Concerns regarding the knowledge focus

It has been found that there is a gap in the knowledge whereby integrated water resource management and teacher education within an African context has not been covered sufficiently well. The literature is essentially western European and North American with some Asian and Australasian input. There is scant exposure to integrated water resource management and teacher education experience with African practitioners. This is particularly so within a mountain-oriented environment, which could indicate that integrated water resource management or integrated catchment and river management is a bridge too far for rural Africa at the moment. No incorporation of African-based indigenous knowledge systems exists either. Among the issues and trends covered by the literature review, the importance of mapping and spatial literacy was mentioned, as was the need for field data, from extensive field experience, to ‘speak’. Spatial data in a catchment should be recorded and even, if necessary, modelled to determine trends. Another characteristic that emerged from the literature is that catchment areas are very appropriate settings to test the socio-spatial reality. Pre-university training in Geography is also weak leading to problems during tertiary training and beyond. Amongst these problems is a tendency on the part of learners and students to hold scientific misconceptions. It is thus clear that the research methodology as explicated by phases 1 to 3 needed to be properly set up to explore this gap in knowledge. The chapter that follows describes the research methodology in detail.

Chapter Three
Research Methodology

3.1 Introduction

This study was developed as a research project towards the design of a teacher education process for the inclusion of new environmental knowledge on catchment and river management. The purpose of the study was to inform the development of a teacher education curriculum text on the teaching of catchment management in the current Geography curriculum. As an iterative design research process to this end, the study was framed as a qualitative case study in the interpretivist paradigm. It was qualitative as the study relied on different individuals and realities (though equally valid), and also because the study was primarily interpretive and exploratory (Leedy and Ormrod, 2010, p. 106). The interpretive design was used as the study is concerned with understanding and analysing a phenomenon through gaining new insights and developing new perspectives (Leedy and Ormrod, 2010, p.136). The research was integrated in and aligned with my professional teacher education work practice as a process that was undertaken with five participating Postgraduate Certificate in Education students who undertook a period of teaching practice in three schools in a rural river catchment context.

The methodology for the iterative design research work was influenced and informed (to a degree) by my pedagogical observations as a Geography lecturer on fieldwork with students and in the challenges of writing the publication *Teaching Water* (Khan et al., 2014). It became clear that there were gaps in the grasp of suitable teaching and learning practices for catchment and river management at a typical rural South African school/s and a need to more closely research commonly-held ideas on pedagogy for informing teacher education Geography courses on catchment and river management.

A research strategy was necessary as I wanted the site and emerging data to inform the questions arising in our work on the inclusion of catchment management as a new arena of environmental knowledge in the Geography curriculum. This led me to integrate a design-based research process in my teaching so as to work with my students to clarify how to teach river and catchment management in Geography.

Design research or design-based research has a long and diverse history emerging in the 1990s in collaborations on practical problems in education, and developing towards solutions

that inform our methods of teaching particular topics (there is more on design-based research in the next section). For this study, I have taken a pragmatic perspective around the practical problem of developing pedagogy in teacher education for the teaching of catchment and river management in Geography. With this in mind, I developed this study as a design-based research case study in three work integrated research phases with the purpose of informing pedagogical practices for the topic of catchment and river management. The study is intended to inform the design of a proposed course resource book on the pedagogy of catchment and river management in a rural South African setting.

Phase 1 was developed in order to clarify the subject matter knowledge for the new content around catchment and river management. There was a need to research the changes in curriculum regarding the topic and the associated systems thinking, especially in the latest iteration of the national curriculum statement. In this phase I was acting as the researcher within my professional role of developing teacher education courses in Geography Education.

The second phase researched the lecture-based delivery of this key knowledge to selected group of students. In this phase I was acting as a lecturer with some researching of the student responses towards the lecture material. This phase involved research and developing lecture material. A key concern in the developing pedagogy was fieldwork as the initial exploration of the content was tested and refined (Phase 3) in fieldwork sessions in a major river catchment. This comprised the need to observe students learning the concepts and teaching the material to school learners on teaching practice in the field. The student teachers drew together these data and experiences into perspectives and pedagogical principles for teaching the topic in a rural setting in the foothills of the northern KwaZulu-Natal Drakensberg. In this phase I was the teaching practice assessor but also a researcher. This was therefore a critical dual role.

3.2 A Case Study Design

The methodology for this study was oriented around the development of a teacher education programme on catchment and river management to explore an engagement with complex social-ecological systems perspectives as outlined in the previous chapter. The case study therefore comprised the phenemona of learning the pedagogy of catchment and river management by students and the teaching of it by the selfsame students in the field. As such, the research programme was orientated around the generating of data to inform the design of

materials for a new environmental knowledge of catchment and river management, which is implicit in recent catchment and river management theory, and to explore pedagogical practices that exemplify this. The proposed research was formulated as a design-based research case study.

Yin (2009) defined case study research as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the phenomenon and content are not clear. Somekh and Lewin (2011) defined case study research as an approach that seeks to engage with and report the complexity of social and educational activity. In the case of this study, the complex social and educational activity was a three-phase process that explores curriculum, a series of lectures and the teacher education students that I worked with on the teacher education module. According to Yin (2003), case studies are best used when one intends to answer the 'how' and 'why' questions which seek explanation. As indicated above, I sought to answer a 'how' question, namely how one might develop a teacher education module and pedagogy oriented towards teaching complex social-ecological systems for teaching catchment and river management in Geography education.

3.2.1 Boundaries of the case (and sampling)

The case study was limited to one university lecturer, five postgraduate students (nine initially volunteered for the study at the beginning of Phase 2, but four dropped out before Phase 3 commenced), and a particular university campus and three secondary schools in the upper uThukela area in the northern Drakensberg foothills of KwaZulu-Natal. In this, the sampling was convenience (I took on students who were already readily available in a course I was teaching them) and purposive (the students were selected for a particular purpose, i.e. an instructed course on catchment and river management, and the subsequent teaching practice experience (Leedy and Ormrod, 2010, p. 212). The three schools were situated on an approximately 8km long transect in a deep rural area, and can be characterised as disadvantaged and resource-poor educational environments (see Figure 3.2). The three schools were also selected according to convenience and purposive sampling (they were close to where the students were staying, and were situated in an upper catchment). The university campus was also a convenient choice or sample as it was closest to the Drakensberg range. The nearest major city (Pietermaritzburg) is approximately 200km away. Therefore this case study's findings are limited to a particular study in a place and time (the bulk of the data collection was carried out between March and August 2016).

3.2.2 Ethics in research

Ethical clearance has been covered in part on page iv in the preliminary pages of this study. Ethics, positionality and reflexivity in the research are discussed in a little more depth below. Full ethical clearance was given by the relevant authorising committee at Rhodes University. I strived to adhere to ethical considerations throughout, including respecting the anonymity of all participants, whether human or institutional (except for the name of my university). All participants were given a briefing on the catchment and river management research project on 3 May 2016. It was emphasised that all participants were volunteers, and that they could withdraw at any time. With regard to the university campus where I conducted my research, this was indicated in the research clearance application. Furthermore I am a lecturer (permanent staff) at UKZN and took the initiative in conducting research at the site. The three schools were accepted as teaching practice sites by the convenor of the teaching practice experience at UKZN (the Department of Education in KZN would have been thus informed). Regarding the normative and political dimensions of the research project, I filled in a form covering these dimensions while attending a course on the governance of social-ecological systems in Reims, France (URCA and SENSE, 2016). The key contents of the form follow: essentially this study contained many significant normative and political dimensions. I approached the study through the lens of someone educated in my particular academic disciplines (English, Environmental and Geographical Science, Education, City and Regional Planning) but also with my recreational interests playing a role. These disciplines have also influenced the values, primarily nature-and Geography-based, that were inherent in the study. External factors influencing the study included the funding agency (the South African National Research Foundation), state policy (such as curricula) and my supervisors. Power structures and asymmetries between me and the human and institutional participants can be seen as unequal and different. Most of the power resided with me in my capacities or roles as a university lecturer and teaching practice assessor. In deep rural areas of South Africa, there are contexts such as clan/ kin/ ancestor/ river/ cattle, of which I have little knowledge or personal experience. These contexts can also extend to traditional medicine and beliefs in witchcraft and sorcery. The power of the knowledge embedded in the study could activate pre-service and in-service teachers, including deep rural schools in catchment and river management, to increase the schools' agency in catchment and river management, and to bridge the theory and knowledge that is seen in, for example, a Swiss catchment versus that of an African catchment.

The reflexivity required for doing the particular design-based research involved examining my own beliefs (including values and judgements) and practices through the phases of the research. I approached Phase 1 as an academic researcher but also through the lens of having been a Geography teacher in the 1990s and a university lecturer since 2002. This experiential knowledge allowed me to make sense of the curricula and the likely hurdles to be encountered when working with these curricula, which I found reflected in journal articles. My reflexivity during Phase 2 would have been influenced by my role as a university lecturer, who delivered the material to the students in much the same way as I had since the beginning of 2016 (the students had already had a number of lectures for the Postgraduate Certificate in Education course). As I was the transmission agent and the students the recipients of the transmission of the knowledge, my reflexivity was bounded by those contexts. I found the students' oral responses in class slightly better than their written answers in the questionnaires (Appendix One). I found the jump from Phase 2 to Phase 3 more challenging where the students were the practitioners and I became the assessor. My expectations of the students derived from own experiences as a student in the course field trips I had undertaken at the University of Cape Town in the late 1980s and 1990s. My academic training in English Language and Literature also played a role in the expectations I had of lesson structure and content. I was initially quite critical of the students' subject matter knowledge and competence in their lessons but I came to understand that the students were significantly challenged in an under-resourced and desperately poor deep rural area whereas I had had everything facilitated for myself during the predominantly urban fieldtrips I took at the University of Cape Town. I also, in comparison to the students, took all my courses in my mother language.

3.3.3 Quality and trustworthiness in the research

A good case study has clear boundaries and a successful data analysis outcome. The findings of a good case study must also have import beyond the space and time of the original study. Starman (2013, p. 36) listed four advantages of case studies cited by George and Bennett, in comparison to quantitative methods: "Their potential to achieve high conceptual validity, strong procedures for fostering new hypotheses, usefulness for closely examining the hypothesized role of causal mechanisms in the context of individual cases, and their capacity for addressing causal complexity". Flyvbjerg (2006, p.21), writing about the misunderstandings of case study research, highlighted "the proximity to reality, which the

case study entails", and that "case studies often contain a substantial element of narrative. Good narratives typically approach the complexities and contradictions of real life."

A case study also allows itself to be guided by the findings of the study and does not try to dictate conclusions. According to Flyvbjerg (2011, p. 301), if we decide to use a case study in our research, this does not mean the selection of a method, but rather a selection of what will be explored. "An individual case can be studied from different perspectives – both qualitative and quantitative" (cited in Starman, 2013, p. 32). Starman (2013, pp. 39-40) went on to note:

> A case study is 'ideal for generalizing findings using the type of test that Karl Popper (in Flyvbjerg 2006, p. 228; Flyvbjerg 2011, p. 305) called 'falsification'; in social science, … falsification therefore states that a hypothesis is considered to be scientific when its defender is able to determine the conditions under which the hypothesis could be refuted. Falsification is one of the most rigorous tests to which a scientific proposition can be subjected – if just one observation does not fit with the proposition, it is considered to not be valid and must therefore be either revised or rejected.

A good case study is therefore one where all observations are tested and, if proved false, thrown out or refuted.

The case study's validity and trustworthiness depended on my integrity as a teacher educator who wished to develop a new progressive orientation to the teaching of catchment and river management in graduate teacher education. It also depended on the quality of the conceptual and curriculum analysis that I undertook; and the quality of the lecturing that I offered to the Postgraduate Certificate in Education students. Another factor that influenced the success of the case study was the materials that the student teachers developed for engaging with the concepts and issues in the field (students improved these materials after the first teaching lesson input). There was very careful planning, resourcing and the setting up of a meaningful fieldwork experience that was oriented towards the development of sustainability competences in a catchment and river management context. The case study also depended on careful generation and collection of evidence of the abovementioned processes for use as data in the study (which there was), and careful adherence to ethical protocols as outlined in the ethics clearance application form that I submitted. I also used data analysis strategies such as cross-referencing to ensure that my interpretations of the data and the process as it unfolded

were robust, rigorous and accountable. In addition, I strived to develop and maintain relations of trust with the Postgraduate Certificate in Education students, who were part of the research process in Phases 2 and 3, and who needed to have a clear understanding of the process that they were involved in (it was entirely voluntary on their part). I therefore took especial care to negotiate the case study intervention as a research process clearly with them, and with the Head of the Teaching Practice at the School of Education, University of KwaZulu-Natal. Lastly, I also used strategies of reflexivity regarding my own role in the process, and I made use of professional colleagues and links in the Fundisa for Change programme, the Geography Education Association and the mountain Geography network to obtain feedback and critique on the unfolding research process, especially from the perspective of the knowledge and pedagogical analysis work I undertook. To this end, I presented a poster on the topic at the International Mountain Conference at Innsbruck, Austria in September 2019 (Heath, 2019).

3.3 A Design-Based Research Case Study in Three Iterative Phases

The research unfolded as a design-based research case study, as indicated in the introduction to this chapter. The case study approach used followed Leedy and Ormrod (2010, p.108) who defined a case study as "a type of qualitative research in which in-depth data are gathered relative to a single individual, program, or event, for the purpose of learning more about an unknown or poorly understood situation". In this case I focused on the programme and the phased events that were used to generate data for the analysis of a graduate teacher education programme for catchment and river management pedagogy. The pedagogical design principles outlined in Chapter Seven and the recommendations that follow in Chapter Eight are the culmination of the design-based research case study.

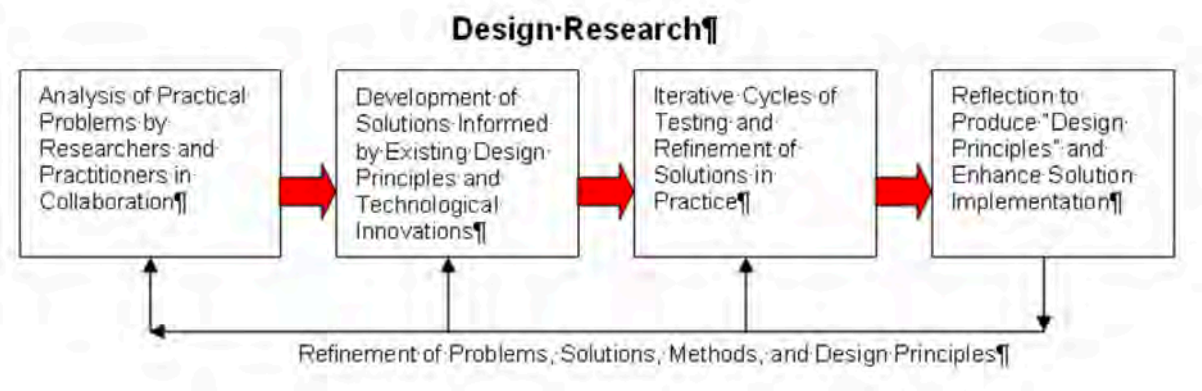
3.3.1 Design-based research

This study was conducted in stages, with each stage informing the next, and thus iterative, design-based research was identified as a key prism for the findings.

Reeves (2006) provided a useful synthesis (see Figure 3.1 below) of a process for design-based research. The developing process in Figure 3.1 corresponds with the design of the research process that I and the students undertook to develop a teacher education pedagogy for the introduction of the new concepts, content and imperatives that have developed with

much of the new environmental content knowledge that has been introduced into Geography in the last decade.

Figure 3.1: The design-research process



Source: Reeves, 2006

According to Zheng (2015, p.399), "DBR [Design-Based Research] focuses on examining a particular intervention by continuous iteration of design, enactment, analysis, and redesign". In the case of this study, the design process was centred on a developing process of research to successively clarify the prevailing curriculum context and new environmental knowledge towards a Geography education course in river and catchment management. Certainly, for social-ecological system research, design-based research was appropriate to explore how the key components and outcomes of social-ecological system knowledge (as it is such a clear framework) were developed through the series of lectures, which were designed through a curriculum review process in the first analytical iteration. This served to develop lectures (Appendix Six) to inform the design of lessons prepared by the students in the second analytical iteration. "As an emerging paradigm, DBR highlights how the design principles evolve by multiple iterations as well as what kinds of intervention can lead to improved outcomes" (Zheng, 2015, p.400). In this study, topic-specific pedagogical content knowledge was what the study wished to derive and clarify to contribute to the development of pedagogical design principles for geographical studies of social-ecological systems that informed sustainability competences.

For the concept of catchment and river management, higher order thinking skills needed a good command of fluvial knowledge to master the key concepts. It was shown to be essential that students understood the working of an ecosystem in a catchment, with whatever was happening upstream affecting downstream. Sustainability competencies for catchment and

river management were the core concern of the study to enable student teachers to base their work on teaching practice and fieldwork. These are "systems thinking competence, anticipatory competence, normative competence, strategic competence and interpersonal competence" (Wiek et al., 2011, pp. 207-211) (see 3.4.1 for more explanation of these concepts). A design-based research approach also enabled the study to shine a light on how a curriculum for catchment and river management might work best. Towards this end, the study opened with a curriculum analysis that informed specific content and pedagogy for the first phase of the study, and the subsequent work with student teachers to inform a proposed text on catchment and river management for teacher education. Thus, a design-based research approach explicated how effective pedagogy led to the thesis and a proposed course text. This will inform curriculum planners and discipline specialists on how best to design and produce materials for the catchment and river management section of the curriculum.

The research instruments used in this study are also ideal for design-based research, as Zheng (2015, p.409) explained: "DBR can be descriptive and explanatory in nature … miscellaneous data such as interview data, questionnaires, and various kinds of notes were adopted in most DBR … DBR is typically conducted using multiple forms of data". The same author went on to show the parallels between this study and many other forms of design-based research-based research: "In addition, the qualitative approach and miscellaneous data (three-phase iterative process) were adopted in most DBR" (Zheng, 2015, p.410). The qualitative approach is well suited to a case study, and miscellaneous data were extracted from the three-phase iterative process.

Feulner (2016), following Plomp (2013), emphasised that "design research follows a holistic approach, and does not emphasize isolated variables". She went on to explain that "research projects using DBR have the common goal to develop educational interventions … in real world situations. They are developed on the basis of both theoretical and empirical research findings. Through multiple iterations, these interventions are assessed in practice and then modified according to the finding of the accompanying research" (Feulner, 2016). In the case of this study in teacher education, it was the student teachers who were developing and modifying pedagogical content knowledge sequences for the social-ecological knowledge in question. Furthermore, the author explains…that students are encouraged to "create a sustainable learning experience" and "tasks that lead to a change in perspective" (Feulner, 2016).

Pipere, Veisson and Salite (2015, p.9) in their review of teacher education for sustainability, draw attention to the use of design-based research that "is oriented to the problems of practice and can help usable knowledge about developing, enacting and sustaining innovative learning environments (DBRC, 2003)."

The three iterative phases included:

- A detailed curricula analysis (Chapter Four) for the framing of critical subject matter knowledge was the first design iteration (Phase 1) towards the mapping of content for a series of lectures.
- The delivery and review of the formative series (this comprised a pilot study) of teacher education lectures (Chapter Five) on catchment and river management (Phase 2). This explored and refined topic-specific pedagogical content knowledge towards lesson planning.
- Supported design research fieldwork engagement on teaching practice with student teachers in the Upper uThukela river valley (Chapter Six). This exploratory work was developed as an experiential laboratory for students to produce and present teaching and learning materials on catchment and river management (Phase 3). As such, this enabled an applied review and assessment of the topic-specific pedagogical content knowledge on the part of the student teachers.

PHASE 1

The first phase was centred on an analysis of what actually is in the present curriculum (especially the difference between the theory within the curriculum and the reality of South African education) and previous curricula since 1994. This date is significant in that it was the first time in the twentieth century in South Africa that the country was treated as a united entity, with education policy written for all its inhabitants. Regarding theory within the curriculum, this refers to the implicit knowledge and how it has been constituted and developed in relation to new environmental knowledge and catchment and river management practices. Apropos the reality of South African education, attention was drawn to the state of Geography education and fieldwork in all schools, but it also gave attention to disadvantaged high schools as that was where many of the University of KwaZulu-Natal Postgraduate Certificate in Education graduates would be teaching.

Formative analysis

Here data were generated through the analysis of curriculum documents to frame the content as catchment management concepts for the proposed graduate teacher education programme, Phase Two. The topics selected and the lecture sequence became the formative design for the delivery of the catchment management module as a series of lectures that were reviewed in Phase 2

PHASE 2

In the second phase, the phase one analysis informed the design, delivery and assessment of a series of lectures on catchment and river management, which were given to selected Postgraduate Certificate in Education students at the University of KwaZulu-Natal Education Faculty (now School of Education). The design (topics) reflected the curriculum analysis into a preliminary framing of pedagogical content knowledge (PCK) that related the concept of participatory integrated water management (PIWM) and was explored in the reality in South Africa, especially the Drakensberg region. The initial formative publication *Teaching Water* (Khan et al., 2014) was a key resource that opened up the perspectives to these lecture contents, and which served as the beginnings of a framework on how to teach the topic. The curriculum analysis (in phase 1) and the *Teaching Water* publication were therefore points of departure for the teacher education module and thus contributed to the lecture materials to be designed, constructed and assessed.

Formative analysis

The course delivery and content were fully documented along with student responses, using questionnaires, as a deliberative process of design-based research. The developing analysis was centred on the meaning-making experiences of lecturer and students in the lecture room and how this was ultimately carried into lesson planning (in the third phase) by the student teachers. Therefore, in this phased work with the formative content, a pedagogy was framed for teaching catchment and river management. This pilot study phase developed as a process of designing, enacting and refining topic-specific pedagogical content knowledge for a catchment and river basin management module, an iterative process in support of deliberative design-based research by the student teachers.

PHASE 3

The third phase comprised this clear shift to the student teachers as design researchers working the curriculum out of the lecture-informed topic-specific pedagogical content knowledge perspectives on catchment and river management. The design challenge was to plan for classroom and fieldwork with the materials by developing lessons for rural students. My mediating oversight of this process also served as a review of the last two phases towards the clarifying of the necessary contents and contours of a teacher education text for future courses. The students were challenged to design programmes of work following on from the abovementioned lectures and deliberative review (phases 1 and 2). Their work was centred on the design of teaching programmes prepared by the students to be presented to fellow learners and their university tutor, polished and enacted in the field. Care was taken to record on video key teaching and learning 'moments' in the field, which aided in analysis in relation to the topic-specific pedagogical content knowledge uncovered and explored in the lecture series following the associated curriculum analysis. In addition, the use of the materials and lessons on teaching practice was also tracked and assessed while cognisance was taken of time and context [health, safety, and ethics]. Here data were generated through university tutor-on-student teacher observation sheets (formal assessments), lesson plans and student reflective sheets.

Formative analysis

To summarise, Leedy and Ormrod's (2006, p.146) table, distinguishing characteristics of different qualitative designs was adapted to form Table 3.1 which relates to my methods in italics).

Table 3.1: Qualitative design features and how they were used in this study

Design	Purpose	Focus	Methods of Data Collection	Methods of Data Analysis
Design-based research case study	To understand one person or situation (or perhaps a very small number) in great depth *In my case, I focused on the topic catchment and river management in the phase 1 curriculum and performance analysis.* *This fed into teaching in the Postgraduate Certificate in Education (PGCE) to review content and method using a Pedagogical Content Knowledge analysis process student feedback and lesson design work following the series of lectures (phase 2).*	One case or a few cases within its/their natural setting *In my case, the case was situated in the normal course of my teaching practice as lecturer of Geography Education in the PGCE context in KwaZulu-Natal, and fieldwork was situated in part of an important catchment management area which could be used for the placement of teaching practice students, and of relevance to the teaching context of the PGCE students.*	• Observations • One-on-one debriefing sessions after teaching practice lessons • Appropriate written documents and/or audiovisual material • Lecture feedback in the form of questionnaires *In my case I worked with the PGCE Geography Education group, and with a smaller group of five PGCE students who participated in the lectures and the in-depth fieldwork engagements. I analysed documents on the different curricula (Phase 1), developed teaching and lecture materials (integrated water resource management concepts and approaches – phase 2); and student responses (questionnaires) to the lecture series – phase 2 – that fed into the design of fieldwork materials and student responses (to assess lesson progressions and ascertain their reflections on the teaching experience - phase 3), including their written work; with video and photographic evidence also collected.*	• Categorisation and interpretation of data in terms of common themes • Synthesis into an overall portrait of the case (s) *As outlined below, I used three key lenses to guide the analysis of the case study:* • *Social-ecological systems in an integrated water resource management context* • *Social learning* • *Practice architecture* *I analysed the unfolding case study involving analysis of curriculum documents; lecture processes; and fieldwork processes using these lenses. The cumulative analysis informed the development of a perspective towards a progressive catchment and river management teacher education process that aligned with the nature of new environmental knowledge, the present Curriculum and Assessment Policy Statement requirements, and social-ecological systems-oriented fieldwork that also developed sustainability competence amongst teacher educators.*

(Adapted from Leedy and Ormrod, 2006, p.146).

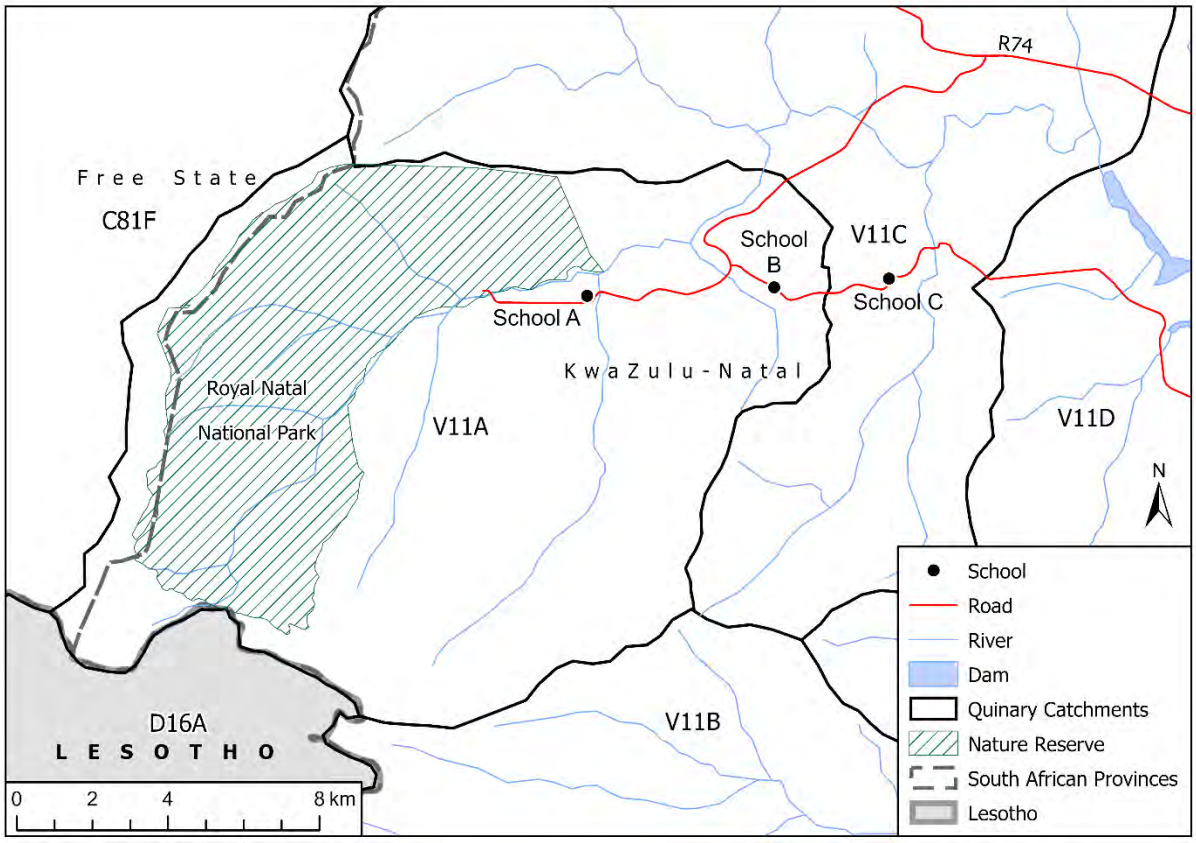
The research was integrated into and aligned with my professional practice to develop as a design research process. The three-phase design research case study therefore broadly followed these iterative techniques with the focus being on a cumulative process of empirical design work with experiences and data informing and deepening insights on pedagogy that culminated in the student production of materials and lesson plans for the Upper uThukela river valley. Methods of data collection adhered to Leedy and Ormrod's (2006) suggestions, with particular focus placed on records generated through the three-phase process (respectively Chapters Four, Five and Six), and on and its outputs in terms of lesson assessments (Appendix two), learning materials and lesson plans (Appendix three). Thus, the developing case study as an iterative design-based research process was centred on the teaching programme that emerged as a collaborative research process to develop topic-specific pedagogical content knowledge for teaching catchment and river management in Geography Education. The three-phase design was specifically informed by the opening curriculum analysis (Chapter Four), the lecture series (Chapter Five and Appendix 6) and the field-based materials development for the upper uThukela (Appendix five), all of which informed the teaching practice that concluded the research process.

Case study site:

The case study was firstly located at the Education Building of the Pietermaritzburg campus of the University of KwaZulu-Natal (UKZN) (for the series of lectures). UKZN is a five-campus university and the Pietermaritzburg campus is known for liberal arts and applied environmental sciences. Secondly, extended fieldwork was located in the Upper uThukela river valley because it contained a number of secondary schools (quite near to each other, and with suitable accommodation close by in a KZN Wildlife reserve). It was therefore appropriate for University of KwaZulu-Natal students doing teaching practice, with pressing catchment and river management issues, and literature already exploring design-based research (Thorrington-Smith, 1960; Goldblatt, 1998; Maluti Drakensberg Transfrontier Project, 2007). The study area (see Figure 3.2) contained poorly-resourced schools and with a teaching corps facing distinct challenges. As such, it is emblematic of both South African schools situated in a significant river catchment basin, and peripheral rural communities. Schools A and B could be called the most 'privileged' of the three schools, with fairly sound infrastructure and facilities. School A is in a more economically active area (proximity to a national park) than School B. None of the schools has a library, however. School C is much smaller in terms of learner numbers (about 200 learners) and infrastructure than the others,

and is showing its age. All three schools are mother tongue Zulu-speaking and historically disadvantaged 'no-fee' (Quintile 2) schools (see 6.6 for the relevance of this information). In no way can the schools be compared to academically high achieving suburban schools in the province.

Figure 3.2: Study area of phase 3 research – the three high schools in the two quinary catchment areas (V11A and V11C)



Acknowledgement: Map compiled by Brice Gijsbertsen, School of Applied Environmental Sciences, UKZN Pietermaritzburg Campus.

3.4 Development of a Theoretical Framework for Teaching Catchment And River Management in Graduate Teacher Education for the Analysis

This was an iterative process whereby each phase informed the next in the cumulative insights emerging in the case study. As such, it was a design-based research process centred on the development and clarification of pedagogical content knowledge in relation to the teaching of river and catchment management.

The successive generation of theoretical insights (comprising pedagogical content knowledge) for teaching catchment management in graduate teacher education was centred

on deriving an in-depth grasp of new environmental knowledge in a developing process of teacher education. Key elements constituting this formative schema were:

- social-ecological systems,
- associated sustainability competencies, and
- teaching sequences (topic-specific pedagogical content knowledge) and fieldwork pedagogy.

The work preceding this has shown that teachers have to absorb and teach new environmental knowledge, which is more complex, specific and issue-based than in previous times. It is also clear that the emerging theory of social-ecological systems is increasingly influencing catchment and river management.

The study thus developed from an analysis of the Curriculum and Assessment Policy Statement (South Africa. DBE, 2011) and the teaching of catchment and river management. There are three essential components to the teaching of this topic in the Curriculum and Assessment Policy Statement document, namely:

- "the importance of managing drainage basins and catchment areas;
- the impact of people on drainage basins and catchment areas;
- and a case study of one catchment area management strategy in South Africa" (South Africa. DBE, 2011, p.43).

This, however, needed interpretation and further analysis from the perspective of complex social-ecological systems knowledge. The theory and scientific content knowledge for catchment and river management within the Curriculum and Assessment Policy Statement would need to be tested against Wiek et al.'s (2011) sustainability competencies in curriculum processes. For the purposes of this study, it was important to detail what fieldwork methods were suggested. Fieldwork (time permitting) has the following skills mentioned in the Curriculum and Assessment Policy Statement: "collecting and recording data using a variety of techniques**;** processing, collating and presenting fieldwork findings" (South Africa. DBE, 2011, p.16). These skills include collecting material in the field, and after-excursion activities in the classroom.

3.4.1 Social-ecological systems and sustainability competencies

The term 'social-ecological system' (SES) derives from Berkes and Folke (1998) who suggested it should "emphasize the integrated concept of humans in nature while not

reducing any discipline to a prefix" (Norberg and Cumming, 2008, p.278). Social-ecological systems thinking and practice is a rapidly emerging area of study in the sustainability sciences, and is influenced by theorists on transdisciplinarity and complexity. Regarding complexity and social-ecological systems, the analysis work was heavily influenced by Norberg and Cumming (2008). Following the awarding of a Nobel Prize to Lin Ostrom in 2009 and the incorporation of social-ecological systems in modern environmental thought, the theory and practice of social-ecological systems has developed quickly. Ostrom's theory (2005, p.15) (a framework for institutional analysis) deals with a framework centred around the following key components: related ecosystems (climate patterns, pollution patterns and flows into and out of focal SES), resource systems, interactions, resource units, actors, governance systems, and outcomes. Cash et al. (2006) published the different scales (spatial, temporal, jurisdictional, institutional, management, networks, and knowledge) and the relevant levels (for example, spatial from global to patches) that are necessary to understand a social-ecological system.

Understanding the theory necessarily leads to the development of sustainability competencies because adaptive management is necessary in a social-ecological system. Any such system is attuned to complexity and time/ scale differences. As mentioned above, spatial variation is another key concept within the theory, and the authors also point out that local area knowledge and indigenous knowledge systems are important to getting all communities involved (Norberg and Cumming, 2008). It was therefore necessary to take note of change, the interconnectedness, and the respect for different sources of biodiversity. The understanding of sustainability competencies derives from De Haan (2006, p.22) who has written on what constitutes *Gestaltungskompetenz* (or shaping competence), which is the "specific capacity to act and solve problems." There are a number of sub-competencies that are described in the sustainability competence literature that show a remarkable affinity with what students typically do in Geography fieldwork (De Haan, 2006; Wiek et al,. 2011). Wiek et al. (2011, pp.207-211) undertook a synthesis study on sustainability competences and defined a set of core interrelated competencies, namely "systems thinking competence, anticipatory competence, normative competence, strategic competence and interpersonal competence" as being central to the sustainability sciences. Systems thinking competence is the ability to think in terms of a metabolic system with inputs (causality) and outputs (consequences and knock-on effects). Anticipatory competence relates to the ability to foresee or anticipate, plus plan for, events and consequences, while normative competences

refer to negotiating and navigating principles, values and targets. Strategic competence relates to the collective ability to design and implement strategies (plans) which lead to sustainability, while interpersonal competence refers to the ability to work together as a team to achieve a shared goal within a framework of trust and mutual respect. These competences provided a useful framework for analysing whether or not key data from the research addressed the outcomes that became evident in emergent topic-specific pedagogical content knowledge. This was in relation to catchment and river basin management concepts and practices being taught, with reference especially to fieldwork. Student teachers developed to an extent such competences via their fieldwork programme, and were supported to use those competencies in their teaching practices.

3.4.2 Fieldwork pedagogy

The next key element of the theoretical and analytical framework was to orient the study around key fieldwork techniques, and test the learning and effectiveness of these against the Curriculum and Assessment Policy Statement (South Africa. DBE, 2011) catchment and river management imperatives. Fieldwork has always been a critical and essential component of (especially Physical) Geography teaching and, despite issues of legality and safety, is still expected of learners, according to the Curriculum and Assessment Policy Statement document. Therefore, fieldwork has to be reemphasised to the student teachers who needed to see the intrinsic value and need for fieldwork. Finally, this part of the theoretical framework was developed via an analysis of the importance of understanding how fieldwork linked to social-ecological systems was developed in a real-world rural context (and examined in a case study) in a South African river catchment. The analysis was oriented to assessing the development of an appreciation and understanding of the integrated knowledge and pedagogical approach to Geography education, as informed by the curriculum, and all the realities impinging on that policy in South Africa. Of particular interest in framing the design process is what the curriculum specifies for fieldwork, and the associated knowledge, skills and attitudes/ values newly graduated teachers should have (as shown in the policy). The beginner teacher competencies and collective roles of teachers, as described in the Policy on Minimum Requirements for Teacher Education Qualifications, also had a bearing on the teacher education programme, and especially its interest in developing the disciplinary, practice and pedagogical knowledge of teachers-in-training (Department of Higher Education and Training, 2011). These elements provided the study with an emerging grasp of learning processes (within a web or mesh) intended to produce a new understanding and appreciation

of Geography education, particularly the inclusion of outdoor-based Geography education (South Africa. DBE, 2011, p.16). This understanding naturally derived from case context and teacher education activities, which have been informed with data from the participating students' work.

3.5 Data Analysis Process

3.5.1 Data analysis framework

As indicated above, the study developed as an unfolding design and review process (iterative and cumulative) over time through the differentiation of topic-specific pedagogical content knowledge. The design research was undertaken within course-based work with student teachers attending lectures and developing lessons for the teaching of catchment and river management in a rural school context of teaching practice. The research was undertaken in three analytical phases of work integrated design research to clarify pedagogical content knowledge in three design research phases:

1. A curriculum review to inform course design
2. Lecture series to introduce new environmental knowledge (including social-ecological systems, pedagogy and sustainable competencies)
3. Teaching practice lesson design and fieldwork

The study was designed as a case study of a teacher education process, with fieldwork undertaken in the upper uThukela catchment basin between Bergville and the Royal Natal National Park in central KwaZulu-Natal. Consent was obtained from the five student teachers as well as the three schools in order to meet ethics requirements for research with human participants.

My interest was to see how the teaching of social-ecological systems theory translated into a rural teaching and learning context that is representative of many other South African communities. The context was informed by the education I had received in environmental and Geographical science and regional planning, as well as by my recreational pursuits in mountainous areas and my own ecology-based values.

Data were generated from student teacher lesson plans and reflective reports, which comprised the teaching practice record. Additionally, formative assessments written by me (the university tutor) were used to shed light on the systemic (in terms of social-ecological

systems) elements in the lesson plans that the students developed for teaching the topic. Three lenses were selected to analyse the data, and an elaboration of each follows underneath. These served to clarify pedagogical dimensions of the course design that were derived and refined using three analytical lenses:

- The acquisition of key concepts related to social-ecological systems;
- Social learning transactions associated with the acquisition of foundational knowledge; and
- Tracking key elements of practice architecture influencing pedagogy and learning in a rural school context.

Analytical lenses were derived for each of the focus areas in phases two and three of the design review process. The analysis of data in each phase was used to inform the design process as an iterative progression with curriculum content analysis (phase 1), course content and pedagogy induction (phase 2) and school-based lesson delivery and assessment in a rural schools context (phase 3). In this way, the design insights derived in each analytical phase informed succeeding phases that provided cumulative insights using three analytical lenses. Accumulating insights were then synthesised using analytical statements to inform the design of a proposed text for teaching catchment management in teacher education.

Figure 3.3: Design research analytical lenses and research phase progression

Design research focus area	**Content: topic specific PCK**	**Learning/ pedagogy**	**Contextual influences**
Research lens	Social-Ecological Systems	Social Learning	Practice Architecture
Design research phases	Phase One (curricula analysis)		
	Phase Two (series of lectures)	Phase Two (series of lectures)	Phase Two (series of lectures)
	Phase Three (Teaching practice fieldwork)	Phase Three (Teaching practice fieldwork)	Phase Three (Teaching practice fieldwork)

3.5.2 The selected model of a social-ecological system to analyse the coherence in the topic-specific pedagogical content knowledge emerging through the study

Probably the most ideal model to explain the social-ecological system is the Hahn et al. (2008, p.120) model. This model emanated from a study of human/environment interactions around a wetland outside Stockholm, Sweden. From the key factors in this model, it appeared to be the most appropriate representation of a social-ecological system especially with regard to the specific study area. The model hinges around external drivers, change and surprise all of which drive the system. Change and surprise are especially apposite as the uThukela river is particular prone to weather events including cloud bursts over the mountains. The role of people in the management of a social-ecological system is shown by the different community players or participants plus the government agencies that function there (management: actors and organizations). A river basin or quaternary catchment is a dynamic ecosystem (with various components) where there are inputs and outputs in and out of the components of a system (ecosystem functions and dynamics). All this depends on a learning environment (knowledge systems and social memory) between and across actors and organisations. The community that has lived in the upper uThukela has been relatively cohesive for over a hundred years, with its own knowledge system (which generates social norms and rules), with links to indigenous knowledge systems, and its own embedded social memory. This model bears a very close resemblance to Maynard Hufschmidt's (1986, p.22) model of a generalised watershed management system (in physical output terms) (Hamilton and Bruijnzeel, 1997, p.345).

Understanding the model informed the sustainability competences student teachers developed and supported in their teaching of catchment and river basin management. A catchment basin, with all the factors within, was an ideal experiential laboratory to develop these competencies through exploratory teaching practices within the context of Geography fieldwork.

3.5.3 Social learning as a framework for looking into the topic-specific pedagogical content knowledge in relation to learning

The second lens was chosen to review how the participating group of students learnt together through the initial series of lectures and activities. This vantage point on social learning transactions was carried into Chapter Six (phase 3) as the students worked as a professional learning community (or a community of practice) preparing for teaching practice and teaching in the differing rural schools. Arjen Wals' (2007) framework in his chapter

"Creating Networks of Conversations" from his book *Social Learning: Towards a Sustainable World* was selected as a suitable lens through which to assess social learning transaction as the students undertook their design research work as a collaborative process of lesson planning, delivery and assessment. The Wals' framework is posited around the following key components: 1. Orientation: actors, issues and challenges; 2. Self-awareness: eliciting one's frame; 3. Deframing: reframing/ clarification/ exposure to other frames; 4. Co-creating: re-constructing of ideas; 5. Applying: collaborative actions; 6. Reviewing: assessing issues/ challenges addressed (Wals, 2007, p.499.) Steps in the learning process included social learning during lectures, where there was delivery of course materials, discussion in class and reflection; and teaching practice (fieldwork), where a number of steps in the process had to be completed.

3.5.4 Practice architectures as a lens for identifying enabling and constraining processes at play in the study

The third analytical lens was practice architectures, as the practice architectures associated with lectures and teaching practice had to be explored and understood to inform the intended course materials on catchment and river management for Geography education. Practice architectures included the educational infrastructure where the lectures and teaching practice were undertaken, plus the socio-educational dynamics behind these (more on this will follow below). Kemmis's (2009) article "Understanding professional practice: A synoptic framework" was an influential text, following Theodore Schatzki's framework in his book *The Site of the Social* (2002), to understand this section. Practices are defined by Schatzki as "open-ended spatial-temporal manifolds of actions" (Schatzki, 2005, p.471). Kemmis et al. (2014) have usefully unpacked the following phenomena: cultural-discursive (sayings: semantic language), material-economic (doings: physical space, time, work/action) and social-political arrangements (relatings: social space, solidarity and power). The practice architecture analytical lens of phase two was also bridged to the enabling and constraining dimensions of phase three (a number of schools in a deep rural environment), where real and pressing restraints occurred.

The analytical processes can be summarised into the Table 3.2 that follows.

Table 3.2. Summary of analytical processes in iterative stages/ phases

Iterative phases	**First phase (Chapter 4)**	**Second phase (Chapter 5)**	**Third phase (Chapter 6)**
		Pilot phase	**Review phase**
Analytical processes	Analysis of the three curricula applicable between 1994 and 2020 to frame the formative design for the foundational lectures.	Questionnaire results in terms of catchment and river management lectures. These were analysed through the three lenses of social-ecological systems, social learning, and practice architectures.	Data derived from lesson assessments, lesson plans and reflective reports in a fieldwork context. These were analysed using the three lenses of social-ecological systems, social learning and practice architectures.
	Analysis of problems. First iteration.	Development of solutions. Second iteration. Testing of first iteration.	Third iteration. Testing of second iteration.

3.6 Contribution to New Knowledge

An in-depth study of teacher education pedagogy with student teachers working in South African catchments had not, to the best of my knowledge, been undertaken. Thus, this exploratory design-based research case study was enacted within a context of Geography teacher education. It was designed as a design research process to develop and clarify pedagogy for catchment and river management as new environmental knowledge to inform a pedagogy text in teacher education. The study was developed through initially constructing a theoretical framework informed by social-ecological systems, social learning and practice architectures. The design research analysis process flowing from a concern to clarify pedagogical content knowledge and was explored in three iterative stages with analysis of key dimensions using three analytical lenses, namely a social-ecological systems model, categories for social learning processes and a typology for contemplating the enabling and constraining dimensions of practice architectures. The design research process and work with these analytical tools served to enable the case study to generate new theory and practice for

informing a course text on catchment and river management for teacher education in South Africa, with specific reference to fieldwork in a mountain catchment. The design research process, inclusive of the mediated work with the young teacher educators developing their teaching practice lessons tied in with the United Kingdom's Quality Assurance Agency's definition of fieldwork as being "active engagement with the external world (QAA, 2002)" (Fuller et al., 2006, p.89) which was and is critical for sustainability to emerge in society.

Chapter 4
Results: Curriculum Analysis (phase 1)

4.1 Introduction

The first phase of the research methodology was centred on an analysis of the subject matter knowledge in the curricula between 1994 and 2020 so as to review the curriculum history of the topic (see in particular Chapter One, section 1.1.3). The chapter thus plots the change from geographical knowledge to issue-based teaching so as to scope some of the contours of implicit pedagogy. Regarding the theory of the subject matter knowledge and its associated pedagogy, this refers to the knowledge of the field and how it has been constituted and developed in relation to new environmental knowledge and catchment and river management practices. Here data were generated through an analysis of curriculum documents to frame the proposed lecture series as topic-specific pedagogical content knowledge for a graduate teacher education programme in phase two of the research (Chapter 5). The design-based research process produced observations in Chapter 7 which led to five design principles. In this phase, in contrast to the following phases (two and three), my role was purely that of researcher scoping the topic to contemplate and derive a formative framing of the content and pedagogy for the proposed course. This topic-based curriculum research was informed by gaps and uncertainties that had emerged in the earlier writing of the Fundisa for Change course materials (Khan et al., 2014).

The first phase of the research methodology was centred on an analysis of the subject matter knowledge in the curricula between 1994 and 2020. The chapter plots the change from geographical knowledge to issue-based teaching, and what to do about those issues. Regarding the theory of the subject matter knowledge, this refers to implicit knowledge and how it has been constituted and developed in relation to new environmental knowledge and catchment and river management practices. Here data were generated through an analysis of curriculum documents to frame the proposed graduate teacher education programme which occurred in phase 2 of the research (Chapter Five).

4.2 Design-Based Research

The intention of this chapter was to ascertain the subject matter knowledge, following an analysis of the South African curricula between 1994 and 2020, which in turn would inform a dedicated course on catchment and river management. This would comprise phase 1 and to this end, the following sections of work were analysed: catchment and river management, and fieldwork, in the three different curricula. Attention was also given to the diagnostic report published by the Department of Basic Education in 2015, where it was stated that there is a marked difference in attainment scores between Human and Physical Geography. This was referred to in the literature review (Chapter Two). The issues of landscape recognition and spatial literacy (or spatial reasoning), in the mapwork examination paper, were also reviewed in the diagnostic report (mentioned in Chapter Two). This had import for the fieldwork experience of teaching practice, where mapwork competence and spatial reasoning were and are essential to the successful undertaking of fieldwork. Finally, an analysis was conducted on social-ecological system knowledge(s) and the three curricula as a topic-specific concern. The intention of the research was to designate the critical subject matter knowledge that would inform and frame the knowledge to be imparted to the students in phase 2 (the lectures), enabling them to develop the necessary topic-specific pedagogical content knowledge to teach the topic on teaching practice.

4.3 Progression of the Curriculum

4.3.1 Catchment and River Management

Catchment and river management is now firmly established and detailed in the South African Further Education and Training curriculum. However, as will be seen, this was only explicitly elaborated on in the 2011 curriculum (the third iteration since 1994). Teachers trained before this date may not even know what the concept refers to, and certainly not what it entails.

As is widely known, disparate and widely differing educational systems (19 different education departments) were merged into one single system in 1994. These systems had differing standards, and by extension, life chances for the pupils differed accordingly.

This chapter considers three different curricula in place after 1994. These curricula show the changes in geographical thinking and the progression to prioritise issues to be taught. In the National Assembly Training and Education Department (NATED) Interim Syllabus

(Department of Education, 1995), catchment and river management was not explicitly mentioned. However, the importance of the drainage basin unit in conservation and hydrology, and even administration, started gaining traction in South Africa. The National Assembly Training and Education Department syllabus mentions the subject matter knowledge "drainage basins", and "environmental conservation and management", as well as "ecosystem" (South Africa. DoE, 1995, p.10). Thus, although catchment and river management is not explicitly mentioned, learners who were trained under this syllabus would have been able to transfer understanding easily to the fundamentals of social-ecological systems (especially 4.2, 4.3 and 4.4 as follows) and catchment and river management.

> For Standard 10 (Grade 12), attention is directed to Geomorphology (3), and 3.1. (Drainage basins…). Under 4. Ecosystems, environmental balance and conservation, attention is given to 4.2. concept of an ecosystem; and 4.3. ecological processes and 4.4. human impact on the ecosystem: imbalance of the ecosystem; environmental conservation and management. (South Africa. DoE , 1995, p.10)

The 1995 curriculum furthermore contained an emphasis on holistic thinking skills and systems thinking for relevant teaching approaches, all applicable to this study on catchment and river management using a lens of social-ecological systems:

> Under 3.1 (Teaching approaches), attention is directed to a holistic of global approach (3.1.1), problem-solving (3.1.2), the systems approach (3.1.3), interdisciplinarity (3.1.4), and the scientific approach (3.1.5) … it is recommended that teachers introduce the concept of systems into their thinking; pupils should be aware that Geography encompasses the study of very complex human-environmental ecosystem …; several components of the syllabus could be taught as sub-systems such as those associated with … drainage…. (South Africa. DoE, 1995, p.3)

With its emphasis on systems thinking, the 1995 document, therefore, was a relatively good attempt at unifying differing syllabi. It was, furthermore, a technocratic document. However, it was very sparse and needed fleshing out. The interim syllabus contained some interesting and connected thinking regarding the importance of the environment.

Regarding the National Curriculum Statement (2003), there was much more definition in what needed to be taught, and the concept of scale from the global to the national (World, Africa, South Africa) was introduced. Moreover, the systems approach was mentioned (South Africa. DoE , 2003, p.12). The palpable rate and effects of climate change and environmental

change in the late 1990s, along with new legislation, made the explicit mentioning of catchment and river management in 2003 an imperative in the new curriculum. The National Curriculum Statement (NCS) stipulated the following subject matter knowledge regarding the teaching of fluvial processes:

> Grade 12, under national scale (fluvial processes and landforms), context: South Africa, fluvial processes:
>
> - flowing water on the surface of the earth-drainage basins: characteristics, drainage patterns, importance and impact of humans;
> - river profiles; superimposed and antecedent rivers;
> - catchment and river management. (South Africa. DoE, 2003, p.39)
>
> Grade 12, under national scale (people and their needs), context: South Africa and the world, water as a crucial resource in South Africa – availability of water; distribution and supply of water to South African citizens; sustainable use and management of water. (South Africa. DoE, 2003, p.45)

Therefore, in two different sections of the 2003 curriculum, attention was given to catchment and river management, environmental management of hydrological systems, and sustainable use and management of water, and at the national scale, and in Grade 12. Thus, there was potential for blurring and diffusing the focus of the subject material because the two topics are interrelated.

As one can see, there is very little detail or specificity regarding "catchment and river management" and "sustainable use and management of water". These are implicit rather than explicit – no sub-topics were mentioned, nor was there any elaboration. There had, however, been a clear improvement in at least mentioning catchment management. It was left to educators to make sense of what the subject matter knowledge was, and to teach what they thought the specifics were.

The more recently released Curriculum and Assessment Policy Statement (Geography Further Education and Training Grades 10-12), includes a strong imperative on catchment and river management, and includes the following sub-topics:

Catchment and River Management (3hrs) (Under Geomorphology, Grade 12 in Term 1)

- Importance of managing drainage basins and catchment areas;

- Impact of people on drainage basins and catchment areas;
- Case study of one catchment area management strategy in South Africa. (South Africa. DBE, 2011, p.43)

In comparison to the first two curricula, the detail is explicit, a catchment management strategy is mentioned for the first time, and a case study approach is employed. The first two sub-topics of this subject matter knowledge would have been covered in previous syllabi, and thus that content knowledge is familiar to teachers, but the inclusion of the third is problematic for the following reasons:

1. Most catchment management agencies are not operational (indeed only the Breede-Gourits, and the Inkomati have functioning webpages), and their catchment management strategies are at the incipient stage. There are major problems of institutional capacity in them and indeed in the Department of Water Affairs and Sanitation. In the article "Our future is here: Empty taps, dry lands, thirsty power plants" published by the *Mail and Guardian* on October 25, 2019, the problems facing the Vaal River water management area and the Department of Water and Sanitation are clear. Pollution, political interference with contracts, and mismanagement (chiefly corruption and over 1000 job vacancies) within the Department of Water and Sanitation are very real issues. In addition, issues of political controversy also attend the catchment management agencies (Bourblanc, 2012, p.637). In addition, as Rogers et al. (2010, p.505) pointed out, there is "no tested precedent" for catchment management agencies in South Africa. Hence, there is no institutional memory or experience for such an initiative. Moreover, managerial capacity will not derive from the ranks of the national Department of Water and Sanitation (DWS) either. Meissner, Stuart-Hill and Nakhooda (2017, p.26) pointed out that "all conversations, interviews and engagements have shown that the CMA environment requires a different set of skills compared to the known job profiles of regional or the national DWS officials". The authors (ibid., p, 24) also pointed out that late coming and a lack of a service culture are features of Department of Water and Sanitation officials: "From current observations of several stakeholder meetings, we observed that DWS officials often arrive late for these meetings and failed to cater to the needs of attendees, therefore adding to the negative perceptions of the DWS".

2. There has been confusion over the actual areas of the catchment management agencies, and they have been reduced in number from 19 to 9 (Department of Water Affairs and Forestry, 2012). In fact, there has been major confusion about the catchment management agency or agencies intended for KwaZulu-Natal (three were originally proposed: Usuthu to Mhlathuze, Thukela (the most important in KwaZulu-Natal), and Mvoti to Umzimkulu. In 2013, however, only one catchment management agency in KwaZulu-Natal was gazetted, namely the Pongola-Umzimkulu, which covered the whole province (Meissner et al., 2017, p.19). There is major difference in climate and vegetation between the north and south of the province. All these changes and shifting of the goal posts would have obviously affected the establishment of catchment management strategies, as every strategy is naturally catchment- and area-bound.
3. Catchment management strategies were only explicitly detailed in the 2011 curriculum and thus this subject matter knowledge would be generally new to teachers. As of 2017, a functioning catchment management strategy, which is by necessity very complex with competing demands, was not operational in any of the catchment management agencies.

> The required CMS for each WMA and CMA also sets principles for water allocation and considers issues related to water resource protection, use, development, conservation, management and control. In the case of South Africa, these measures must be in line with the National Water Resource Strategy (Meissner and Funke, 2014). However, a CMS is yet to be drafted for either of the established CMAs. (Meissner et al. 2017, p.21)

Writing of the management of the Elbe river basin in Germany (which is generally homogenous in culture and language, as well as being in a highly developed country), and its competing issues, Meissner et al. (2017, p.21) stated that

> this is something that South Africa's CMAs should expect when their strategies are implemented even when they are well established and functioning; everything could be a constant challenge because of pressures from various sectors and the CMAs will have to manage a complex natural resource system with the aim of socio-economic development. (Meissner et al., 2017, p.21)

To reiterate, the South African experience of catchment management agencies and their catchment management strategies is not be without problems. Ashton found that the integrated catchment management approach in South Africa has not been successful to date, due to a lack of information and expertise on the part of the general public, and over-exploitation of water resources. Ashton also noted that people have to be empowered before one can expect them to function in terms of catchment management: "IWRM (integrated water resource management) and, ultimately, ICM (integrated catchment management), will not succeed if suitable legal, institutional and administrative frameworks do not support the approach" (Ashton, 2000, p.10). The idea that local people, often uneducated and usually poverty-stricken, can contribute meaningfully to sophisticated management plans can be seen as 'pie in the sky' thinking. However, Versfeld (1995) correctly pointed out that little effort has gone into "understanding, learning and applying local knowledge" and that there is a "real, people-based, demand for sound land management" (p.150). Malzbender et al. (2005) found that while the Water Policy White Paper allowed for and encouraged public participation; it was very short on specifics and very "vague" on how public participation should actually happen (Malzbender et al., 2005, p.5).

Immediately before the section on catchment and river management, "Drainage Basins in South Africa" and "Fluvial Processes" would have been covered. The critical concepts necessary to understand catchment and river management would have been listed in the former and include: drainage basin, catchment area, river system, watershed, tributary… source, confluence, water table, surface run-off and groundwater (South Africa. DBE, 2011, p.43). These basic concepts are essential to understanding the dynamics of catchment and river management before more advanced subject matter knowledge is taught.

However, this is not the only place in the curriculum where water management is mentioned. In Grade 10 (Term 4), under the topic Water Resources, and the sub-topic Water Management in South Africa, the following is mentioned:

- rivers, lakes and dams in South Africa;
- factors influencing the availability of water in South Africa;
- challenges of providing free basic water to rural and urban communities in South Africa;
- the role of government initiatives towards securing water: inter-basin transfers and building dams;

- role of municipalities: provision and water purification; and
- strategies towards sustainable use of water – role of government and individuals (South Africa. DBE, 2011, p.26).

Compared to the 2003 curriculum, the management of water is dealt with more coherently and explicitly in the 2011 one. Water management is introduced in Grade 10 but a further elaboration of "strategies towards sustainable use of water," which is what a catchment management strategy is, comes later in Grade 12.

There is some more referencing to management strategies in the document, where in Grade 11 (Term 4), under the topic 'Resources and sustainability' and the sub-topic 'Soils and Soil Erosion', the following (*inter alia*) is mentioned:

- management strategies to prevent and control soil erosion (South Africa. DBE, 2011, p.36).

Management strategies to address soil erosion, which is caused mainly by fluvial action following incorrect land management, have to play a cardinal role in catchment management agencies' management strategies (mentioned in Grade 12) so this content knowledge covered in Grade 11 is very useful preparatory knowledge for the next grade. Given that the prevention and management of soil erosion is an integral part of catchment and river management, it is correct that this section is covered in Term 4 of Grade 11, and that catchment and river management follows in Term 1 of Grade 12. However, care would have to be taken for synergy and coherence to be established between the two, such as briefly revising soil erosion before starting catchment and river management in Grade 12.

Thus, in conclusion, catchment and river management was only explicitly detailed in the third curriculum (2011) since 1994. The inclusion of catchment management strategies is necessary but problematic in terms of what is happening on the ground. In addition, most teachers of Geography have had no or little training in management or strategy.

4.3.2 Fieldwork

The NATED (National Assembly Training and Education Department) Interim Syllabus in 1995 included an emphasis on field work: "3.2.6. Undertake well planned and meaningful field-work – this includes observation and measurement in the field and the recording and processing of data; the interpretation of written and graphic information" (South Africa. DoE,

1995, p.4). These constitute the basic skills necessary in fieldwork. From its earlier inception as an independent discipline, Geography contained an imperative to survey and measure in the field and also to test hypotheses in the open air, and the imperatives mentioned in this document were no exception.

In the National Curriculum Statement (2003), fieldwork appeared under essential geographical skills and techniques (LO 1), and under acquiring information, "to answer questions, learners should start by gathering information from a range of sources in a variety of ways. The skills and methods involved in this process include…interviewing and executing general fieldwork skills" (South Africa. DoE, 2003, p.10). The phraseology had not changed much from the 1995 definition. Fieldwork was explicitly mentioned, detailed and explained (as under acquiring, organising and analysing geographical information) as a general competence, *inter alia*, which was expected of a Grade 12 learner:

Table 4.1: Geography skills and field methods

Skill	Acquire geographical information	Organise geographical information	Analyse geographical information
Field Methods	Interviewing, observing, completing questionnaires, doing measurements, e.g. Global positioning systems (GPS), making notes, taking photos, drawing maps and making sketches	Classifying and summarising data	Making inferences from field observations

(South Africa. DoE, 2003, pp.12-13)

The priority of fieldwork continues in the latest iteration of the National Curriculum Statement (the Curriculum and Assessment Policy Statement) in that field work is listed under geographical skills: "practising field observation and mapping…" (South Africa. DBE, 2011, p.9), and in the Overview of Geography Content in the Further Education and Training Band:

Grade 10 The atmosphere – under geographical skills and techniques, field work and practical work are mentioned;

Grade 11, Geomorphology – under geographical skills and techniques, map techniques and field work are mentioned (South Africa. DBE, 2011, p.13)

The Overview of Geography Skills and Techniques in Grades 10, 11 and 12 mention fieldwork skills thus:

Table 4.2: Fieldwork in Overview of Geography Skills and Techniques in Grades 10, 11 and 12

Grade 10	Grade 11	Grade 12
Fieldwork • Using maps and other graphical representations: atlases, synoptic weather maps; temperature graphs • Collecting and recording data, using a variety of techniques: using weather instruments, collecting weather information form the media • Processing, collating, interpreting and presenting fieldwork findings: line graphs, bar graphs, maps, diagrams and synoptic weather maps	Fieldwork • Observation • Collecting and recording data • Processing, collating, interpreting and presenting fieldwork findings	Fieldwork (time permitting) • Collecting and recording data using a variety of techniques • Processing, collating, interpreting and presenting fieldwork findings

(South Africa. DBE, 2011, pp.15-16)

Therefore, fieldwork is explicitly stated in the 2011 curriculum right through all the Further Education and Training grades, and more attention is given to listing its components. This is sound policy but unfortunately the implementation of these grand aims tells a very different story in practice, at least in the vast majority of South African schools (Wilmot and Dube, 2015). Moreover, the proviso "time permitting" is given for fieldwork in Grade 12 in this document. Given that catchment and river management is taught in Term one in Grade 12, this proviso conveys a sub-textual message that fieldwork is not essential for the teaching of the topic. As has already been stated, the teaching of catchment and river management is tailor-made for fieldwork; therefore this proviso in effect negates a primary teaching method of this section of work.

Regarding assessment in the Curriculum and Assessment Policy Statement, "conducting fieldwork, recording and interpreting findings" is explicitly mentioned under assessment tasks (South Africa. DBE, 2011, p.51). "Conducting field work, recording and interpreting

findings" is mentioned under all three possible assessments (1-3): data-handling task, mapwork task, and research/ essay writing task (South Africa. DBE, 2011, p.54).

For the catchment and river management lessons which have been detailed in Chapter Six (phase 3), both sub-topics under fieldwork were evident. The collecting and recording of data occurred during the fieldtrip lessons (measurements and basic sketch maps). Technology-enabled fieldwork had been encouraged during the lectures the students had attended (especially GPS-enabled measurements) but poor internet connectivity and data costs may have played an inhibitory role; processing, collating, interpreting and presenting data occurred to a lesser extent, primarily due to time constraints, during the wrap up of the lesson. Ideally, the second sub-topic required a whole lesson indoors after the fieldtrip but for reasons of time and timetabling, this was not possible.

Regarding assessment, in most cases the student teachers assessed their students' work in the form of completed worksheets, examples of which are in Appendix Five (as I would ask this explicitly during the feedback after the lesson). This mostly pertained to a data-handling task and not to a mapwork task, nor to a research/ essay writing task.

4.3.3 Conclusion to curriculum progression

In conclusion, this analysis of curriculum documents and literature, in terms of catchment and river management, and fieldwork, has shown the following:

1. There were notable differences between the subject matter knowledge of the three curricula. There appears to be more synergy between the 1995 and 2011 curricula than between those of 2003 and 2011.
2. The new subject matter knowledge of catchment and river management (especially that of a catchment management strategy) would have to lead towards teachers being retrained especially with regard to the teaching of the "importance of managing drainage basins and catchment areas" (South Africa. DBE, 2011, p.43), given that there has been blurring and some confusion in previous curricula.
3. The inclusion of teaching catchment management strategies may be seen as putting the cart before the horse, given that not one catchment management strategy is presently operational, as of 2017. In addition, most catchment management agencies are not yet in place, despite many years in the making. It is clear that a catchment management agency has to be operational before a catchment management strategy is devised.

4. The importance of teaching fieldwork is diluted or ‘fudged’ in Grade 12 of the Curriculum and Assessment Policy Statement (South Africa. DBE, 2011, pp.15-16) by the insertion of the words “time permitting”. This means in practice that catchment and river management, which is taught in Term One in Grade 12 (South Africa. DBE, 2011, pp.15-16) would not have to be taught with fieldwork.

Having completed an analysis of curricula, it is appropriate to examine examination performance. Every year the Department of Basic Education publishes a diagnostic report on learner performance in the National Senior Certificate examinations. The examinations are directly linked, or should be, to the curriculum. This shows how learners have responded to the curriculum through examination performance. In Geography there has traditionally been a difference between Physical and Human Geography. The next section in this chapter seeks to examine the differences between the two fields in Geography.

4.4. Diagnostic Report Results

4.4.1 Physical versus Human Geography Performance: Diagnostic Report Results

The assessment standard for geomorphology in the Curriculum and Assessment Policy Statement (for the trial and end-of -year examinations) (under which Catchment and River Management falls) comprises a *“short objective type questions for 15 marks to cover content on Climate and Weather and Geomorphology”*, and another 30 mark question on Geomorphology. There were no questions linked to fieldwork in the report. These questions appear in both questions one and two in Section A. Learners must answer any three questions (out of questions one to four), therefore it is essential for them to answer at least one Physical Geography question, which falls in both questions one and two (South Africa. DBE, 2011, p.58).

There is no indication of problems with the catchment and river management section explicitly, in terms of the recent examination diagnostic report for the National Senior Certificate examination published by the Department of Basic Education (2015). However, there is a general problem with conceptual thinking in terms of Physical Geography, and the diagnostic report states that the average marks per questions one and two (see above) (Physical Geography) for 2014 were 36 and 33, which compare poorly with questions three and four (Human Geography) where the average marks were 55 and 48 (South Africa. DBE,

2015). Thus, there is 19 and 15 mark differences between answering questions in either Human or Physical Geography. Only the Curriculum and Assessment Policy Statement is being analysed as that was the curriculum being used with reference to the diagnostic report (the year 2015). Diagnostic reports are also quite recent and no online record exists before 2011.

4.4.2 Implications from mapwork and spatial literacy results

According to the Department of Basic Education (2015) Diagnostic Report for the Geography examination (Paper Two – Mapwork), , there is an issue with recognising both human and natural features on maps.

Learner performance in the mapwork examination declined from pass marks in Multiple Choice (55%) and Application and Calculation (57%) to Map and Photo Interpretation (44%) and GIS (39%) (South Africa. DBE, 2015). As the diagnostic report makes clear, "d. candidates struggled to identify human-made features on the orthophoto map" and "e. candidates struggled to identify natural features on the orthophoto map" (South Africa. DBE, 2015, p.77). This points to problems to do with spatial literacy and general mapwork competence. Furthermore, there was a problem in learners being able to identify features properly on different types of maps commonly used. This is significant as the learners had previously studied the features in theory but were seemingly unable to transfer that knowledge to the cartographic representation. As the report states, under Question 3 (Application and Interpretation): "h. candidates were not able to identify features studied in theory on the topographic map and the orthophoto map" (South Africa. DBE, 2015, pp.82-83).

Relating this to what has been detailed in Chapter Six (phase 3), the issues of landscape recognition and spatial literacy were in evidence during the fieldwork exercise. This could be seen in the sketch maps produced by the student teachers for their lessons (see Appendix Five) and the general issue of spatial (un)reasoning that came to fore during the fieldtrips. However, it must be said that student teachers' work improved towards the end of teaching practice. In some cases, I showed the student teachers how to draw sketch maps (example in Appendix Five), in particular in terms of what to include. This was well received by the students.

4.4.3 Social-Ecological System (SES) Stream and Curriculum Analysis: Social-Ecological System Knowledge(s)

In the Hahn et al. (2008, p.120) model, the following components or variables of a social - ecological system are given prominence: external drivers, change and surprise; social norms and rules; management: actors and organisations; ecosystem functions and dynamics; knowledge systems and social memory. For the purposes of understanding the social-ecological system dynamics in the various curricula studied, this model was applied against the three curricula and analysed.

External drivers, change and surprise are referred to in "human impact on the ecosystem" and less directly in "imbalance of the ecosystem" in the 1995 curriculum. Human impacts are also covered in the 2003 and 2011 curricula (mentioned once in both). Social norms and rules are not mentioned in the 1995 curriculum, nor in the 2003 one. These would be covered under "importance of managing catchment basins and drainage basins" in the 2011 curriculum but indirectly and implicitly. For management: actors and organisations, this is mentioned once, and conservation twice, in the 1995 curriculum. For the 2003 curriculum, this category is mentioned once (catchment and river management). Regarding the Curriculum and Assessment Policy Statement in 2011, management is mentioned twice, with the importance of management and a catchment management strategy case study. This shows clearly how management has grown in importance, both in terms of its importance and the specifying of a management strategy. "Ecosystem functions and dynamics" are well covered throughout the curricula (mentioned four times in the 1995 curriculum, once ['characteristics'] in the 2003 one, and indirectly [ecosystems would have to be covered in a case study] in the 2011 one). Knowledge systems and social memory would be indirectly alluded to in "human impacts" in all three curricula, and it would also indirectly feature in the "importance of managing drainage basins…" and the "catchment area management strategy" in the 2011 curriculum. However, it would be up to the teacher to make those connections as it is not directly mentioned.

For ease of reference, the following table includes the specific sections on catchment and river management in the three curricula.

Table 4.3: Specific sections on catchment and river management in three curricula

NATED 1995	NCS 2003	CAPS 2011
For Standard 10 (Grade 12), attention is directed to Geomorphology (3), and 3.1. (Drainage basins…). Under 4. Ecosystems, environmental balance and conservation, attention is given to 4.2. concept of an ecosystem; and 4.3. ecological processes and 4.4. human impact on the ecosystem: imbalance of the ecosystem; environmental conservation and management. (South Africa. DoE, 1995, p.10)	Grade 12, under national scale (fluvial processes and landforms), context: South Africa, fluvial processes: • flowing water on the surface of the earth-drainage basins: characteristics, drainage patterns, importance and impact of humans; • river profiles; superimposed and antecedent rivers; • catchment and river management. (South Africa. DoE, 2003, p.39)	Catchment and River Management (3hrs) (Under Geomorphology, Grade 12 in Term 1) • Importance of managing drainage basins and catchment areas; • Impact of people on drainage basins and catchment areas; • Case study of one catchment area management strategy in South Africa. (South Africa. DBE, 2011, p.43)

Thus it was determined that social-ecological system conceptualisation occurred in the all the curricula between 1995 and 2011. In the 1995 curriculum, catchment and river management was not mentioned; it took until 2003 for the concept to be mentioned, and till 2011 for the concept to be explicitly detailed. Crucially, the mentioning of a catchment management strategy was only mentioned in the 2011 curriculum.

4.5 Design-based Research, including the Question 'How did curriculum analysis influence formative design?'

This section seeks to answer the first research question "How can a teacher education programme on catchment and river management be designed that is Curriculum and Assessment Policy Statement Geography-aligned, and that reflects a complex social-ecological systems perspective?"

This first phase of research enabled the review and differentiation of the subject matter knowledge in terms of the different curricula that have been on offer in South Africa since 1994. It was clear that there are both opportunities but also obstacles arising from the curriculum research. These have been shown in points 1- 4 in section 4.3.1. The curricula analysis, including examination performance criteria, in this chapter has helped to lead to the

formative design, collation and presentation of a specialised course comprising catchment and river management which will be analysed in the next chapter (phase 2 of the research).

Therefore, this phase of research ascertained the subject matter knowledge falling under the topic catchment and river management which is presently applicable to South African secondary schools. In the Curriculum and Assessment Policy Statement (2011), it is the importance of managing drainage basins and catchment areas, the impact of people on drainage basins and catchment areas, and a case study of a catchment area management strategy in South Africa. This constituted the new and explicit environmental knowledge that teachers are expected to mediate with learners. In particular, the three sub-topics are about cause and effect, values, sound human management, and the implementing of human-led catchment management strategies. In this, the topic-specific subject matter knowledge is a good representation of the knowledge needed for understanding a social-ecological system and for acquiring sustainability competencies (this helps towards the answering of the second research question, specified in Chapter One). The examination performance as shown in the Department of Basic Education's diagnostic report (2015) portrayed very real issues, not least the difference between Human and Physical Geography questions, and underperformance in spatial literacy and map reading.

Fieldwork also comprises an important part of this essential subject matter knowledge, especially the skills mentioned under Grade 12, namely collecting and recording data, and *inter alia* processing and presenting fieldwork findings (South Africa. DBE, 2011, pp.15 and 160). Hence, fieldwork competences would have to be aligned to the three sub-topics under catchment and river management. Student teachers would have to be trained in the content and methodology of the sub-topics, but also had to be given the fieldwork methodology and tools. A thorough coverage of 'hard' geographical skills (fieldwork methods for acquiring geographical information, mentioned on pp.12-13 of the Curriculum and Assessment Policy Statement [South Africa. DBE, 2011]) would have to be mastered by the student teachers, which is essential for any area- or field-based enquiry.

It was thus clear that student teachers needed a course to equip them with the knowledge, skills, attitudes, and values necessary to teach the new environmental knowledge inherent in the latest iteration of the curriculum, namely the Curriculum and Assessment Policy Statement, which came into being in 2011. Student teachers would not have acquired the necessary contents for this and clarification of how to teach the topic of catchment and river

management using fieldwork and a social-ecological system approach. In particular, the students needed to be trained to teach the new subject matter knowledge. To this end, a course (phase 2, Appendix Six) was designed to cover the three curriculum sub-topics of catchment and river management; namely the importance of managing drainage basins and catchment areas, the impact of people on drainage basins and catchment areas, and a case study of one catchment area management strategy in South Africa. I felt that the course needed more than simply the subject matter knowledge to teach these three sub-topics. Student teachers needed to be taught about the wide-ranging theory and philosophy of catchment and river management, aligned to a social-ecological system approach. They also needed the international case experience to buttress local knowledge.

Chapter 5
Series of lectures results (Phase 2)

5.1 Introduction

Following on from the phase 1 analysis, it was determined that an entirely new course would have to be designed and compiled to introduce the new environmental knowledge and associated teaching methods to the selected Postgraduate Certificate in Education students participating in the study. This series of lectures would comprise the formative design research process, clarify pedagogical content knowledge with participating students and track this through to lesson planning and teaching practice in a rural river catchment context. The Curriculum and Assessment Policy Statement document calls for specific knowledge and skills in catchment and river management and it was clear from the curricula analysis that this subject matter knowledge had not been clearly communicated at school before 2011 (at least not at a satisfactory level).

By July 2016, the selected Postgraduate Certificate in Education students at the Pietermaritzburg campus of the University of KwaZulu-Natal had already had lectures on the following topics in their regular Postgraduate Certificate in Education Geography Teaching 401 course:

- Introduction to the course: defining Geography teaching,
- Children and spatial concept development,
- Place and the making of teachers,
- Effective Geography teaching including the use of teaching resources,
- Interpreting the curriculum,
- Values in Geography,
- Creative worksheets,
- Organising fieldtrips, and
- Mapwork. (Heath, 2016)

This body of pedagogical knowledge had laid the foundations for the students to think deeply about what it meant to be a Geography teacher in contemporary South Africa, as well as prepared them for an extended length of teaching practice in the field. In particular, the lectures on organising fieldwork, effective Geography teaching including teaching resources, and interpreting the curriculum were ideal preparation for the proposed series of lectures on

catchment and river management as well as the inclusion of catchment and river management fieldwork.

An advertisement about the entirely voluntary series of lectures and fieldtrip experience was sent out during the course lectures and nine students (however, the number dropped to five later on) subsequently volunteered. Lectures commenced in May 2016 and were held in the Education Building, University of KwaZulu-Natal, Pietermaritzburg campus (each lecture lasted one and half hours). On 17 May 2016 the initial student visit to the teaching practice schools occurred, and this was excellent for orientation and framing, as well as discussion in class, about the study area. The last and seventh lecture (after the student vacation and at the start of teaching practice) was held in the Research House at Mahai, Royal Natal National Park. This lecture was influenced by my then recent attendance at a course on the governance of social-ecological services in France.

It was therefore decided to include the following key content areas in the course:

1) Introduction to catchment and river management, and participatory integrated water management,
2) Reality of catchment and river management, and participatory integrated water management in South Africa,
3) Catchment management strategies,
4) Importance of the Drakensberg/ Maluti water system,
5) Useful teaching and learning resources for catchment and river management (with the emphasis on fieldwork),
6) Complex adaptive systems,
7) Social-ecological systems, and sustainability competencies (see Appendix Six).

This course design flowed from the curriculum and contextual work reported in Chapter Four. I considered this the ideal mix of lectures to lecture students on the demands of the new environmental knowledge (subject matter knowledge) in the curriculum, and also to prepare them for the realities of the study area. The lecture on fieldwork would ensure that fieldwork skills were allied to the key subject matter knowledge.

The following table shows the linkages between the subject matter knowledge clarified in phase 1 and the content designed to be covered in phase 2.

Table 5.1: Subject matter knowledge and linkages to course content

Subject matter knowledge in phase 1	Course content in phase 2
The importance of managing drainage basins and catchment basins (see Chapter Four, section 4.3.1)	1.Introduction to catchment and river management, and participatory integrated water management 2. Reality of catchment and river management, and participatory integrated water management in South Africa 3. Catchment management strategies 4. The importance of the Drakensberg/ Maluti water system 6.Complex adaptive systems 7.Social-ecological systems, and sustainability competencies
The impact of people on drainage basins and catchment areas (see Chapter Four, section 4.3.1)	1.Introduction to catchment and river management, and participatory integrated water management 2. Reality of catchment and river management, and participatory integrated water management in South Africa 6. Complex adaptive systems 7.Social-ecological systems, and sustainability competencies
Case study of one catchment area management strategy in South Africa (see Chapter Four, section 4.3.1)	3.Catchment management strategies 4. The importance of the Drakensberg/ Maluti water system 6. Complex adaptive systems 7.Social-ecological systems, and sustainability competencies
Fieldwork (see Chapter Four, section 4.3.2)	5.Useful teaching and learning resources for catchment and river management (with the emphasis on fieldwork) 7.Social-ecological systems, and sustainability competencies

The topic design work in the above table was developed through the curriculum analysis in Chapter Four (especially pp.64-66, 69-71). The lecture topics and hence design decisions were structured as follows to scope the necessary introductory content knowledge on

catchment and river management, and to introduce participatory integrated water management.

Regarding explicit design principles, student teachers needed an introduction to catchment and river management (in terms of conceptualisation) as the research in Chapter Four (see section 4.3.1) had shown that mixed messages and concept dilution regarding catchment and river management were evident in the different curricula. The new environmental knowledge as expressed in the Curriculum and Assessment Policy Statement needed elaborating and emphasising. They also needed an introduction to key disciplinary concept knowledge. In terms of 'Participatory Integrated Water Management' (PIWM), students needed to understand the constraints and opportunities of this highly ambitious policy. Catchment and river management models would help immensely in student teachers being able to teach the importance of catchment areas and drainage basins (see Chapter Four). For 'Reality of catchment and river management, and participatory integrated water management in South Africa', student teachers needed to be shown the South African experience and reality regarding catchment and river management, and PIWM. Moreover, the intensity of droughts is increasing and catchment areas are becoming increasingly degraded – this would help with being able to teach the impacts of people on catchment areas. With respect to 'Catchment management strategies', the students needed elaboration on the conceptualisation of a catchment management strategy. This concept had not been mentioned in curricula prior to 2011 (see Chapter Four, section 4.3.1). There was a dedicated lecture on 'The importance of the Drakensberg/ Maluti water system'. With respect to 'Useful teaching and learning resources for catchment and river management (with the emphasis on fieldwork)', it was decided to give a dedicated lecture on teaching and learning resources regarding catchment and river management, with a focus on fieldwork. Students had already had a general lecture on fieldwork but I felt it was essential to marry fieldwork theory and techniques with catchment and river management. Regarding 'Complex adaptive systems', I decided to give a lecture on complex adaptive systems as a preamble for social-ecological systems in the next lecture. A catchment basin is a complex adaptive system, where many factors and agents combine. This in turn requires continual adaptive management at the right time and place, and also scale. With respect to 'Social-ecological systems, and sustainability competencies', catchment and river management is essentially the management of a social-ecological system. It is furthermore an ideal vehicle to support the development of sustainability competences, as decision-making and the weighing of values is constantly needed.

To construct the topic-specific pedagogical content knowledge, I compiled 37.5 pages of notes and 74 academic references (of which Messerli and Ives, 1997, *Mountains of the World: A Global Priority* was very influential) (see Appendix Six). I also sourced information from three different academic courses, both in South Africa and overseas. The specialised course I attended in France on the governance of social-ecological systems informed the last and seventh lecture (URCA and SENSE, 2016). Key lessons and notes from my master's degree in City and Regional Planning (Davies, 1999 and Gasson, 1999) had a major influence. In addition, I used many photocopies of maps, graphs and tables to illustrate what I was saying. I gave the students seven questionnaires (the questionnaires were not exactly aligned to the lectures but broadly followed them) for data collection.

In this phase, in contrast with the previous one (phase 1), I occupied a dual role as that of a course lecturer and assessor along with that of a course design researcher. Phase 2 thus developed as a process of reflexive practice and course evaluation that included topic deliberation with the participating student teachers to inform the contours of topic-specific pedagogical content knowledge into the proposed phase 3 process of teaching practice and fieldwork.

5.2 Students' Responses towards the Topic-Specific Pedagogical Content Knowledge in Lectures

The design research tool for the second section of this chapter was the use of questionnaires to ascertain the student teachers' responses towards the topic-specific pedagogical content knowledge delivered by me as lecturer.. The questionnaire responses generally aligned with the lecture series (the questionnaire on social-ecological systems included questions on complex adaptive systems too). Student teachers' responses were analysed in terms of the three major lenses employed in the research, namely (1) Hahn et al. model (2008) of social-ecological systems, (2) social learning (Wals, 2007), and (3) practice architecture (Kemmis et al., 2014). The first section of this chapter involved clarifying an understanding the topic-specific pedagogical content knowledge emerging in the lectures (see Appendix Six) and determining how often key terms and concepts shaped pedagogy.

For the first lens, I was very interested to see how the students' prior geographical knowledge and training informed their responses on the questionnaires. The second lens was chosen because a group of student students comprised a social learning group by learning and

discussing together during lectures and into their lesson planning for teaching practice that followed. The third lens was practice architectures, which needed to be tested and understood in the lectures.

5.2.1 Evidence of social-ecological systems perspective in the teacher education programme

This section presents data in relation to the first research question (How can a teacher education programme on catchment and river management be designed that is Curriculum and Assessment Policy Statement Geography-aligned, and that reflects a complex social-ecological systems perspective?). It reports on the five aspects of social-ecological systems thinking identified by Hahn et al. (2008), and how they emerged through data sourced from the questionnaire answers in Appendix One (these questionnaires were based on the lectures given (mainly), and prior academic learning, plus the initial teaching practice visit to the study area). Regarding the first component of the model, external drivers, change and surprise, this was answered in length in a summary of answers to the question: Why is the uThukela a complex adaptive system, do you think? (each student's response is separated by a / and six students answered the questionnaire).

> *It's because uThukela changes from time to time and this supplies large amount of water/ The Thukela is a big river and it is known for the greater distribution of water. The Thukela floods especially during the rainy seasons. The Thukela is a river and any natural disaster might happen at any time/ It is because you will never know what is gonna happen in the river. There is a lot of uncertainty like for instant drought or flooding…/ uThukela river is complex adaptive because the river is unpredictable, in some years you find the river in extreme drought state and in some years it flood excessively/ Uthukela is a complex adaptive system because it is able to adapt during drought seasons and also become flooded during raining season/ It is a combination of social and ecological factors therefore we must be prepared for uncertainty/….* (Appendix One, pp.10-11)

The answers clearly show that external drivers in the form of climate, change and surprise (unpredictability) are features of this river system. It is clear that the students correctly identified that climate, change and surprise are key external drivers of the upper uThukela social-ecological system. They were also able to correctly identify the climatic pattern of the valley in that years of drought are suddenly broken by flooding and widespread damage to crops and livestock. The second component of social-ecological systems thinking, social norms and rules, was noted in an answer to a question that shares concerns with management:

What issues do you think the uThukela region will bring to the Pongola-Umzimkulu CMS [catchment management system]?

> *I think the poor communities will find it difficult to balance conservation with development. Irresponsible development/ The river is big on its own and already the Pongola-Umzimkhulu CMS covers a big region. It will be unmanageable/ Land degradation, issues related to zonation of land uses/* (Appendix One, pp.7-8)

Another question also alluded to social norms and rules practised by the inhabitants of the upper uThukela valley: What did you notice about your visit to the upper uThukela that makes the area a crucial socio-ecological system?

> *I noticed a parasitic relationship between humans and rivers. People always take from the river. Traditional healers extract herbs and never replant. They pollute water through littering/…it also has high erosion zones. / Irresponsible development such as pathways and roads/ Social factors such as overgrazing contribute to soil erosion.* (Appendix One, pp.11-12)

It is clear that the social norms and rules (or lack thereof) practised at the time are having a deleterious effect on the environment, and that one of the student teachers correctly classified the relationship between people and the river as "parasitic". No other social norms were indicated at the time by the student teachers.

Management – actors and organisations – (the third social-ecological system dimension) was given prominence in the questionnaire answers. This also had to do with the attention paid to management in the lectures and consequently the questionnaires. The method and theory of participatory integrated water management is the preferred approach of the South African government. The following question was posed regarding this: Do you think PIWM is a realistic policy for SA and particularly KZN catchments? Five students answered 'yes' and one student 'no.' The reasons for their answers were as follows:

> *Yes, PIWM is a realistic policy since it is a process that involves natural and human resources in a catchment and also it take into account social, economic, political and institutional factors/ Yes, it is paper and ink but as for implementation our officials fails to make it happen. They also fail to monitor reason being they care more about economics than nature/ Yes, if we could learn to use our water wisely and also be able to protect our water sources it will be a benefit to our country and our communities/ Yes, because our government has even started programmes like Working for Water projects where people are being paid to remove alien plants along the coast of rivers/ Yes, it's a realistic policy because it emphasises*

> *the need for many stakeholders to participate in management of catchments/ I think this is a realistic policy and can result to proper management of catchments if this policy can be well implemented.* (Appendix One, p.5)

Most students were keen to point out successes in catchment areas such as Working-for-Water, and that, with proper implementation, the policy could succeed. There was, however, one dissenter who wrote that "our officials (actors) fails to make it happen".

Understanding scale, and at the appropriate level, is key to successful participatory integrated water management (PIWM). The following question was posed to the students: Do you think the key issue of scale is understood, and properly implemented, by people in the catchments? Only one student answered in the affirmative while four students answered in the negative. This is slightly contradictory to the answer above where students were questioned on whether or not PIWN was a realistic policy for the country and province. The reasons for the students' answers are set out below (most students felt that the inhabitants did not understand, and/or are not well educated regarding scale:

> *No, most people in the catchments lack some information about the importance of catchments/ No./ Yes, in the rural areas people are aware of the environment and what they plant and when to plant. We understand the season the water flow and how to conserve our nature and water/ No, the people in the catchment areas are not well educated regarding the issue of scale, thus they will fail to implement it/ I think people in the catchments areas don't really understand the issue of scale, thus they tend to fail to properly implement it.* (Appendix One, pp.5-6)

In answer to the question: What geographical problems did you notice in the catchment when you went to the schools for the initial TP visit?, student teachers answered that:

> *There is lot of erosion, most catchment is dry, area is dry, people or households are situated far from catchment and there is overgrazing in most uphills/ It dry, cold and far from the city/ I noticed that it was very dry and that many of the areas showed evidence of erosion/ At the school I was at the was no available drinking water. The girl have to go long distance to fetch water/ There was high erosions near the catchments and the too many cattles grazing near the catchments. People near the catchments have cultivated lands ploughed inappropriate.* (Appendix One, pp.8-9)

It is clear that these aforementioned problems are the fault of inadequate or no management. It could be said that the upper uThukela is a profoundly unmanaged area. The student

teachers were also given a lecture on catchment management strategies and their answers to the questions can be found below: What are the contradictions you notice in the CM strategy policy? Do you think stakeholders in the upper uThukela will ever agree on a strategy?

> *There are contradictions between development or use of resource and conservation. It is difficult to achieve equilibrium when people are poor/ It says that we need to use water and at the same time conserve water/ The contradictions are that the strategy points out the importance of considering the poor in CM while practical it not happening/*
>
> *Yes they will because a proper strategy entails a proper involvement/ Yes/ Yes I think they will agree only if the people are well taught about the management strategy.* (Appendix One, p.7)

The student teachers' answers were remarkably astute and realistic about the contradictions inherent in catchment management strategy policy. However, the entire class felt that stakeholders would agree to a common strategy. This observation is very important considering what has been written about catchment management strategies (see Ashton, 2000 and Meissner et al., 2017).

Another two questions dealt with a catchment management strategy. The first (What issues do you think the uThukela region will bring to the Pongola-Umzimkulu CMS?) and the second (How does one design a CMS?) were respectively answered as follows. The first has also been included under social norms.

> *I think the poor communities will find it difficult to balance conservation with development. Irresponsible development/ The river is big on its own and already the Pongola-Umzimkhulu CMS covers a big region. It will be unmanageable/ Land degradation, issues related to zonation of land uses.*
>
> *Include things like sustainability, equity and control/ One can design CMS by inviting all stakeholders interested and affected to discuss about current management strategies and working to more effective strategies together.* (Appendix one, pp.7-8)

From a management perspective, students correctly pointed out that extremely poor communities will choose development over conservation, and that the proposed Pongola-Umzimkhulu CMS covers a vast area, and is discontinuous. The student teachers' answers regarding the latter question were excellent and proof that the students had been attentive during lectures. Students wrote generally about management problems and did not

foreground actors and organisations in their answers, except for one student who wrote about officials.

Regarding an ecosystem functions and dynamics perspective (the fourth dimension of social-ecological thinking), students provided information via responses to a fieldwork question: Describe your previous fieldwork experiences at school – where, how, what? It was significant that most of the fieldwork had been river studies and that the focus had been on river health.

> *We assess water pollution at Cumberland by observing the number of living organism found in the river e.g. dragonfly/ Howick Waterfall, study of life in water (river system) looking at what a health river has/ No, I didn't have any fieldwork.* (Appendix One, p.10)

Asked what they had learnt about catchment and river management during their undergraduate years, students gave the following answers, which do point to an ecosystem functions and dynamics concern:

> *Water pH level, water management, water source, most important dam, rivers in SA, testing of water quality.* (Appendix One, p.2)

Lastly, concerning the dimension of knowledge systems and social memory, student teachers gave the following answers to the question: What are the existing beliefs, including indigenous knowledge systems, of the people living in the study area regarding CRM?

> *People believe that protecting water sources and keeping them clean is important. Since they depend mostly on subsistence farming for their survival/ I think people are lacking proper knowledge on CRM and they are not concerned about managing rivers because they don't understand their importance/ Rivers are used as a means of cleansing evil spirits. Thus they are highly protected. Some traditional healers as well as religious members use rivers for the purpose of baptism. Therefore certain parts of the river would be protected/ I heard that people simple because its an ethical thing to do and that rivers are seen as dangerous thing. Children are forbidden/ not allowed to swim because they might pick up pathogens.* (Appendix One, p.4)

Student teachers generally wrote on the use of rivers to communities, and that there is also a spiritual importance given to the river. However, an element of danger is also associated with rivers.

Students responded generally in terms of danger and the cold in answer to the question: What are your acquired beliefs about the Drakensberg? i.e. what have your parents and community told you about the mountains?

> *Mountains has lot of different vegetation, however it's not safe to go there since there are lot of dangerous animals such as snakes. Due to lot of vegetation cattles were grazing there and collected every afternoon/ Nothing much about the mountains including the Drakensberg/ That the mountains are beautiful and that it shows and that it is very cold/ My beliefs about the mountains is that there by. It very cold during the winter. It is where the ice falls and my parents told me that the Basotho tribes also uses the mountains/ They have told me that the Drakensberg area is very cold, especially during winter months. They have also told me that mountains contain dangerous animals*. (Appendix One, p.9)

5.2.2 Cross-referencing of topic-specific pedagogical content knowledge to the subject matter knowledge in Chapter Four

In the curricula analysis, in the topic-specific pedagogical content knowledge, external drivers, change and surprise are referred to as human impacts which are covered in the 2003 and 2011 curricula. In the lectures, students ascribed climate and weather to external drivers. Social norms and rules are not mentioned in the 1995 curriculum, nor in the 2003. These would be covered under "importance of managing catchment basins and drainage basins" in the 2011 curriculum but only indirectly and implicitly (South Africa. DBE, 2011, p.43). The student teachers did not find any, or very little, evidence of rules in the study (during the lectures, after they had gone for the initial visit). Social norms *vis a vis* the environment were seen as extractive and even "parasitic" (Appendix One, p.11). For management – actors and organisations, this is mentioned once, and conservation twice, in the 1995 curriculum. For the 2003 curriculum, this category is mentioned once (catchment and river management). Regarding the Curriculum and Assessment Policy Statement in 2011, management is mentioned twice, with the importance of management and a catchment management strategy case study. During the lectures, student teachers gave remarkably accurate and prescient answers to management issues such as participatory integrated water management (most students thought it would work), scale (most students thought that catchment inhabitants would not grasp it), management problems, and catchment management strategies. Crucially, students identified contradictions in catchment management strategy policy but felt that stakeholders would agree to a common strategy. "Ecosystem functions and dynamics" are well covered throughout the curricula (mentioned four times in the 1995 curriculum, once

["characteristics"] in the 2003 one, and indirectly [ecosystems would have to be covered in a case study] in the 2011 one). In the lectures, students indicated river studies and river health as their reference points for this dimension. Knowledge systems and social memory would be indirectly alluded to in "human impacts" in all three curricula, and it would also indirectly feature in the "importance of managing drainage basins…" and the "catchment area management strategy" in the 2011 curriculum. In the lectures, the student teachers ascribed the use thereof, spirituality and some danger to the people living in the catchment in respect of catchment and river management beliefs (Appendix One, p.4). With respect to the acquired beliefs about the Drakensberg on the part of the student teachers, danger and the cold featured most in their answers (Appendix One, p.9).

In terms of the second lens, social learning (Wals, 2007), the points below summarise the topic-specific pedagogical content knowledge of the lectures.

1. Orientation – actors, issues and challenges

The actors comprised one lecturer and nine students. The median age of the students was 24, and the cohort included four males and three females. This would later decrease to three males and two females. Six students held a Bachelor of Science degree, with two holding a Bachelor of Social Science and one a Bachelor of Arts (Appendix One, pp.1-2).

With respect to issues, five of nine students felt that Human Geography had received more attention than Physical Geography at university, with one dissenting and two feeling that a balance had been obtained (Appendix One, p.2). Only four out of six students felt confident about being able to teach integrated water resource management or participatory integrated water management (PIWM) at the Further Education and Training level (Appendix One, p.5).

Regarding challenges, a median of only a little over two weeks had been dedicated to the study catchment and river management at university (Appendix One, p.3). Only one of nine students had had training or exposure to social-ecological systems at university (ibid.). Five of six students felt they had not been adequately prepared at school to teach PIWM, with most students answering that they had not been taught any water management at school (Appendix One, p.6) (the participation number had dropped from nine to six students at this stage). All six students (100% of the students who answered the particular questionnaire) said they had not been adequately prepared at university to teach PIWM, which is highly significant (Appendix One, p.6). In explanation, students (only five students answered here) stated the following, pointing generally to lack of time and detail:

> *I only had the introduction, I still lack some information and I haven't been reading much literatures/ Not really, we are made aware that water is controlled and not accessible as we think/ Because I still need to develop my knowledge on PIWM/ This was not taught but not in details or clearly/ This was not given enough time at university and it was not tested that much.* (Appendix One, pp.6-7)

Regarding the intended use of technology, especially cell phones, to geolocate work on fieldtrips, students answered that the cost of data bundles, issues of accuracy, and not knowing how to geolocate with it put them off using cell phones, which was a missed opportunity for fieldwork (Appendix One, p.10). Students, however, stated that they would use the following other cell phone functionalities: "Cameras, videotaping, sound recording/ I will use the video of my phone and the camera to capture the moments/ Google and Google Maps" (Appendix One, p.10). During phase 3 of the research, however, out in the field this did not happen (see Chapter Six, section 5.2.3).

2. Self-awareness – eliciting one's frame.

Students had clear memories of catchment and river management at school. Only two of the nine (at this stage of the research there were nine participants) had done fieldtrips to a catchment basin at school though (Appendix One, p.1). Eight of the nine students had completed a university course in geomorphology and had been upskilled in the river valley dynamics, including anti-erosion measures (ibid., p.2). Only one of the nine students had completed a hydrology course, where the focus had been on river health (ibid., p.2). Technological aids, especially Geographic Information Systems (GIS) and Global Positioning System (GPS), have been a feature during catchment and river management training at university (ibid., p.2).

3. Deframing-reframing/ clarification/ exposure to other frames

Students felt that the fieldwork methods of "Geolocate and georeferenced, videotaping and voice recording/ Educational Presentation/ Teaching management strategies" looked most appealing (Appendix One, p.10). In addition, after having been lectured on catchment and river/ watershed management models, students were asked which model (Hufschmidt, 1986, Gregersen et al., 1988, Falkenmark, 2004) was theoretically most useful. Three students felt that Gregersen et al. (with its clear linkages and emphasis on water yield) was most useful with only one stating that Hufschmidt was best. The answers for such a choice were as follows:

Gregersen=Because this model give a clear idea on what factors affect the water yields in the rivers/ This model clearly links with the land uses we observed in Bergville and shows the linkages to the watershed, which may affect the management of the watershed/ Gregersen's model is clear and it is applicable to the area of Drakensburg. The important aspects that entail water management are clear, e.g. fisheries/ Hufschmidt=This theory is broad, it covers almost everything that is related to RCM of uThukela. (Appendix One, p.3)

4. Co-creating, re-constructing of ideas

This was most pertinently answered in the question: How will you approach social learning using a SES template? (Appendix One) which was answered thus (this was right at the end of the course, after the students had been lectured on social-ecological systems and social learning):

I will approach it through involving many different stakeholders that are in the area/ SES will allow learners to think strategically about their environment and capacity building will be encouraged/ Will use persuasive and deception approaches like for instant, telling people not to litter rivers isn't enough but telling them that they are putting their livestock in danger and aquatic species such as fish could motivate them/ I will invite community members and local authority and teach them about the importance of managing drainage basins/ By making communication however, set the boundaries. For instance, making sure that there is a communication between I and the community/ Gather communities or learners ask them question with respect to their beliefs. Then teach and add to their indigenous knowledge/ I will ask factual question. (Appendix One, p.12)

5. Applying – collaborative actions

Although during a course, where the student teachers were participants, there was not much opportunity for the application of collaborative actions, some sign of this can be seen in the students' answers in the questionnaires. Students' answers were remarkably synergistic and this is most clearly seen in the answers to the question: Why is the uThukela a complex adaptive system, do you think?(in Appendix One). The answers are significant because they were answered after a few days of teaching practice had commenced. Answers contained very similar phrases, with synergistic and collaborative thinking, such as:

It's because uThukela changes from time to time (first student)… any natural disaster might happen at any time (second student)… There is a lot of uncertainty like for instant drought or flooding (third student)... the river is unpredictable, in some years you find the river in extreme drought state and in some years it flood excessively (fourth student)… it is able to adapt during drought seasons and also become flooded during raining season (fifth

student)… it is able to adapt during drought seasons and also become flooded during raining season (a student answered twice on the forms) (Appendix One, pp.10-11)

6. Reviewing – assessing issues/ challenges addressed (Wals, 2007, p.499)

The questionnaires (one to seven) show the development and increasing confidence of the student teachers. It is significant how the thinking changed between questionnaires 1-6 (Appendix One, pp.1-10), which were answered after the lectures at UKZN, and questionnaire 7 (ibid., pp.10-14) which was answered after a few days of actual teaching practice. These answers show immersion in, and commitment to, the project. This development of thought can be most clearly seen in the following question (How will you approach social learning using a SES template?). The use of keywords such as "stakeholders", "strategically", "capacity building", "persuasive", "communication", "with respect to their beliefs" and "add to their indigenous knowledge" shows that the student teachers had reviewed by assessing the issues and addressing the challenges (Appendix One, p.12). They had clearly learnt a lot during the series of lectures, and had been aware of the deep-seated issues and challenges, but were now ready to put that knowledge into practice.

5.2.3 Practice architectures

This next section seeks to describe and explain the practice architectures, the third lens of research, that were evident during lectures. The theory used was Kemmis et al.'s (2014) theory of material-economic, cultural-discursive and socio-political architectures.

Material-economic architecture

The lectures, except for the last, were held in a seminar room in the UKZN Education Building, the same venue as previous lectures. The last lecture took place at the Research House, Royal Natal National Park, after the commencement of teaching practice (in this venue the lecture was given in the common room). The format of each lecture took the form of myself in the front, next to a whiteboard, as the lecturer, and the students seated around a table. The turnout of students decreased from nine to five at the end of the lectures (Appendix One, pp.1 and 11). Reasons for leaving the course were issues such as finances and family responsibilities. Lectures were held once a week and for about an hour and a half in each case.

Cultural-discursive architecture

The dominant discourse during the lectures was that of catchment and river management, framed where possible within a social-ecological systems perspective (see Appendix Six). The

first orientating feature of the lectures was the Curriculum and Assessment Policy Statement requirements in catchment and river management (ibid., p.1). The Curriculum and Assessment Policy Statement provided a major underpinning architecture to teaching practice experience, as it was the Curriculum and Assessment Policy Statement that informed the lessons to be taught. Key lessons and issues regarding catchment and river management and social-ecological systems were referenced both from an international and a South African perspective (ibid.). The delivery of the educational material took place by means of a lecturing format but with time given for discussion plus question and answer sessions (seven questionnaires were handed out to be filled in). I was cognisant that the students had not had much experience in mountains or with mountain-oriented education so I strove to project a mountain-oriented education perspective wherever possible.

Social-political architecture

The power relationship between me and the students reflected the voluntary nature of the lectures, plus that it was not an examinable course and that therefore I was not assessing students (this would change in the third phase though). My role was a facilitative and enabling one. The context for the course was set out in the briefing on catchment and river management on 3 May 2016. During that briefing it was emphasised that all participants were volunteers, and that they could withdraw at any time. The format of the lectures, together with the course expectations and outcomes, was detailed (because it was voluntary the learning space was quite social, with much discussion rather than a formal lecture). Regarding the format of the authority, university and lecture rules prevailed. I really enjoyed lecturing the students and a cooperative solidarity existed between us, as we both had a project to complete in the third phase of the research. The students would broaden their knowledge, and the lecturer would help to upskill the students in catchment and river management processes, and also provide data for this study (Kemmis et al.. 2014).

5.3 Synthesis of Findings, including Design-Based Research Insights

The lecture series set out to teach social-ecological systems thinking towards the design of Geography lessons with fieldwork in a rural catchment setting. I felt that the students responded constructively and comprehensively to the topic-specific pedagogical content knowledge (see Appendix One, pp.1-14). With respect to the acquisition of social-ecological systems competence and perspective during lectures, students displayed a generally

sophisticated and nuanced appreciation of the issues and processes at hand in their questionnaire answers (Appendix One, pp.10-14). In particular, they showed a healthy and educated view of some government-mandated initiatives like the chances of participatory integrated water management (which depends on scaled management) succeeding (Appendix One, pp.5-7). This shows that the series of lectures served its purpose and produced the necessary thinking for students about to go into teaching practice. Regarding social learning, it was shown that despite some issues and challenges (chief of which was somewhat poor preparation for catchment and river management, and social-ecological systems), students were accurate in their answers to the rest of the social learning criteria outlined by Wals (2007). It was shown that students were frank about their self-awareness, open to deframing approaches, and remarkably similar in co-creating and applying collaborative actions. Finally, the reviewing of social learning showed a pathway of perspective to the next phase. With respect to practice architectures, the data showed that the material-economic practice architecture (both venues) was enabling of delivery of materials, discussion and debate. A number of key texts and theories (chiefly educational policy and catchment and river management theory within a social-ecological system framework) in Appendix Six informed the cultural-discursive practice architecture. Students appeared to have grasped the key content, as seen in their good answers in the questionnaires (Appendix One). Socio-politically, the architecture that existed between me and the students was non-evaluative, enabling and contained a cooperative solidarity. Overall, the delivery of the educational materials to this cohort of graduate students was successful.

Chapter 6
Findings from Students' Teaching Practice (Phase 3)

6.1 Introduction

Phase 3 comprised the student teachers teaching the topic and making explicit the topic - specific pedagogical content knowledge for a review. The subject matter knowledge has been outlined in Chapter Four, and the students had been taught a course on catchment and river management in phase 2 (see Chapter Five). Thus, after the series of lectures and immediately after the student vacation, the five student teachers commenced teaching practice (the third phase of research) for six weeks in the upper uThukela area, between Bergville (KwaZulu-Natal) and Witsieshoek (Free State). They were based at three schools. I occupied a dual role during this phase, one as a teaching practice assessor and the second as a researcher reviewing the topic-specific pedagogy and its effectiveness in a rural catchment management context.

Student lesson design, delivery and assessment as a design process emanating from the course in river and catchment management concepts and pedagogy were reviewed. This was in order to probe how the concepts were taught (during lectures), and social learning in the classroom and associated preparation for teaching practice fieldwork were conducted. This was done along with the shaping influence of the practice architectures in both the lectures setting and the rural classroom-based teaching practice. This analytical progression would have significant import regarding the potential of teaching strategies in rural areas. Essentially, this phase of the research would contribute more in-depth knowledge on how teacher education practice reflected grasp of new environmental content knowledge and engagement with sustainability concerns related to catchment and river management in the rural setting of teaching practice. As such, this was the final iteration of the iterative design research and review process of the three research phases. These started with the analysis of the curriculum and new environmental content knowledge which informed the formative design of the series of lectures and the application to teaching practice that followed.

6.2 Research Tools and Lenses

The main research tool was the use of observation and analysis of teaching materials to probe the topic-specific pedagogical content knowledge evident in the teaching undertaken by each

student teacher. This was reviewed with the same three lenses employed in phase 2 of the design research process, namely:

- social-ecological systems,
- social learning, and
- practice architecture.

For the first lens, the teaching practice experience was tested against social-ecological system theory. The emergence of sustainability competences through social-ecological systems would also be analysed. The second lens (social learning) was to be used regarding how the students' learned together on teaching practice (however, there were limitations because the students' lessons were meant to be individual work and there does not appear to be much collaboration between the students and their mentor teachers in the reflective reports - see Appendix Four). The third lens was practice architecture as the teaching practice had to be tested and understood within enabling and constraining factors, i.e. as a specific time-and place-based experience.

The introductory table below summarises the general educational experience reported by the students. It includes lesson topics taught and the associated sustainability competences specified, and the experiments conducted on fieldwork. The decision on whether or not the lesson had to be repeated is also shown.

Table 6.1: Analysis of lessons and experiments employed

Date	School	Lesson plan topic	Sustainability competence potential in lesson plan topic	Location of fieldwork	Experiment	Measure data?	Repeat lesson? (Specific issues in lesson)
30.7.16	School A	River and catchment management: importance of drainage basins management.	Systems thinking Normative Strategic	Along Busingatha stream	Mini-stream assessment scoring system (mini-SASS)	Yes	No (confused sub-topics – mis-conceptualised)
3.8.16	School B	Catchment management strategy (CMS)	Strategic Systems thinking	Down to uThukela River	Mini-SASS	Yes	Yes (misinterpreted scale and mis-conceptualised)
30.7.16	School A	Catchment and river management (CRM)/ human impacts	Anticipatory Systems thinking Strategic	Along Busingatha stream	None	Yes. Questionnaire on human impacts.	No (mix up sub-topics – mis-conceptualised)
13.8.16	School A	CRM-importance of catchments	Systems thinking Normative Strategic	Down to uThukela River	Mini-SASS	Questionnaire on importance of catchments and indigenous knowledge systems	No. (not coherent enough – some mis-conceptualisation)
6.8.16	School A	Human impacts on catchment basins	Anticipatory Systems thinking Strategic	Veld around school and down to uThukela River	Erosion experiment-bottles and vegetation-variable flow	Worksheet completion	No
19.8.16	School A	CMS	Strategic Systems thinking	Upslope from school in SE direction. Classroom	Plan to do mini-SASS but not done due to weather	No	Yes (misinterpreted scale and mis-conceptualised sub-topic)

6.8.16	School B	Impact of people on catchment areas	Anticipatory Systems thinking Strategic	Down to stream parallel with road	No	No worksheet	Yes (No framework and wetland confused – mis-conceptualised)
20.8.16	School B	Human impacts on catchments	Anticipatory Systems thinking Strategic	Down to stream parallel with road		No. Not empirical enough.	No (mis-conceptualisation of terms)
12.8.16	School C	Impact of people on catchment areas	Anticipatory Systems thinking Strategic	Down gravel road to stream		No	No (mis-conceptualisation of sub-topics)
20.8.16	School C	Importance of managing catchment areas	Systems thinking Normative Strategic	Down gravel road to stream	Mini-SASS	Yes	Yes (oxygen source confused – mis-conceptualisation of science)

6.3 Evidence of the Development of Social-Ecological Systems Thinking Teaching Practice

This section presents data in relation to the second research question: How can engagement with new environmental knowledge and fieldwork practices lead to the development of sustainable competencies that reflect engagement with a complex social-ecological systems perspective? It reports on the five aspects of systems thinking identified by Hahn et al. (2008). Regarding the first component of the model (external drivers, change and surprise), the significance of this became apparent during the student teachers' fieldwork with the learners. The weather was a major external driver, affecting the level of the uThukela significantly following a cold front (mid-latitude cyclone) that passed through the area in the first week of teaching practice. A thunderstorm with lightning affected one fieldwork lesson, forcing the student teacher, university tutor and learners to move quickly to a classroom (Appendix Two, p.6).

The second component of social-ecological systems thinking, social norms and rules, was noted by students in their reflective reports. One student reported on how environmental issues and risks emerging from local practice had been incorporated into the lesson. She explained that: "There was evidence of pollution, erosion, mining and mis-utilisation of the riparian zone … This questionnaire was to give learners a clear picture of how the community has damaged the environments of the river banks and have impacted on the water quality and state of the natural environment" (Appendix Four, p.4).

Management: actors and organisations (the third social-ecological dimension), or the lack thereof, was given prominence in the student teachers' lessons during the fieldtrips. In particular, the teaching of a catchment management strategy case study (a requirement in the Curriculum and Assessment Policy Statement) proved difficult for some students in terms of clearly illustrating scale, boundaries and zoning in a catchment. One student noted: "I should have provided with a strategy that would manage the whole catchment not the small areas of a catchment … therefore I had to repeat the lesson' (Appendix Four, p.7). Another student noted "the lesson was supposed to orientated around one strategy in a catchment … The objectives did not orientate around a specific catchment management strategy" (Appendix Four, p.2). In these two quotes, the student teachers are referring to a single catchment management strategy, which uses zoning to separate land use, for a particular catchment. On occasion, activities were oriented around the impacts of people on catchment basins, whereas they needed to be oriented around a catchment management system. In particular, activities

needed to be re-aligned to a bigger scale for a catchment management system because the whole catchment, not only a small part of it, is the focus. This was seen in the following comment from a lesson assessment form: “Re-align to a macroscale for a catchment management system” (Appendix Two, p.6). Human impacts would also fall under management in the sense that management decisions, or the lack of them, contribute to the negative effects that people can have on a catchment, as evidenced in the following comment: “A good section but please understand the nuances of human impacts: dams, IBT (interbasin transfer) (mostly negative)” (Appendix Two, p.8). It appeared that key understandings and concepts regarding the management of social-ecological systems and catchments, that the student teachers conveyed to learners, were sometimes confused and related in disassociated ways (for example, the sketch maps the student teachers drew provided evidence of scale confusion, and no understanding of the boundaries of a catchment basin) during the fieldwork-based teaching practice (Appendix Five, pp.18-19, 21). Geographic discontinuity (one student confused different and distant catchment basins) was evident at times. “On the 26th of August I repeated the lesson in class showing them different charts and worksheet. The main purpose was to teach the catchment management strategy from macro point of view. Like for instance zoning, dividing the catchment for different purposes, the upper uThukela is zoned for conservation not for heavy industries while the areas next to Amajuba are zoned for heavy, light industries, formal and informal human settlement” (Appendix Four, p.7).

From an ecosystem function and dynamics perspective (the fourth dimension of social-ecological thinking), students focused on the river basin. The mini-stream assessment scoring system (SASS) experiment was used in an appropriate and successful manner most of the time. However, there were two areas where a need for improved understanding became apparent. Firstly, a student confused atmospheric concepts (in that the student thought a catchment gave all the oxygen people need) (Appendix Two, p.10). Secondly, there was some inappropriate use in terms of systems thinking (in the misconceptualising of scientific processes such as a student confusing an area that had been made wet by a leaking tap for a wetland) (Appendix Two, p.7, alluded to). I emphasised that on a fieldtrip it is also very important for learners to measure what is seen (human impacts on catchment areas needed to be measured using experiments, observation and measurements) (Appendix Two, p.8). An ecosystem perspective was evidenced by the statement in a reflective report that: ‘My learners were very happy about this activity (the mini-SASS) and enjoyed it as they were looking for the different animals in

the river. They were very disappointed by the result as they showed that the Thukela River was not healthy" (Appendix Four, p.5).

Regarding the dimension of knowledge systems and social memory, one student explained that "the lesson was to focus on using indigenous knowledge and also extracting the knowledge that the learners carry with them in terms of protecting and preserving the rivers" (Appendix Four, p.5). Significantly, one student teacher noted (in Appendix Four, p.7) that "the spring was not even recognised by members of the community hence I [taught] my learners ways of conserving and managing springs". This implies that, while one can have the intention to mobilise indigenous knowledge, in some cases a community may not be forthcoming in sharing information about what might be a precious resource which has cultural or core survival significance in the area.

6.4 The Development of Sustainability Competences following a Social-Ecological System Experience

The following two questions on sustainability competences (Wiek et al. 2011) were given after the last lecture, and a few days after teaching practice had commenced, which is what makes the data significant, as the students were embedded in the study area and had had several days of teaching experience already (see Appendix One, p.13):

In answer to the question:Which one of Wiek et al.'s five competences is most crucial to the study area?, students answered thus and the respective reasons for the choice are given immediately afterwards:

> Strategic competence: *This is very crucial because every thing needs a proper plan in order to be successful.*
>
> Normative: *Rural communities work according to their beliefs and these belief are usually centred. Rural communities always work together.*
>
> Interpersonal competencies: *Because if you have the ability to make friends with all the stakeholders in the community it will be easier to formulate a strategy on how to overcome a problem in a catchment. What is important is good communication/ relationship.*
>
> Shaping competence: *Because if you are competent in shaping you are able to shape things and solve most problems you encounter.*

I think normative competence and anticipatory competence are most crucial to the study area: You have to think ahead in every system especially in studies that involve river catchment management. And also you have to do things properly in order to be supported.

Trust: *You have got to trust your members in order to produce successful management skills.*

Values: *If someone understand your beliefs regarding water system, it is easier to work with that person.*

These answers show the students' thinking in what they thought were the most influential of sustainability competences in the catchment basin. Normative ("rural communities work according to their beliefs…") was answered most often while strategic, interpersonal and anticipatory also received mentions. In a number of cases, students confused the explicit sustainability competences with other terms such as values, trust and shaping competence (in this the student confused the English translation for the German term *gestaltungkompetenz* for an actual sustainability competence).

In answer to the question (List the competences as priorities with most important to least important) (Appendix One, p.14), students answered thus:

Strategic-Normative-Anticipatory-Systems Thinking-Interpersonal competence

Normative-Strategic-Systematic-Anticipatory-Interpersonal

Interpersonal-strategic competence-systems thinking-anticipatory-normative sustainability-anticipatory- shaping-normative-interrelated

Anticipatory-normative-strategic-systems thinking-interpersonal

Values Scenarios/ Knowledge, skills, attitudes, problem solving

What is significant in this series of answers is that 'strategic' is mentioned in the top three in four of the five answers. This is slightly different to the answers to the question above (Which one of Wiek et al.'s five competences is most crucial to the study area?). 'Normative' was mentioned in the top two in three of the five answers. 'Anticipatory' was mentioned in the top three in two of the five answers. One student misinterpreted the question by giving unrelated answers (the fifth answer).

The following question was posed to the students before their teaching practice: Why are sustainability competencies so crucial to implementing a catchment management system (Appendix One, p.8). Answers to this are listed below:

> *Sustainability involves the importance of preserving resources/ We need to make sure that whatever is done but we still have our water even for future generations./ Because it involve skilled prectionas (sic)[practitioners] that will help poor communities to learn by doing CM, helping them to adapt to ever changing natural world.*

Here students are correctly identifying the need for preserving resources and for future generations. The idea that the natural world is in a state of flux and that people need to adapt was given in the last quote. This is in line with the notes on complex adaptive systems.

6.5 Social Learning

In terms of the second lens, social learning (Wals, 2007), the below-mentioned explains the dynamics and processes of social learning during the fieldwork-based teaching practice (it must be emphasised at the beginning that opportunities for social learning in this phase were limited due to the assessment regime of teaching practice – each student was meant to produce work in the form of lesson plans and lessons on their own, and were assessed accordingly. Students were meant to form strong relationships with their mentor teachers at the schools concerned; unfortunately there is not one mention of this happening in the reflective reports [Appendix Four]):

6.5.1 Orientation – actors, issues and challenges.

The actors comprised one lecturer, five students, three schools (with mentors), one university and two government departments (Department of Basic Education for policy, and the KwaZulu-Natal Department of Education for operations). The issues were that the three schools were poorly-resourced schools, and poverty is widespread in the surrounding community. One student answered the question: What geographical problems did you notice in the catchment when you went to the schools for the initial TP [teaching practice] visit?, with “at the school I was at there was no available drinking water. The girl (sic) have to go long distance to fetch water” (Appendix One, pp.8-9). The challenges were that the students were based quite a distance from the schools and relied entirely on a tourism operator to get

them to school and back. Students were also isolated from resources, such as Wi-Fi and libraries.

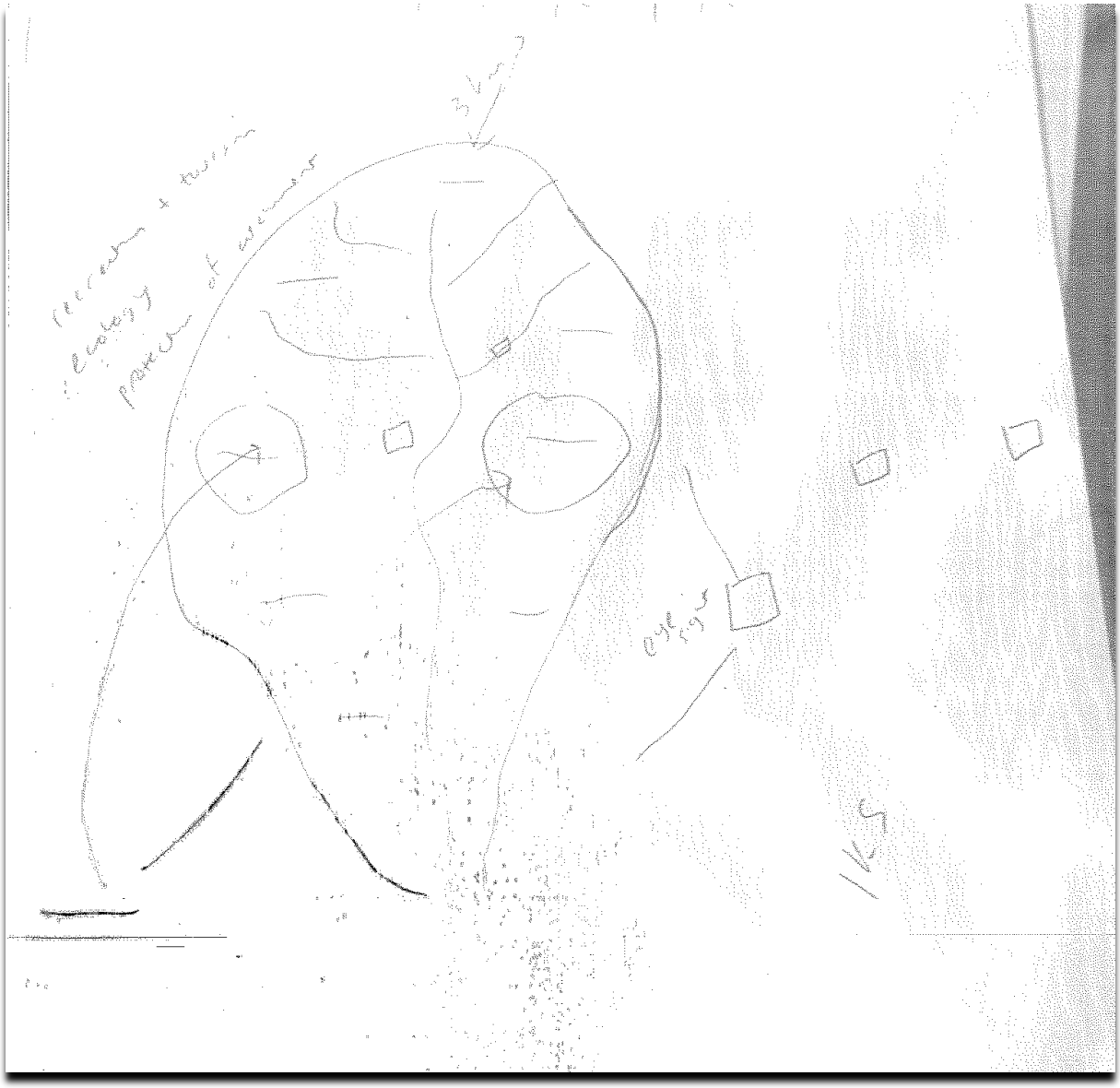
6.5.2 Self-awareness – eliciting one's frame

This was seen in the preference of topic the students chose to teach: impacts of people on catchment areas taught five times, followed by importance of managing catchment areas three times, and a catchment management strategy two times, plus the experiments (mini-stream assessment scoring system) four times) (Appendix Two, pp.1-10). Lesson plans were correctly completed but required improved clarity and focus (Appendices Three). The sketch maps in Appendix Five (pp.18, 19 and 21) show an acceptable attempt at self-orientation but which could also be improved in some respects (for example, scale and orientation).

6.5.3 Deframing-reframing/ clarification/ exposure to other frames

Deframing and reframing would have followed their university tutor's visits, with an emphasis on lesson coherence and scientific discipline. Both lessons on catchment management strategy case study had to be repeated (Appendix Two). The student teachers seemed to particularly like graphic and illustrated help, for example with their sketch maps and lesson conceptualisation (Appendix Five, p.20, see below). The sketch map shows the borders of a catchment basin, which I drew for a student.

Figure 6.1: University tutor's illustration of a catchment management strategy



6.5.4 Co-creating, re-constructing of ideas

For the co-creation and co-reconstruction of ideas, this was borne out in the second visits by the university tutor. The student teachers' second attempts were more successful than the first (Appendix Two, pp.2, 4, 6, 8, 10), and all students passed the teaching practice overall.

6.5.5 Applying – collaborative actions

As this was teaching practice, no collaborative actions between students were allowed. However, there was a general synergy of topics and experiments. Students had either consciously or unconsciously collaborated in the similarity of lessons, especially the employment of the mini-stream assessment scoring system (see Table 6.1). For students

living in the same residence and forming a community of practice, there was nothing wrong in discussing their lessons but it was also important to independently conceptualise lessons.

6.5.6 Reviewing – assessing issues/ challenges addressed

The reflective reports (Appendix Four) I requested from the students provided a good vehicle for reviewing and assessing their experience of teaching practice, especially the lessons they presented. Students were remarkably open and frank in these reflective reports, and addressed how they needed to improve their fieldwork performance.

In the students' reflective reports, the question: What can be done in order to improve?, was answered in the following way:

> *A lesson must focus on one sub-topic to avoid confusion to the learners and also to the teacher. Safety measures must be always mentioned or given to the learners. Follow up activity or homework is very important, it helps in testing learners and refreshing their minds on what they did during the lesson. Feed backs also must be clear to the learners.* (Appendix Four, p.1)

> *The lesson must be orientated around a specific catchment management strategy. The strategy has to be the focus. Objectives of the lesson have to be orientated around a specific catchment management strategy. Case study given to the learners has to be orientated around a catchment management strategy. Subject knowledge need to be improved. The lesson must be repeated on a classroom in order the learners to understand what a strategy is.* (Appendix Four, pp.2-3)

> *The things that did not go so well is that there were a fewer learners who were taking part in the field trip and this had a negative impact on delivering the lesson as planned and caring out the activities that were planned for the day. The trip ended up taking less time. Next time I should make sure that I get to school early so that I can give my learners motivation to take part in the trip.* (Appendix Four, p.4)

> *In my perspective the challenge was to make sure that the learners were safe while we were in the river because the learners were jumping on the rocks* (Appendix Four, p.5)

> *What I need to do in my next fieldtrip is to give learners worksheets and sketch maps before we embark on the trip.* (Appendix Four, p.6)

> *I could not finish my lesson on the trip because there were unforeseen circumstances. It rained a lot hence I had to finish my lesson in classroom…The things that I need to pay*

attention to next time, is weather I have to ensure that it does not become a problem. Decentralize power or authority. For instant if learners are over abundant, I should choose class leaders that would assist me in the trip. (Appendix Four, p.7)

I then have to repeat the lesson so that my learners will understand well about the topic we covered. Next time I have to improve in all the aspects that did not go well in my lesson .(Appendix Four, p.8).

The learners were fully involved in the lesson even although I had two learners who were dunked, but manage to keep classroom management. What made the lesson to be good is that what was being taught is something that was around the environment. During the lesson learners were fully engaged in group discussion and completing their worksheets. (Appendix Four , p.9).

The worksheets required some improvement because they did not have marks for each question asked and some organising details such as date and duration of fieldtrip. However, some aspects of classroom management were not well facilitated because there were few learners that were not displaying good behaviour during the fieldtrip. The fieldtrip was successful although it need some more organisation and informing the whole school stakeholders, including the security guards. (Appendix Four, p.10)

In this fieldtrip only two learners were able to come and one thing that might have negatively influence attendance of learners can be a weather since it was cold and showing signs of rainfall…the fieldtrip lesson had to be repeated in the classroom because there was little attendance. (ibid., p.10)

One student cited the weather as a factor:

The weather also play a role in the lesson, there was a wind of which result in other learners to lack focus and a teacher to try by all means to do the lesson as she planned. (Appendix Four, p.2)

Another student incorrectly indicated industry (there is absolutely no industry there) as a feature of the upper uThukela;

The lesson began with identifying activities that take place in a catchment. In the area of the upper uThukela there are a lot of tourism, industry and farming activities taking place. (Appendix Four, p.5)

It is clear from the student teachers' answers in their reflection reports that lesson coherence and organisation, learner attendance and safety, and the weather (very influential towards the success of fieldtrips) were all challenges to be overcome. These obstacles were overcome in that all students passed their teaching practice experience.

6.6 Practice Architectures in Teaching Practice

This section seeks to answer the third research question:What opportunities and challenges exist and emerge for teacher education and student teacher practitioners in such an approach?

6.6.1 Material-economic architectures

The three secondary schools in which the students were teaching serve a very poor community with high unemployment. None of the schools had a library and the nearest one for learners was the municipal library in Bergville, 50 kilometres away. The schools were sparsely furnished, with only chairs and desks, a blackboard and a teacher's desk furnishing the classroom. There was no educational material on the walls. The fieldtrip lessons were characterised by low learner turnout at times. Rural poverty undoubtedly affected the learner turnout, and this in turn affected the successful delivery of the content. For this reason, I suggested to one student teacher that she use the strategy of repeating her lesson, in a classroom format, to the whole class (Appendix Two, p.2). The student teachers were limited by only being able to teach on Saturdays, as the timetable during the week did not allow for the length of time needed for a fieldtrip. The time spent on assessment averaged 2.5 hours for each student. This included my writing of a report during the lesson, and giving verbal feedback to the student teacher for about 45 minutes.

The fieldtrips were held in two severely degraded quinary catchments, with very visible evidence of overgrazing and poor land management in the form of denuded slopes and erosion gullies (dongas). A quinary catchment is the smallest scale catchment there is, being the fifth level catchment after primary, secondary, tertiary and quaternary catchments. This poor land management (sand mining occurred while I was there supervising the students) has had many other effects such as sheet erosion. This affected the enjoyment (and the motivation) of the fieldtrip for all concerned, including the student teacher, me as the assessor, and the learners, as no one enjoys degraded surroundings (especially along the Busingatha stream, Appendix Four, p.4). The one quinary catchment in which two of the three high schools were situated, was ideally placed for student teachers and learners to analyse and understand the social-

ecological system framework. The very important uThukela river also runs through it from the sheer escarpment above to the inhabited areas underneath. Land use differentiation occurs as the protected area (Royal Natal National Park) is reasonably pristine but across the river sand-mining, extensive road building, and pollution occur. The other quinary catchment, in which the second high school was situated, is very different in character as it is far from a protected area. This catchment also does not have a major river running through it but only tributaries of the uThukela. The Khombe river lacks the stature, in terms of width and current, of the uThukela. However, the student at School C did not take his learners to this river but to an even narrower stream closer to the school. This affected the lesson in that learners could not appreciate the dimensions and effects of a significant river.

6.6.2 Cultural-discursive architecture

The social-ecological systems discourse that the students had been exposed to before the teaching practice would have influenced their general understanding of what to include in lessons. I took as a point of departure the assumption that the students would have been fully conversant with the theories of social-ecological systems, as well as catchment and river management. This was after they had attended a dedicated course on those two topics (Appendix Six). Indigenous knowledge systems was not referred to explicitly but as "what we have learnt from our families and communities"; nonetheless, it did play a role (Appendix Four, p.5). The Curriculum and Assessment Policy Statement provided a major underpinning architecture to teaching practice experience, as it was the CAPS that informed the lessons to be taught. In particular, fieldtrip lessons had to cohere around a particular sub-topic under catchment and river management. This was evidenced by one of the comments on a lesson assessment form: "Don't confuse or mix the sub-topics – the [fieldtrip] lesson must cohere around one sub-topic (Impact of people on catchment areas, and importance of management of drainage basins mixed)" (Appendix Two, p.1) Moreover, in the case of the catchment management strategy case study prescribed by the CAPS curriculum, the curriculum can be said to be ahead of reality as only one catchment management strategy has been drafted in South Africa, and this is not in the eastern half of the country. National and provincial education policy influenced the norms and standards expected in lessons, as in the performance criteria stated in the lesson assessment form.

6.6.3 Social-political architectures

The altered power relationship between me and the students affected my relatings to them in that my role prior to assessing the lessons had been a facilitative and enabling one. I had to adapt to being a critical assessor and the students also had to adapt to considering me in a new role and light. A particular concern of mine was to ensure lesson coherence around the particular sub-topics in catchment and river management, and to ensure that the correct geographical terms and concepts were used (Appendix Two, pp.1-10). In addition, I was a complete outsider to the community of the area, in that I did not understand the vernacular language, nor was I aware of some of the cultural and social precepts there. However, I felt welcome and enjoyed the experience.

Regarding the presence of political authorities and management, there was no evidence of any land or any other kind of management at all, which is a political function. No government offices, including police stations, were visible during the fieldtrips. The area should actually comprise a buffer zone adjacent to a formally protected area, according to environmental law as mentioned below, but this is not the case. No activities damaging to the formally protected zone are normally permitted in a buffer, with only farming allowed in the next zone that occurs, the transition zone. This is supported by the uKhahlamba Drakensberg Park World Heritage Site (UDPWHS) Integrated Management Plan (Ezemvelo KZNWildlife, 2012). From what I and the student teachers observed, these principles are not being followed, nor are illicit activities being discouraged, within the stipulated five/ ten kilometre border zone from the Royal Natal National Park (an integral part of the UDPWHS) boundaries. However, it should be borne in mind that the area has a long and contested history, with an initial resettlement of surrounding communities to this area during the colonial era (the Upper uThukela Location) (Pearce, 2006). The area also experienced at least one major incident of political violence and a failed Apartheid-era plan to move people from the area (Wright and Mazel, 2007).

6.6.4 Practice architecture during fieldwork as compared to lectures

Students were working outside rather than sitting in a university seminar room. The multiple contexts at play during fieldwork delivered a considerably more complex learning and teaching environment than during lectures (Chapter Five). One of those contexts, I believe, was how I as the facilitating lecturer during the course had to negotiate and traverse my new role as professional assessor (university tutor) during fieldwork in addition to my other role as researcher. This took careful balancing and a need to listen carefully to students'

explanations of what they did during teaching practice. The most important conclusion to be drawn is that during lectures, a very organised university environment prevailed (with a select group of students), whereas during fieldwork the environment was not always optimal (it included issues such as learner behaviour) for the effective delivery of topic-specific pedagogical content knowledge. Moreover, the fieldwork surroundings were not beautiful and pristine but heavily degraded and polluted. Fieldwork trips would start from the three schools that had very sparse classrooms (a blackboard, a table and chair in the front for the teacher, and desks for the children).

6.7 Conclusion

The analysis of the social-ecological systems process, social learning and practice architectures shows that this phase was a multi-contextual environment that affected the smooth delivery of concepts envisaged in the previous chapter (Chapter Five). Regarding social-ecological systems, there was development and elaboration of each of the components. These in turn led to the development of sustainable competencies. I would say the progression and development were not perfect but they were worthy attempts in a difficult teaching and learning environment. For social learning, it was clear there were a number of issues and challenges that needed addressing. Having seen the reviewing section, it is clear that these issues and challenges had been at least been attempted through frank reflection. For the practice architectures, it was a combination of the multiple and at times contesting contexts that affected the delivery of topic-specific pedagogical content knowledge. However, it can be adjudged a success in that not one student failed teaching practice, and that every lesson was successfully completed in sometimes very difficult conditions (not least the weather).

Chapter 7
Discussion of findings, recommendations and conclusion

7.1 Introduction

The summary of the foregoing chapters describes the multiple contexts making up and informing the design research process undertaken over the three-phase design research process. These provided cumulative insights on topic-specific pedagogical content knowledge, learning associated with this, and some of the enabling and constraining factors that need to be considered to inform the development of a new course resource book for teacher education. There are also implications for further educational research that will be considered in the proposed development of the resource book that the research was designed to inform.

In Chapter Four, the critical new environmental knowledge (section 4.3.1) in the Curriculum and Assessment Statement was reviewed as the subject matter knowledge on catchment and river management to be taught. An analysis of learner performance in the National Senior Certificate surfaced an issue with learner performance, especially regarding Human Geography versus Physical Geography marks and the identification of human-made and natural features on orthophoto maps (South Africa. DBE, 2015). It was noted here that the interplay of spatial map skills with Human and Physical Geography is a necessary foundational knowledge competence for understanding catchment and river management, and by extension social-ecological systems. As noted in the development of the Fundisa-for-Change module (Khan et al., 2014), there is a need for strong foundational concepts to underlie teaching about water and yet these are not seemingly developed in schooling. The result is that student teachers enter a teacher education programme without the necessary foundational knowledge (this has been shown in Appendix One, pp.1-3). Added to this, teacher education is seldom geared to rurality or rural conditions of schooling where issues to do with integrated water resource management and catchments impinge on livelihoods and environmental quality on a daily basis. This focus has become increasingly important, and this study was orientated to contribute to that area of schooling.

In all three research phases (Chapters Four, Five and Six), these matters were progressively explored and reviewed as matters relating to the clarification of topic-specific pedagogical knowledge in the teaching of catchment and river management in Geography Education.

The literature review outlined issues regarding catchment and river management, and integrated water resource management. In Chapter Two, the relationship between these and Geography education was addressed. The contours of pedagogical content knowledge were scoped in a review of the foundational theory of the topic. Noted here were issues to do with socio-cultural dynamics, and geospatial reasoning.

The landscape of South African secondary and tertiary education was also addressed in the literature review (section 2.5) regarding the realities of education in this country, in so far as they relate to the topic of this thesis. The current status of fieldwork (section 2.5.4) was also probed in this chapter, as were the dynamics and differences between Human and Physical Geography (section 2.5.2). Issues in the higher education curriculum were outlined (section 2.5.5). The key linkages between Geography education and environmental education/ education for sustainable development were also scoped (section 2.5.6).

The methodology chapter was premised around two central areas, firstly design-based research (section 3.3) and secondly, the use of case study data (section 3.2) to progressively inform the design work on knowledge, learning and the challenges of teaching in a rural context of schooling. As the study was qualitative and interpretative, the intention was to successively analyse the emerging case evidence so as to develop a thesis related to the differentiating of topic-specific pedagogical content knowledge for teaching the topic in rural schooling and mountain catchment settings.

To this end, the three phases of the design research case study were conducted using three lenses (section 3.3.1) to probe the topic-specific content knowledge: the lens of a social-ecological systems perspective, the processes of social learning playing out through the phases, and practice architecture in play as the case study unfolded. The underlying purpose of this analysis was to inform a teacher education pedagogical programme for introducing catchment management in Geography Education.

A theoretical framework for teaching catchment and river management in graduate teacher education was explored and clarified through the three-phase design research process (section 3.4). A preliminary framework of topic-specific pedagogical content knowledge was developed through the phase 1 analysis of curriculum content and outcomes in recent years. Here fieldwork was a central concern (section 3.4.2). The preliminary design was implemented as a series of lectures and tasks. How these carried over into lesson design work was reviewed and refined through the succeeding two phases of the study that followed.

Transitioning from phase 2 to phase 3 was centred on a collaborative process of co-engaged social learning where the lesson planning and teaching of the student teachers were treated as the extrapolation and implementation of topic-specific pedagogical content knowledge. This was rich, diverse, complex and uneven owing to the diversity of the teaching and learning environments in the rural study area (section 6.5). The fieldwork demands of the curriculum were shown to be not grounded in the reality of what was actually happening on the ground (Wilmot and Dube, 2015) (see Chapter Four, section 4.3.3), and unrelated to the realities of rural secondary education contexts of the study. Hence, it was important to look into the practice architecture (see 6.6) in relation to both the rural context and the existing norms of teaching and learning practices was emphasised.

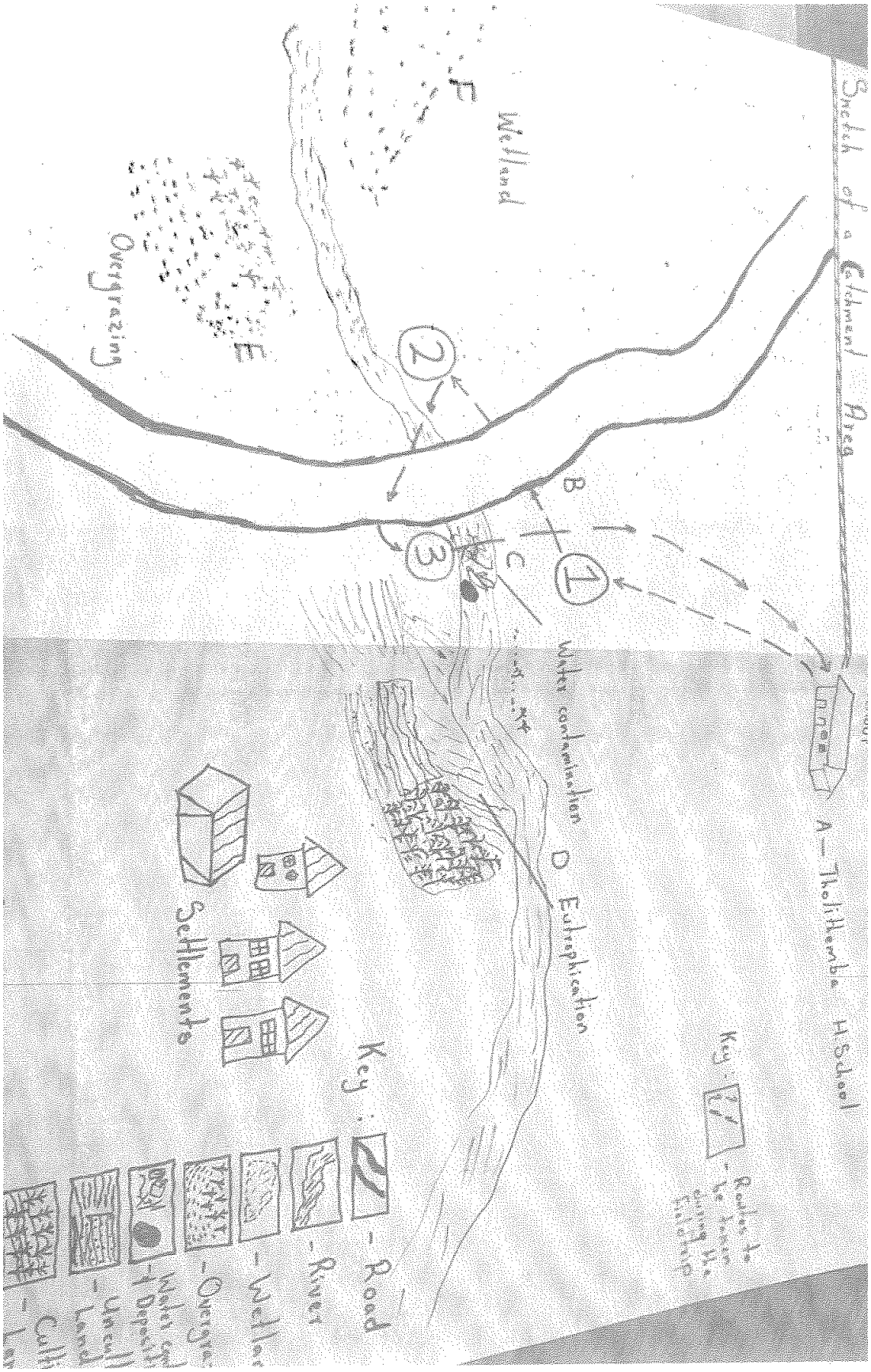
The exploratory design work towards the development of solutions was undertaken in Chapter Four (the curricula analysis) which was followed by Chapter Five (the formative design course) and Chapter Six (the actual fieldwork during teaching practice). These stages of the study also included a design reflection to generate design principles. This was undertaken following Reeves (2006). Accumulating evidence and insights have informed the framing of design insights as recommendations that will influence the structure of a proposed resource book on the study topic. The course content was structured according to the critical subject matter knowledge in the previous chapter. The topic-specific pedagogical content knowledge explored in the lecture series aimed to address, and educate on, the subject matter knowledge related to catchment and river management. This phase of the case study was reviewed using questionnaires. The data were revealing in terms of student performance and evidence of their grasp of the study topic (Chapter Five). There was a clear Human Geography bias in the student teachers' training and responses (Appendix One, p.2) and not enough exposure to social-ecological systems thinking (Appendix One, p.3). Because of this, the necessary balance of social-ecological system thinking (an interplay between Human and Physical Geography) was not as evident as it should have been. Indeed, a contradiction in students' answers regarding this concept was noted (integrated water resource management/ participatory integrated water management are integrally related to social-ecological systems, in that both society and ecology have to be equally and jointly understood). This contradiction was shown on page 5 of Appendix One, where the students were asked "Do you feel confident about being able to teach IWRM or PIWM at the FET level? to which four students answered "yes" and two students "no." However, on page 6, in answer to the question "Knowing what you know now, have you been adequately prepared at university to

teach PIWM?", all six students , stated "no". Students were also exposed to the theory of sustainability competences during the series of lectures and some very useful data regarding their receptiveness towards sustainability competences that led from this.

An issue with self-awareness (section 5.2.2) through the social learning lens was shown, while the conventional practice architecture of the course of lectures (Chapter Five) played out without any apparent constraints as the students (who were postgraduate) were familiar with the conventions and requirements of a series of lectures (section 5.2.3).

This exploratory phase was duly followed by the iterative testing and refinement in phase 3 and Chapter 6. All student teachers passed their teaching practice. A central issue emerged linked to the teaching of catchment management strategy case studies, namely that students misinterpreted what an actual catchment or drainage was and its boundaries (section 6.3). As a result not one student correctly identified that watersheds were the boundaries of a catchment on sketch maps, and that therefore their lessons of a catchment management strategy case study were necessarily misplaced (Appendix Five, pp.18-19, 21). This meant that the geospatial reasoning of the student teachers appeared to be insufficiently well-developed . The sketch maps of a catchment management strategy case study focused on only a small area or part of the catchment, neglecting the macro-perspective needed for a whole catchment (this has been explained above). For example, a student teacher's sketch map of a "catchment area" on page 21 in Appendix Five showed only a limited perspective of a catchment, primarily activities around a bridge (see Figure 7.1 that follows). The sketch map is provided here for convenience and cannot be characterised as a catchment basin. There was no indication of watersheds, which comprise the borders or boundaries, and the entire catchment basin, with a river and streams flowing downwards off the watersheds (no indication of slope is given). This ties in with the observation regarding human-made and natural feature mis-identification (by learners) on orthophoto maps as noted in the Department of Basic Education Diagnostic Report (South Africa. DBE, 2015). There also appeared to be an issue with lesson conceptualisation and learning sequencing, in that a number of lessons lacked topic coherence (see Appendix Two).

Figure 7.1: Student teacher's representation of a catchment basin for a catchment management strategy

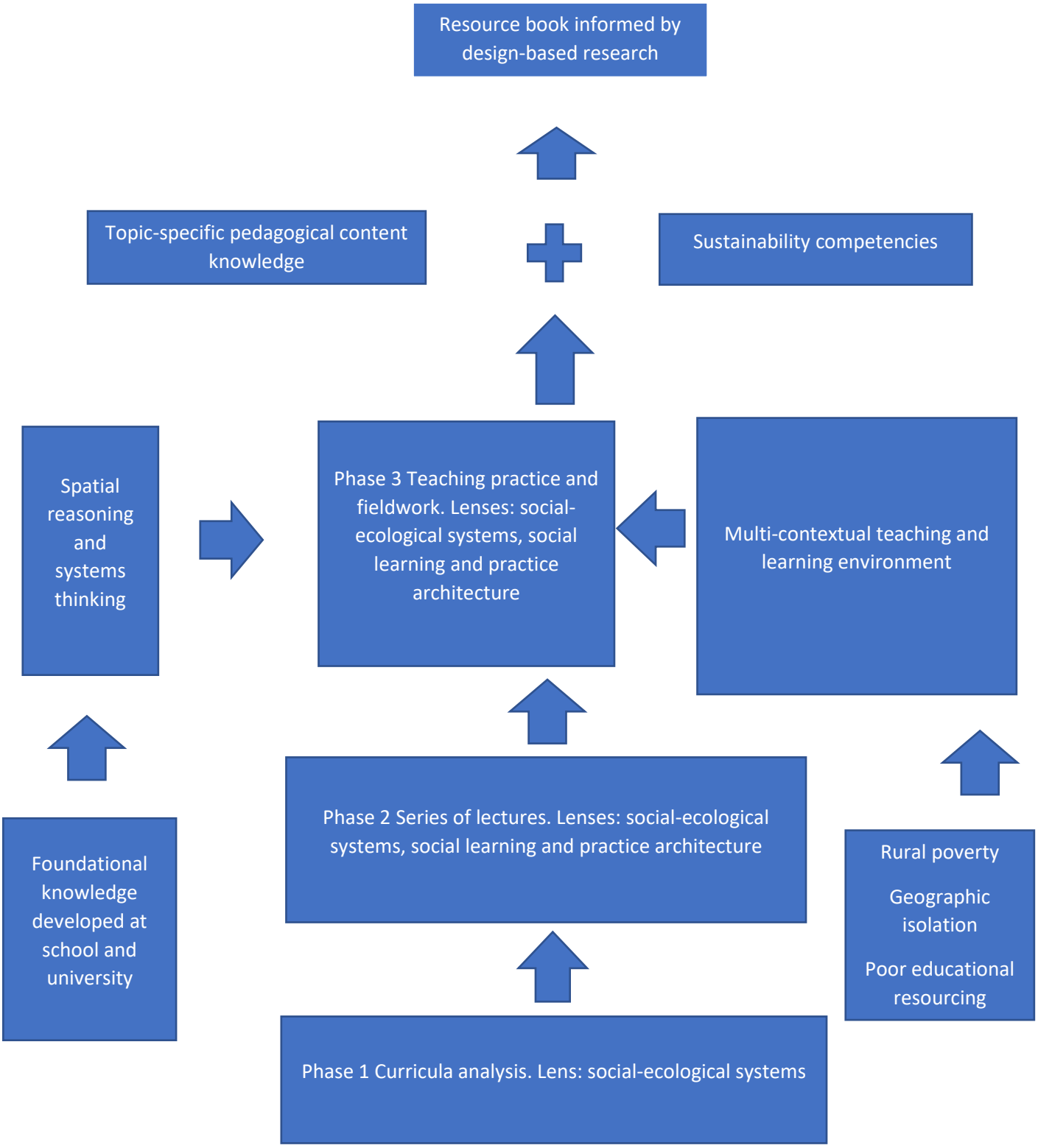


7.2 Development of a Theoretical Model

The theoretical model that has been developed (see below), following the research process, draws on an article authored by Mavhunga and Rollnick (2016). They wrote a paper on improving the pedagogical content knowledge of chemical equilibrium in pre-service teachers, and included a model of topic-specific pedagogical content knowledge on p.115 of the article. In the model I have developed, a number of interacting contexts and processes, chiefly geospatial reasoning, systems thinking and a multicontextual teaching and learning environment illustrate how critical, but also contestable, subject matter knowledge was transformed across three research phases to frame the differentiation of topic-specific pedagogical content knowledge in the students' teaching. In particular, firstly, geospatial reasoning was identified as crucial to understanding and teaching a social-ecological system in the model. Student teachers would need to reference geospatial thinking for every catchment and river management subtopic in the 2011 curriculum. They would also have to think in terms of systems throughout (section 6.3). As the model shows, the foundational knowledge the students received at school and university influences these two skills. Secondly, a multi-contextual teaching and learning environment introduced factors that worked as realities that the students had to experience and negotiate. Factors such as geographic isolation, rural poverty and poor educational resourcing affected this environment. Sustainability competencies on the part of the student teachers reflected a primary concern with normative competences but strategic competences also appeared very important to the students. The student teachers' association with the importance of sustainability competences in a catchment basin was quite well developed and nuanced (Chapter Six, section 6.4). These findings therefore transitioned the ideal expressed in curriculum documents to the reality in deep rurality. The resulting topic-specific pedagogical content knowledge was fully in tune with what had been delivered in the series of lectures (Appendix 6 and Chapter Five). However, the varying experiences of the student teachers have produced a body of knowledge that is fertile ground for the proposed resource book informed by the relevant design-based research. The thesis that has emerged in this study is that a course design has to consider the multi-dimensional contextual principles generated in the design research and the systems thinking/ geospatial reasoning relationship which are necessary for the teaching of catchment and river management in a rural mountain catchment basin. The design and case study process surfaced these multi-dimensional factors that need to be included in future instructional materials for teacher education for this topic. The design

research process has thus shown that so much of the present curriculum, if catchment and river management is taken as a point of departure, is not resonating with the lived realities of the learners being taught in the rural mountain catchment side of this case study. This research is therefore important for informing the design of a catchment and river management course that is more relevant in those settings. This study has opened up design concerns for informing a course on catchment and river management with inputs from Geography, sustainability competences, social-ecological systems and geospatial thinking. This is a difficult section of work on a teacher education course in Geography as it lies within physical Geography (the bias towards Human Geography was shown in Appendix One, p.2) and depends on scientific systems thinking. The model that I have developed from the findings follows.

Figure 7.2 A model of the design research process for clarifying and refining a course design



7.3 Discussion on the Topic-Specific Pedagogy for Catchment and River Management

To answer the first research question (How can engagement with new environmental knowledge and fieldwork practices lead to the development of sustainable competencies that reflect engagement with a complex social-ecological systems perspective?), the student teachers' capital, in terms of catchment and river management (informed by social-ecological systems thinking), was not easily taken up into lesson planning and translated into rural classroom settings. However, despite the difficulties, the fieldwork-based teaching practice was successful. For the ecosystem element, the mini-stream assessment scoring system experiment was used by student teachers in lesson topics such as the impact of people on a catchment basin, and the importance of catchment basins (Appendix Two). As mentioned above, there were some misconceptions around ecosystems such as misunderstanding oxygen production and wetland formation. There was also a need for spatial skills and concepts necessary for a more coherent or holistic grasp of fluvial systems and river catchments as interacting social and ecological systems and processes. The data in Appendix Two suggested that there was an issue with student teacher knowledge both in terms of grasp of the content and the pedagogic challenge of working with systemic concepts (Hahn et al., 2008; Norberg and Cumming, 2008) in a rural teaching and learning context. This apparent issue was related to geospatial reasoning and directly affected landscape and scale literacy (which requires being able to interpret and apply an understanding of geographic scale, as in map scale) on the part of the students (see pp.99-101). Regarding management actors and organisations (see pp.99-100), students at times did not seem to fully appreciate what a catchment management strategy involved, and did not reference the management entities enough in their lessons (Appendix Three). What was significant were the insights that students drew from their own experiences and social backgrounds. These insights included indigenous knowledge systems and the fact that the rivers were a community possession to be protected (see section 6.3). Students referenced the social side of social-ecological systems thinking, that enabled them to mediate their learning from the context of their social awareness (the social norms element shows that students were concerned by how little the community took into account the importance of the catchment, and how they treated it) (see section 6.3). Some students referenced heritage knowledge/indigenous knowledge systems (as mentioned above in regard to the purifying qualities of rivers) to illustrate ecological concepts, especially the damage to ecosystems by the community (Hahn et al., 2008). In this regard, there did appear to be an inclination on the part of students to mobilise indigenous knowledge systems (IKS) but this

was affected by a difference between what the student teachers thought or knew about IKS and what the community thought or knew (see section 6.3). Differing understandings and associated mis-conceptualisations on fluvial systems were factors in obstructing a systems-wide approach to the achievement of highly successful lessons. A number of issues and contexts such as educational resource provisioning and isolation from libraries and Wi-Fi (see Map 1) had an impact on the teaching and learning process. These affected both the social-ecological systems focus of the fieldwork context (teaching catchment and river management in a deep rural environment) and the academic performance of the student teachers in their teaching practice (although all the students passed, not one student scored above a third class pass for teaching practice). The findings above showed that, regarding social-ecological systems thinking, the teaching and learning process was non-linear and complex. For example, the most prominent external driver was the weather (see section 6.3), which informed the level of the rivers after a cold front and also disrupted a fieldwork lesson due to a thunderstorm (see Appendix Two, p.6). In a number of cases, lessons had to be repeated and the student teacher was counselled on the topic and systems coherence of a lesson. The development of the student teachers' sustainability competencies was successful in that the students' answers showed an appreciation of the difficulties and contexts affecting the development of sustainability competences (see sections 6.4, 7.2).

In terms of the second research question (What opportunities and challenges exist and emerge for teacher education and student teacher practitioners in such an approach [sustainability competence development through a social-ecological system framework]?), the following answers emerged.

A number of contextual factors, as elaborated in the summary below, worked together in unison to ensure that the process was highly complex (sections 6.3 and 6.6), circular (section 6.3 and 6.6), historical (section 6.6.3) and social (section 6.5) (the last two factors comprised feedbacks (Norberg and Cumming, 2008). Circularity refers to the ongoing and repetitive complex processes within a system, while feedbacks refer to continuing influences from both history and society. The key trends noted point to a multi-contextual teaching and learning environment affecting the teaching practice. The summary of the material-economic architectures shows the following factors at play: a) the three schools' environments were poor rural community settings in degraded environments. The schools themselves were sparsely furnished and poorly equipped. b) It was also notable that the fieldtrip lessons had very low learner turnout and had to occur on Saturdays. c) the quinary catchment closer to the

protected area was more ideal (in that a major river flowed through it and it contained land use differences) for fieldtrip lessons than the other quinary catchment, on the other side of the common watershed. Regarding the cultural-discursive architecture factors (section 6.6.2), social-ecological systems discourse in especially the series of lectures and teaching practice fieldwork predominated. The Curriculum and Assessment Policy Statement underpinned the structure and content of the fieldtrips with other national and provincial policy providing the norms and standards. Indigenous knowledge systems provided a third context to the discourse. This was explicitly referred to by one student who framed her lesson on the importance of river catchments within an indigenous knowledge system perspective (Appendix Four, page 5). In terms of the dimensions of social-political architecture (section 6.6.3), there was a different power relationship between myself and the students to that which had been experienced previously in phase 2; in addition I was an outsider to the community belonging to the study area. In the phase 2 (Chapter Five) I fulfilled the role of lecturer whereas in phase 3 I occupied a dual role – that of assessor and researcher. My role as researcher was furthermore complemented by the student teachers emerging as co-researchers (this was seen in phase 3). I was especially focused on ensuring lesson coherence and correct geographical terminology on the part of the student teachers (Appendix Two). There was no evidence of any land or any other political management at all in the area. The buffer adjoining the formal protected area was not respected at all in terms of environmental law, and the area as a whole has a contested history with at least one serious case of political violence. Regarding opportunities, the most significant one is the potential of this research to frame a future resource book on the pedagogy of catchment and river management. There is rich data that has the capacity to significantly influence the writers of the next Further Education and Training (Geography) curriculum.

As noted earlier, the opening analysis of the various curricula (phase 1, Chapter Four) uncovered the relevant subject matter knowledge to enable the design of the lecture series (phase 2, Chapter Five). Three sub-topics in catchment and river management were specified from the curricula analysis, of which only one was not problematic. This is the impact of people on catchment areas, which most people would agree is necessary to consider and it was also buttressed by what realities experienced on teaching practice were. However, the other two sub-topics included in the lecture series (the importance of management of catchment areas, and a case study of a catchment and management strategy) came to be considered problematic in the case study as these are not rooted in the management practice

of this country (see Chapter Four, section 4.3.1). The curricula analysis also showed the inherent social-ecological system focus in the present curriculum, and the issues that emerged from analysing the data in Chapter Four using a social-ecological system lens.

Therefore the design of the topic-specific pedagogical content knowledge for the course curriculum (Chapter Five, Appendix Six), and the lesson planning and performance analysis (Chapter Six) that followed was used as a basis to adjust the initial design so as to frame a more comprehensive lecture series on catchment and river management (see Appendix Six). This delivery of the lecture series gave me a forewarning of issues that would emerge, such as the need for the understanding of concepts such as mountain zoning (Appendix Six, section 1) and the critical nature of scale (ibid., section 1). The aim of delivering the course material was therefore to produce sound and holistic conceptualisation on the part of the students of relevant curricula aligned to social-ecological systems and fit-for-purpose teaching contexts (ibid., section 1). Of specific interest was the problem or challenge of the student teachers translating and contextualising the content between Chapter Five (the series of lectures that they received) and Chapter Six (the planning of a series of lessons and fieldwork on teaching practice). This challenge of transitioning from content acquisition to topic-specific pedagogical content knowledge delivery was the result of a number of factors that impacted on the third phase. One of the issues appeared, as already stated, to be geospatial reasoning (something demanding higher order functionality) which played a major role, and this issue appears to have developed through all phases of education. There was thus a major gap between the pilot stage (Chapter Five) and this review stage (Chapter Six), where the realities (such as the need to repeat lessons for a variety of reasons, and poor attendance on the part of learners) of deep rurality in South Africa affected the teaching practice.

In Chapter Five the first research question (How can a teacher education programme on catchment and river management be designed that is Curriculum and Assessment Policy Statement Geography-aligned, and that reflects a complex social-ecological systems perspective?) was addressed. The course on catchment and river management that was put together (Appendix Six) reflected the imperatives in the curriculum (see Appendix Six, section 1) and included the necessary knowledge to support a developing grasp the theories, models and context pertainable to the Drakensberg. There were two parts to this chapter, with the first covering an analysis of the lectures themselves (section 5.1), and the second an analysis of the student responses to the lecturer's topic-specific pedagogical content knowledge (section 5.2). In this chapter, the three analytical lenses (social-ecological

systems, social learning, and practice architecture) were applied to lectures and the student responses.

Chapter Six reflected design research data that informed the first and second research questions: How can engagement with new environmental knowledge and fieldwork practices lead to the development of sustainable competencies that reflect engagement with a complex social-ecological systems perspective? and What opportunities and challenges exist and emerge for teacher education and student teacher practitioners in such an approach?. The student teachers needed to engage with new environmental knowledge and fieldwork practices which would lead to the development of sustainable competencies that reflected engagement with a complex social-ecological systems perspective. This was done by the student teachers generating their own topic-specific pedagogical content knowledge. The process was not as ideal in reality, or expected after Phase 2, but it was a reasonable attempt by the students in a time and place that was affected by challenges and issues. Students delivered a nuanced and sensitive approach towards sustainability competence development within the limitations and challenges of the study area. The third research question was answered by the research data which uncovered a number of opportunities and challenges that emerged for teacher education and student teacher practitioners in a social-ecological system and sustainability competence-led approach. The primary challenges are the multi-contextual issues that affected the teaching practice fieldwork as well as issues to do with geospatial reasoning and systems thinking. With regard to opportunities, I would say that the research was a success and that the course I developed has definite potential to be developed into a resource book for both preservice and in-service teachers.

The first analytical lens (social-ecological systems, sections 6.3 and 6.4) revealed the relevant knowledge in the students' fieldwork lessons. This also informed the development of sustainability competences, although not all competencies, chiefly systems thinking, were developed to the same extent of others. The most important insight emerging from this chapter was that it appeared that the application of social-ecological system-aligned topic-specific pedagogical content knowledge was affected by numerous scientific mis-conceptualisations, influenced in part by an issue to do with spatial reasoning. Language skills related to the framing of lesson plans also emerged in the analysis.

The second analytical lens, social learning (section 6.5), exposed key differences across the contexts of research, namely the focus group learning involving the students in phase 2 (see

Chapter Five, section 5.1) and the social learning (between the student teachers and the learners) on teaching practice in Phase 3. The critical difference between the two phases was that social learning in phase 2 was a group activity amongst the students whereas in phase 3, it was an individual effort by the students teaching to their learners. There was a similarity of topics and methods, and the reflective reports written by the students proved quite clear (see Appendix Four).

Lastly, the third analytical lens (practice architecture, section 6.6) uncovered a vastly different context between the controlled learning environment of a university seminar room (Phase 2, Chapter Five) and the issue-driven context of deep rurality in a mountain foothill environment (phase 3, Chapter Six). Phase 2 comprised a simple and generally one-directional transmission of knowledge from the lecturer to the students. Multiple issues such as poverty and isolation, roles (on the part of the lecturer) and contexts were absent, and students appeared very enthusiastic to receive the information. In contrast, phase 3 showed many different contexts (such as differing rules and institutions) and a variety of roles on the part of the assessor and researcher.

As expressed before, the intention was for the analytical insights to link with the social-ecological systems, social learning and practice architecture in Chapters Four, Five and Six; and thus the insights were based on the data, and formed a narrative.

7.4 Analytical Insights Evident in the Emerging Design Research Data and Corresponding Design Principles to Inform a Revised Course Text

The reflection of this design-based research study clarified design principles, following the analytical insights, to inform teacher education in respect of this section of work. There are thus a number of design principles that will enhance a solutions implementation of the catchment management component of the Geography curriculum, and which will be covered in the next chapter.

This chapter comprises an ordering of these elements against the design insights (topic-specific pedagogical content knowledge which led to social-ecological systems (section 6.3), learning processes (section 6.5) and insights on the practice architecture (section 6.6) in the rural schools in the mountain catchment context of the case study) generated in the three phases and chapters (curriculum, lectures and field teaching practice) with cross-referencing.

These design research insights and the corresponding design principles also show the limitations of the research, as well as implications for further educational research.

7.4.1 Design research insight: The fieldwork-based teaching practice experience proved a successful learning crucible to develop sustainability competences (section 6.4).

Students' answers to the question regarding the suitability of sustainability competences in the study area were marked by sensitivity and context. They were able to prioritise the relevant sustainability competence and substantiate it with contextualised reasoning. Normative competence was most often cited. Students were also able to rank or prioritise sustainability competences in a chain of five competences, albeit with a slight difference in the first question (strategic competence came out first). Furthermore, the students were able to provide appropriate answers to the need for sustainability competence development in the implementation of a catchment management system (Appendix One, p.8), as is evident in the response below:

> *Because it involve skilled prectionas (sic)[practitioners] that will help poor communities to learn by doing CM, helping them to adapt to ever changing natural world.*

➡ **Design principle 1: It is recommended that scenarios involving choices be included in the proposed resource book.**

By posing scenarios where decision-making is involved, sustainability competences can be developed in a group of teachers studying the problem in the scenario. Flow charts involving the cumulative development of problem-solving could be used as a teaching aid to facilitate this. This is especially appropriate for the teaching of a catchment management strategy case study, where scenarios involving decisions upstream would have a variety of consequences downstream.

7.4.2 Design research insight: The cohort of student teachers passed their fieldwork teaching practice despite an issue with foundational concepts covered in school and university.

Appendix Two shows that two students had to repeat their lessons and I recommended that a third student repeat the lesson despite having officially passed. The methodology chapter (Chapter Three) gave an overview of the design-based research case study with its three iterative phases (see Table 3.1). In phase 1, the curricula analysis showed the related issues

regarding foundational concepts, and these were shown to be major issues to be addressed in phase 3. Students' understanding of foundational concepts in Appendix One showed that their prior training had been somewhat insufficient for the task at hand: it was clear that foundational knowledge leaned towards Human and not Physical Geography (Appendix One, p.2). Chapter One showed the multiple curricular changes and educational contexts that affected the ability of learners, through their teachers trained under differing dispensations, to comprehend the knowledge necessary to teach catchment and river management. In particular, as alluded to before, mapwork and spatial reasoning problems had been flagged in the Department of Basic Education Diagnostic Report of 2015 (see Chapter One, section 1.1.5). This would have major import for the ability of National Senior Certificate-holders to have a good understanding of geospatial reasoning. According to the students' questionnaire answers in phase 2 (Appendix One), social-ecological systems (only one out of nine students had been exposed to social-ecological systems [Appendix One, p.3]) and fieldwork had not been done adequately at school (ibid, p.10). The latter involved mainly river-based ecological studies, whereas fieldwork needs to be far more extensive. In phase 3, these issues also followed through with scientific mis-conceptualisation occurring and a number of lessons having to be repeated. There has traditionally been no trace of fieldwork testing or fieldwork simulation in the Department of Basic Education's National Senior Certificate examinations. This leads to fieldwork being specified in the curriculum but not examined, which is an anomaly. This anomalous position leads to learners leaving school without having done any fieldwork, or more crucially having developed any fieldwork competence. It was clear in phase 3 that fieldwork competence was inadequate.

Design principle 2: Adjustments are needed in the design of a teacher education course on catchment and river management.

Fieldwork, mapwork and geospatial reasoning need extra emphasis in a future teacher education course on catchment and river management. The most important findings from the research are that foundational concepts that were taught at school and even university will need to be remediated. Extra support needs to be provided for the teaching of the school curriculum in rural settings. A new integrated section covering the support of foundational concepts needs to be included in the course. Such an integrated section could list the catchment and river management sub-topics and align them to mapwork and geospatial skills. Fieldwork needs to be done in Grade 12 and other grades, and the optional element for it taking place in Grade 12 especially needs to be removed in the successor curriculum to the

Curriculum and Assessment Policy Statement (see Chapter Four). Moreover, fieldwork needs to include a range of experiments in a catchment basin, and each learner group should be expected to measure and report. Exercises that address the shortcoming (addressed in the Department of Basic Education Diagnostic Report) in identifying natural and human-made features on orthophoto maps need to be used more often. To this end, mapwork exercises using 1: 10 000 orthophoto, 1: 50 000 topographical and the 1: 250 000 topocadastral maps should be included. The range in scales will assist in showing the downstream consequences to actions upstream, and other geospatial effects. Understanding scale is crucial to catchment and river management as every action has scaled consequences. Competence in geospatial reasoning can only occur through enough practice in class and with fieldwork.

7.4.3 Design research insight: The teaching of a catchment management strategy case study was identified as an issue across all three phases of research.

Chapter One flagged the issue of student teachers and teachers having to learn new environmental knowledge, of which a catchment management strategy case study is central. Chapter Three (the methodology chapter) explained the methods of data analysis, including new environmental knowledge to be researched (see Table 3.1). The issue concerning a catchment management strategy case study was mentioned in phase 1 (Chapter Four), where it was found out that this sub-topic had not even been mentioned in first two curricula (since 1994), and only explicitly detailed in the third. Students identified contradictions in the catchment management strategy policy and correctly noted issues the uThukela region would bring to the Pongola-Umzimkulu catchment management strategy (Appendix One, pp.7-8). The students' scepticism about a catchment management strategy is buttressed by findings mentioned in Chapter Four, especially the experience in the Elbe river basin, Germany, which was subsequently (after the research) discovered (Meissner et al., 2017). Students at time gave vague answers when it came to defining key terms like case study and strategy in questionnaire 4 (Appendix One, p.7). This vagueness and doubt translated itself into the teaching practice experience later (Chapter Six). In particular, each lesson on a catchment management strategy case study had to be repeated by the students during teaching practice (Appendix Two, pp.2 and 6) The key issue is that the students misunderstood what a case study was, and that a catchment management strategy is based on an entire catchment, not only a little part of it. Moreover, scale and zonation had been covered in the series of lectures (Appendix Six, respectively pp.14-15, 17) but these critical concepts appeared to be misunderstood or mis-conceptualised by students during teaching practice.

Design principle 3: The inclusion of a catchment management strategy case study in the curriculum will require further content and skilling in concepts such as strategy, zonation and scale.

For the teaching of a case study of a catchment management strategy, a series of case studies featuring quinary, quaternary and tertiary catchments should be included in the proposed remediation of the relevant teacher education course. The case studies could include literacy aids such as illustrations, diagrams and conceptual charts (besides obviously maps). The inclusion of the stories and key lessons of local environmental champions could also be added to the remediation guide. For example, there is a particular *inkosi* or chief at Ntsikeni nature reserve in the Umzimkulu district of KwaZulu-Natal who disallowed cattle grazing in the upper areas of the Ntsikeni catchment to protect the biodiversity-rich grasslands (Gemmell, 2014). The key concept of restrictive zonation therefore needs to be made real and "indigenised." The guide also needs computer-aided links (such as Geographic Information Systems) and references (such as Global Positioning System) related to socio-ecological zonation. The concepts of scale and development according to scale could be emphasised in the remediation guide. It was shown in the research that the concept of scale (Chapter Six) was highly misunderstood, and that it will need remediation. To understand scale effectively, more practice exercises regarding mapwork and geospatial reasoning would have to included. Enough exposure to and practice in sketch maps of a catchment management strategy, and related social-ecological zoning, are crucial for understanding and for the development of spatial reasoning. Students need to know what a strategy is and why it is so important. The concept of choices, integral to strategy, allied to sound value formation and ecological imperatives should also be included in a guide. This also ties in with sustainability competence formation. Catchment management strategy case studies also need to combine the conservation of the catchment with the wider developmental needs of the community (development according to scale). Learners in rural areas need to see that there are direct correlations between what they learn and benefits to often poverty-stricken communities. Case studies should also originate from a number of contexts, including where valuable catchment and river management has been conducted before in Africa, for e.g. Ethiopia (Hurni and Messerli, 1990).

7.4.4 Design research insight: The successful negotiation and navigation of a multi-contextual teaching and learning environment by student teachers.

The cohort of student teachers had to navigate and negotiate less than optimal issues such as geographic isolation, poor educational resourcing and deep rural poverty to pass their teaching practice, which they were able to do.

The rural poverty of the surrounding community has been documented by the Nemai Consulting (2012) draft report 'Umkhanyakude District Municipality Environmental Management Framework Socio-Economic Assessment'. Crucial socio-economic indicators such as unemployment and education levels point to a community that can only be classified as extremely poor (see p.5). This poverty could have affected the attendance figures during the fieldtrips (which were held on Saturdays) because it is possible that the learners had work such as cattle herding. Poor educational resourcing also affected the teaching practice. There were no fieldwork aids or equipment visible in the three schools, and classrooms were very under furnished and under-equipped (this has been detailed under material economic architecture in section 6.6.1). Geographic isolation affected the students as they were far away from their support networks, and the nearest library was 50km in Bergville (see Figure 3.2 in section 3.3). Students also had no access to Wi-Fi. When student teachers failed their first teaching practice critique, they were receptive to advice and accordingly self-corrected in their second critique, allowing them to pass overall. Students were also very frank about the challenges they faced and the measures they took or were planning to take to address said challenges (see their reflective reports in Appendix Four, in particular pp.3, 7, 8, 10). They were also able to compile lesson plans that, while not perfect, allowed them to pass (see Appendix Three).

➡ **Design principle 4: Potential of success of series of lectures and other teaching preparation.**

The fact that this cohort of student teachers were able to pass their teaching practice in an area bedevilled by challenges means that the series of lectures, and other teaching preparation the students teachers received, has a higher chance of success in more educationally well-resourced and well-to-do environments. The close attention and support the student teachers received from their university tutor (me) needs to be continued in other environments. This is an approval of the subject content matter presented to the students, and consolidated through their enthusiasm in class during lectures (section 5.3)

7.4.5 Design research insight. The present Curriculum and Assessment Policy Statement does not speak to the reality on the ground, particularly in deep rural environments.

It was clear in phase 1 (Chapter Four) that the present iteration of the National Curriculum Statement (with the inclusion of catchment and river management new environment knowledge) is not without challenges (section 4.3.1). Curriculum requirements are not in step with national or provincial developments in terms of catchment and river management. The three major reasons setting out this contestation are listed after the curriculum requirements in the chapter (section 4.3.1). It is hard to think of a section of work better suited to fieldwork than catchment and river management (which is covered in Grade 12); yet in the present curriculum, fieldwork in Grade 12 is referred to as "time permitting" (South Africa. DBE, 2011, pp.15-16). The research in phase 2 showed that catchment and river management, and fieldwork, had been less than optimally taught at schools and universities (see Appendix One). Hence students were generally unprepared to teach the quite extensive and ambitious requirements of both sub-fields. This was seen in the contradictions, confusion and vagueness of a significant number of the students' answers. Only two of nine students had been on a field trip to a catchment basin (Appendix One, p.1). In Chapter Six (phase 3) the experience of teaching the three sub-topics of catchment and river management emerged. Lesson topic preference is evidenced further by student choice: the catchment management strategy case study was taught twice (20%), the importance of managing catchment and drainage basins three times (30%), and the impacts of people on catchment and drainage basins five times (50%) (Appendix Two). The teaching of fieldwork was also not an uncontested pedagogical experience. Fieldtrips were affected by bad weather (p.105), poor planning in at least one case (pp.103-104), and poor learner attendance (p.106).

Design principle 5: Curricular and teacher performance documents need to be 'rural-and multiple context-proofed' so that expectations and performance work across both urban and rural spheres.

This study was undertaken to inform a remediation of the pedagogy for teaching catchment management in a rural classroom setting that many student teachers would find themselves in, upon entering the teaching profession. The rural- and multiple context- proofing of the curriculum is needed to take cognisance of regional development constraints, geographic isolation, and limited or non-existent resources. Recommendations for such a remediation should include wider and deeper contexts such as the rural economy in curricula, that

scientific conceptualisations in the curricula be made more accessible for especially second language speakers of English, and the educational resourcing/ provisioning of mapwork and fieldwork for improved academic performance. English to isiZulu translation could occur in every feature of a proposed remediation guide, and this could include the use of glossaries for difficult words. The input of curriculum specialists and government officials, for example from the Departments of Basic Education, and Water and Sanitation, could be influential for this section. There needs to be a renewed emphasis on understanding the components and processes of social-ecological systems (sections 4.4.3, 5.2.1, 6.3) and the scientific conceptualisation behind these components and processes.

7.4.6 Design research insight 6: Complementarity of student teacher-developed topic-specific pedagogical content knowledge with course lecturer-developed materials.

The material I presented to the students was heavily influenced by Western theorists and montologists, and even by a course on the governance of social-ecological systems I attended in France (URCA and SENSE, 2016). Appendix Six (pp.1-38) outlines this knowledge (see also Chapter Five, section 5.1), which was, I feel, favourably and frankly responded to by the cohort of student teachers in the questionnaire results in Appendix One (pp.1-14). The student teachers' TSPCK has been analysed and formatted in Chapter Five and Chapter Six (see in particular the responses in section 5.2.1 [social-ecological system knowledge in phase 2], section 5.2.2[the knowledge that came out of social learning analysis] and sections 6.3 and 6.4 [social-ecological system knowledge and sustainability competence development derived from phase 3] and section 6.5 [social learning knowledge]). The following quotation encapsulates the students' concerns with the people in the catchment basins and their understanding of the realities existing there:

> *No, most people in the catchments lack some information about the importance of catchments/ No./ Yes, in the rural areas people are aware of the environment and what they plant and when to plant. We understand the season the water flow and how to conserve our nature and water/ -/ No, the people in the catchment areas are not well educated regarding the issue of scale, thus they will fail to implement it/ I think people in the catchments areas don't really understand the issue of scale, thus they tend to fail to properly implement it.* (Appendix One, pp.5-6)

The students' TSPCK also extended to realising the importance of sustainability competencies regarding the implementation of a catchment management system. The students had not commenced teaching practice by the time this question was posed but the

various answers show a nuanced and realistic appreciation plus a concern with the future as well as with a fast-changing world:

> *Sustainability involves the importance of preserving resources/ We need to make sure that whatever is done but we still have our water even for future generations./ Because it involve skilled prectionas (sic) {practitioners] that will help poor communities to learn by doing CM, helping them to adapt to ever changing natural world/.* (Appendix One, p.8)

Design principle 6: Recommendation of a compulsory virtual Geography teacher training experience

This training experience will cover the joint topic-specific pedagogical content knowledge (TSPCK) in the form of new environmental knowledge, in particular catchment management strategy case studies, and fieldwork competence. This will be included in the proposed resource book.

For all teachers, but especially those trained under the dispensation when not enough or any attention was given to concepts applicable in the new curriculum, the relevant design principle is that all teachers attend a virtual course that is oriented around an upper catchment area, and which has been informed by the jointly developed TSPCK developed in this thesis. They could be shown by experts on how to teach the new environmental content knowledge, and recent fieldwork techniques, both on an online learning platform such as Moodle and with meetings on Zoom. The new environmental knowledge in the curriculum needs to be brought across to in-service teachers in an integrated and mediated manner. Close and sustained interaction between the teachers and the subject specialists needs to occur so that examination performance improves. The fundamentals of fieldwork including the "Collecting and recording data using a variety of techniques; Processing, collating, interpreting and presenting fieldwork findings" (South Africa. DBE, 2011, pp.15-16) should be demonstrated in practice to in-service teachers. Fieldwork preparation needs to be comprehensively covered in the remediation guide. This will include how to do the relevant preparation, including on how to do a thorough reconnaissance of the area before embarking on lessons. Such a preparatory exploration will yield viewpoints, sight lines, the most important rivers, and possible routes for a field trip (this would assist in supporting teachers to plan in more depth and in ways that relate to landscape). In a number of cases, the student teachers did not know basic concepts in Geography and General Science, and hence confused or mis-conceptualised key concepts. In a future guide on the pedagogy of catchment and river management, student

teachers should be instructed on the definitions of social-ecological system components and a glossary to aid in understanding should be included. Efforts should be made to enhance the teaching of social-ecological systems at university level, following the example of the University of Cape Town Environmental and Geographical Science department (it is an option in their Honours programme). More emphasis on Physical Geography needs to be given at the secondary school level to address the gap in learner performance as indicated in the Department of Basic Education (2015) Diagnostic Report. The design research experience illustrated that the graphic representations of systems and models definitely appealed to, and were used by, the student teachers more than complex conceptual narratives mediated in oral discussion. This was borne out by student teachers responding positively to sketch maps and rough diagrams that I gave them (Appendix Five, p.20). Complementarity has to result in combining the scientific notes evident in my lecture notes (Appendix Six) and the TSPCK developed by the student teachers (Chapters Five and Six), which reflected concerns more in tune with the community, indigenous knowledge systems, and rural realities.

7.5 Conclusion and recommendations

This study has explored how social-ecological systems thinking was taught by student teachers while on a fieldwork trip, after they had attended a specialised course on catchment and river management. The students were responsible for teaching the three sub-topics of the catchment and river management section of the current South African secondary school curriculum. The work on this challenging section of the curriculum was undertaken as a process of learning and re-learning (for those students who needed to repeat their first teaching practice lesson) with student teachers who were teaching in a rural schooling context. The study has the potential, and it has been shown that it does have the potential, to inform interventions in poor and rural schools where there are significant issues with the preparation of teachers to teach the new environmental knowledge in the curriculum.

Recommendations (these also pertain to further research), which have been encapsulated as the design principles above, from this case study are that varied and broad responses to the noted multi-contextual challenges are needed in order to prepare and equip student teachers for the demands of the new environmental knowledge in the curriculum. In this case study, Bachelor of Science graduates with majors in Environmental Science and Geography did not yet fully understand and conceptualise the social-ecological systems approach inherent in the

curriculum. The practice architectures' (cultural-discursive, material-economic and social-political) analytical lens suggested that there were multiple contexts and influences in the rural setting where the schools were situated. There were also different institutions affecting practice such as a university and the provincial department of education. Certainly, difficulties with geographic concepts such as scale, boundaries and atmospheric processes had a significant influence on teaching and learning. Therefore, when setting curricula, education department curriculum specialists need to cater for widely differing social contexts of teaching and learning to take account of what is actually occurring in the field. In particular, fieldwork needs resources and specialised teaching aids that all three schools in the study did not have. It is hoped that this study has shown the need for a multi-contextual approach to address the multivariate contexts at play in deep rural and economically challenged area. This also ties in with addressing the 'polycrisis' facing the country (Department of Science and Technology, 2010).

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APPENDICES

APPENDIX 1 (answers transcribed verbatim from the original answer sheets)

QUESTIONNAIRE 1:

What do you remember about CRM from school?	The river pattern, river flow, river mouth/ it is about managing rivers, clean up the river by removing alien plant species that might disturb or distract flow of water in rivers/ it is about managing the river such as cleaning the river and the removal of alien species/ from my understanding I remember how to manage a catchment river and impacts that people or community has on river catchment/ it involves management of catchments and rivers/ I remember preventative measures such gabions and implementation of vegetative cover on the areas where erosion has taken place/ they are important for supplying water that are also used for economic and social purposes/ the drainage system. What or how it is made up. The flow of water impacting on erosion and flooding of the river/ I remember that we must plough along the contours to avoid soil erosion and also prevent overgrazing/
Did you ever do a field trip to visit a catchment basin? Y or N.	Y=2 N=7
Age?	22=1 23=3 24=2 25=2 27=1
Gender (M or F)?	M=4

	F=3
BA or BSc?	BA=1 BSc=6 BSocSci=2
Completed a course on geomorphology? Y or N?	Y=8 N=1
If yes, what did you learn about CRM?	The river pattern, drainage system, river mouth (source of the river), alien species/ I learned how to prevent expansion of a gully, I also learnt how to prevent erosion/ Yes/ I learn strategies of managing rivers, impacts human has on river catchments and also the importance of river catchments/ I learnt about stream ordering, different types of streams and the ways used to manage rivers and catchments/ all forms of erosion that contribute to our soils being washed away. Rivers are significant because they provide us with freshwater/ CRM are vulnerable to illegal dumping of waste materials of all types/ I learn that we should clear the alien vegetation found next rivers because they use too much water/
Did you complete a course on hydrology? Y or N?	Y=1 N=8
If yes, what did you learn about CRM?	Water pH level, water management, water source, most important dam, rivers in SA, testing of water quality/
Do you feel human geography was given more prominence than physical geography during your UG training?	Y=5 N=1 Balance=2

How many weeks were dedicated to the study of catchment and river management at University?	A few weeks/ 3-4 lectures/ less than one week/ approximately 6/ one week/ 2 days/ probably one or two weeks/ one week/
What tools did you use in your CRM training? GIS, map work, etc.?	GIS, remote sensing, maps, GPS/ pictures/ none/ GPS, computer, map on computer in GIS modules/ GIS/ map work/ GIS, mapwork/ sketches and mapwork/ GPS/
Have you had any training or exposure to SES?	Y=1 N=8

Questionnaire 2 CRM models:

Which model (Hufschmidt, Gregersen et al., Falkenmark) is theoretically more useful? (Just give the name)	Gregersen et al.=3 Hufschmidt=1
Provide reasons why.	Gregersen=Because this model give a clear idea on what factors affect the water yields in the rivers/ This model clearly links with the land uses we observed in Bergville and shows the linkages to the watershed, which may affect the management of the watershed/ Gregersen's model is clear and it is applicable to the area of Drakensburg. The important aspects that entail water management are clear, e.g. fisheries/ Hufschmidt=This theory is broad, it covers almost everything that is related to RCM of uThukela/
Which model is practically more useful for the conditions in the upper uThukela valley? (Just give the name)	Gregersen et al. (G)/ Hufschmidt (H)/ Hufschmidt (H)/ Gregorson (G)/
Provide reasons why.	G=Because it gives an indication of different factors that has an influence in the water system of the upper uThukela valley.

	Such factors as forestry agencies, cultivation, community owned lands, deforestation, settlements around reservoirs, fisheries, private landowners/ H=It is because this model takes into consideration all the three major activities of watershed management. This model clearly explain each activity associated with watershed management/ H=This model entails things like offsite and onsite changes. It pays little attention on the philosophy or beliefs and indeginous knowledge/ G=Speaks even about the Philosophy or belief of the community members. Simplifies complexities./
What are the existing beliefs, including indigenous knowledge systems, of the people living in the study area regarding CRM, do you think?	People believe that protecting water sources and keeping them clean is important. Since they depend mostly on subsistence farming for their survival/ I think people are lacking proper knowledge on CRM and they are not concerned about managing rivers because they don't understand their importance/ Rivers are used as a means of cleansing evil spirits. Thus they are highly protected. Some traditional healers as well as religious members use rivers for the purpose of baptism. Therefore certain parts of the river would be protected/ I heard that people simple because its an ethical thing to do and that rivers are seen as dangerous thing. Children are forbidden/ not allowed to swim because they might pick up pathogens/

QUESTIONNAIRE ON PIWM (3)

Do you feel confident about being able to teach IWRM or PIWM at the FET level? Y or N?	Y=4 N=2
Do you think PIWM is a realistic policy for SA and particularly KZN catchments? Explain.	Y=5 N=1 Yes, PIWM is a realistic policy since it is a process that involves natural and human resources in a catchment and also it take into account social, economic, political and institutional factors/ Yes, it is paper and ink but as for implementation our officials fails to make it happen. They also fail to monitor reason being they care more about economics than nature/ Yes, if we could learn to use our water wisely and also be able to protect our water sources it will be a benefit to our country and our communities/ Yes, because our government has even started programmes like working for water projects where people are being paid to remove alien plants along the coast of rivers/ Yes, it's a realistic policy because it emphasise the need for many stakeholders to participate in management of catchments/ I think this is a realistic policy and can result to proper management of catchments if this policy can be well implemented.
Do you think the key issue of scale is understood, and properly implemented, by people in the catchments? Explain.	Yes=1 No=4 No, most people in the catchments lack some information about the importance of catchments/ No./ Yes, in the rural areas

	people are aware of the environment and what they plant and when to plant. We understand the season the water flow and how to conserve our nature and water/ -/ No, the people in the catchment areas are not well educated regarding the issue of scale, thus they will fail to implement it/ I think people in the catchments areas don't really understand the issue of scale, thus they tend to fail to properly implement it.
Knowing what you know now, have you been adequately prepared at school to teach PIWM? Y or N?	Yes=1 No=5
Please explain.	Yes, I can try to teach maybe lower grade such as grade 10 because what I have right now is like the introduction/ No, -/No, at school we only knew where our water comes from and how it is formed. We are never told about any management of water/ No, I have not got enough time to prepare my self but now since I am done with my exams I will prepare my self/ No, this was not taught in my school/ At school I was not even taught about what is PIWM.
Knowing what you know now, have you been adequately prepared at university to teach PIWM?	No=6
Please explain.	I only the introduction, I still lack some information and I haven't been reading much literatures/ -/ Not Realy we are made aware that water is controlled and not accessible as we think/ Because I still need to develop my knowledge on PIWM/ This

	was not taught but not in details or clearly/ This was not given enough time at university and it was not tested that much.

CMS questionnaire (4):

What are the contradictions you notice in the CM strategy policy?	There are contradictions between development or use of resource and conservation. It is difficult to achieve equilibrium when people are poor/ It says that we need to use water and at the same time conserve water/ The contradictions are that the strategy points out the importance of considering the poor in CM while practical it not happening/
What is a strategy?	Is a plan that is used to overcome a contemporary challenge. The strategy should take note of sustainability and equity/ It is an action plan to overcome or address a problem/ It refers to plan of action to overcome challenges/
What is a case study?	Is an empirical enquiry that investigates temporary phenomenon/ Is have enough or deep knowledge about a particular Area or thing/ Refers to a research study of inquiry. It focuses on investigating temporal phenomenon/
Do you think stakeholders in the upper uThukela will ever agree on a strategy?	Yes they will because a proper strategy entails a proper involvement/ Yes/ Yes I think they will agree only if the people are well taught about the management strategy/
What issues do you think the uThukela region will bring to the Pongola-Umzimkulu CMS?	I think the poor communities will find it difficult to balances conservation with development. Irresponsible development/

	The river is big on its own and already the Pongola-Umzimkhulu CMS covers a big region. It will be unmanageable/ Land degradation, issues related to zonation of land uses/
Why are sustainability competencies so crucial to implementing a CMS?	Sustainability involves the importance of preserving resources/ We need to make sure that whatever is done but we still have our water even for future generations./ Because it involve skilled prectionas (sic) that will help poor communities to learn by doing CM, helping them to adapt to ever changing natural world/
How would you align the case study on a CMS to fieldwork imperatives?	Proper involvement of community members, local leaders and more/ I will bring a case study from the CMS of another place then take some ideas and implement them to the CM area of yours/
How does one design a CMS?	Include things like sustainability, equity and control/ One can design CMS by inviting all stakeholders interested and affected to discuss about current management strategies and working to more effective strategies together/

Questionnaire 5 The Drakensberg as a source of water:

Have you ever visited the Drakensberg for recreation? Y or N?	Y=1 N=4
What geographical problems did you notice in the catchment when you went to the schools for the initial TP visit?	There is lot of erosion, most catchment is dry, area is dry, people or households are situated far from catchment and there is overgrazing in most uphills/ It dry, cold and far from the city/ I noticed that it was very

	dry and that many of the areas showed evidence of erosion/ At the school I was at the was no available drinking water. The girl have to go long distance to fetch water/ There was high erosions near the catchments and the too many cattles grazing near the catchments. People near the catchments have cultivated lands ploughed inappropriate/
What are your acquired beliefs about the Drakensberg? I.e. what have your parents and community told you about the mountains?	Mountains has lot of different vegetation, however it's not safe to go there since there are lot of dangerous animals such as snakes. Due to lot of vegetation cattles were grazing there and collected every afternoon/ Nothing much about the mountains including the Drakensberg/ That the mountains are beautiful and that it shows and that it is very cold/ My beliefs about the mountains is that there by. It very cold during the winter. It is where the ice falls and my parents told me that the Basotho tribes also uses the mountains/ They have told me that the Drakensberg area is very cold, especially during winter months. They have also told me that mountains contain dangerous animals/
Do most people (i.e. consumers) in Pietermaritzburg know precisely where their water comes from in the Drakensberg or Drakensberg foothills? Y or N?	No=5
Would you be able to draw a map from your tap to (river) source? Y or N?	Yes=3 No=2

New questionnaire on fieldwork (6):

Describe your previous fieldwork experiences at school- where, how, what?	We assess water pollution at Cumberland by observing the number of living organism found in the river eg dragonfly/ Howick Waterfall, study of life in water (river system) looking at what a health river has/ No, I didn't have any fieldwork/
Describe your previous fieldwork experiences at university- where, how, what?	We went to PortsaintJones in EC to observe different types of erosion and land degradation and to combat land degradations/ Blue lagoon beach. Umngeni River mouth. Walking and studying life on the estuary. Looking and collection of pollution on te estuary. We had black bags to put litter in and we had mud shoes on/ Cumberland nature reserve, an EIA. We check the health of a river. We use cages that were filled with stones and others with leaves and mud to simulate different habitats for invertebrates/
What fieldwork method/ s looks most appealing to you for this project?	Geolocate and georeferenced, videotaping and voice recording/ Educational Presentation/ Teaching management strategies/
Explain why.	Storage for future reference/ It will be more involving if I use presentation. People will have the chance to add knowledge and also to ask/ Because it is where we will get to understand that indegenous (sic) strategies and then add to on them/
Do you intend using your cell phones to geolocate your work in the project?	The problem with cell phones is the issue of accuracy/ No because cellphones are complicated and use up a lot of data/ Yes,

	but the problem is with the data bundles and also I don't know how to geolocate with it/
What other cell phone functionalities do you intend using?	Cameras, videotaping, sound recording/ I will use the video of my phone and the camera to capture the moments./ Google and googlemaps/

Questionnaire on SES (7):

Why is the uThukela a complex adaptive system, do you think?	It's because uThukela changes from time to time and this supplies large amount of water/ The Thukela is a big river and it is known for the greater distribution of water. The Thukela floods especially during the rainy seasons. The Thukela is a river and any natural disaster might happen at any time/ It is because you will never know what is gonna happen in the river. There is a lot of uncertainty like for instant drought or flooding. There is a lot of interaction in the system, the communities uses river for meeting some of their basic needs and wants, e.g. food, sports, herbs / uThukela river is complex adaptive because the river is unpredictable, in some years you find the river in extreme drought state and in some years it flood excessively/ Uthukela is a complex adaptive system because it is able to adapt during drought seasons and also become flooded during raining season/ It is a combination of social and ecological factors therefore we must be prepared for uncertainty/ Its because uThukela has river system which is beneficial to the

	surrounding communities therefore anything that is complex requires a holistic management.
What did you notice about your visit to the upper uThukela that makes the area a crucial socio-ecological system?	The upper uThukela is a big catchment area supplying water to many rivers and areas far from the area of Bergville/ The UThukela is a source of water for the province it provides life for families such as fishing and sporting activities/ I noticed parasitic relationship between humans and rivers. People always take from the river. Traditional healers extract herbs and never replant. They pollute water through litering/ I notice that the area is surrounded by settlements of people residing there and the upper uThukela is the source of the major river in Kwazulu Natal. So it links together the social and ecological aspects/ It support huge population, there are dams, rivers that are important to the whole country, it also has a high erosion zones. The upper uthukela also is near the Drakensberg mountains which attracts tourists from different countries/ Irresponsible Development such as pathways and roads/ Social factors such as overgrazing contribute to soil erosion.
How will you approach social learning using a SES template?	I will approach it through involving many different stakeholders that are in the area/ SES will allow learners to think strategically about Their environment and capacity building will be encouraged/ Will use persuasive and deception approaches

	like for instant, telling people not to litter rivers isn't enough but telling them that they are putting their livestock in danger and aquatic species such as fish could motivate them/ I will invite community members and local authority and teach them about the importance of managing drainage basins/ By making communication however, set the boundaries. For instance, making sure that there is a communication between I and the community/ Gather communities or learners ask them question with respect to their beliefs. Then teach and add to their indigenous knowledge/ I will ask factual question.
Which one of Wiek et al.'s five competences is most crucial to the study area?	Strategic competence/ Normative/ Interpersonal competencies/ shaping competence/ I think normative competence and anticipatory competence are most crucial to the study area/ Trust/ Values. Results: Normative (2).
Give reasons why.	This is very crucial because every thing needs a proper plan in order to be successful/ Rural communities work according to their beliefs and these belief are usualy centred. Rural communities always work together/ Because if you have the ability to make friends with all the stakeholders in the community it will be easier to formulate a strategy on how to overcome a problem in a catchment. What is important is good communication/ relationship/ Because if you are competent

	in shaping you are able to shape things and solve most problems you encounter/ You have to think ahead in every system especially in studies that involve river catchment management. And also you have to do thing properly in order to be supported./ You have got to trust your members in order to produce successful management skills/ If someone understand your beliefs regarding water system, it is easier to work with that person.
List the competences as priorities with most important to least important:	Strategic-Normative-Anticipatory-Systems Thinking-Interpersonal competence/ Normative-Strategic-Systematic-Anticipatory-Interpersonal/ Interpersonal-strategic competence-systems thinking-anticipatory-normative/ sustainability-anticipatory- shaping-normative-interrelated/ Anticipatory-normative-strategic-systems thinking-interpersonal/ Values Scenarios/ Knowledge, skills, attitudes, problem solving.

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

57%

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: River and weather processes - importance of

Assessor: G. Heath Date: 30.07.16 management of drainage basins

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?			✓	Don't confuse or mix the subtopics - the lesson must cohere around one sub-topic. Write down the subtopic.
	2	Are the core questions correctly aligned with the general objectives and the specific content?			✓	
	3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
	4	Is the assessment strategy aligned with the above?		✓		
	5	Was the lesson fully planned?			✓	
	6	Is relevant preparation material available?	✓			
TEACHING AND LEARNING ACTIVITIES – Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		Importance of topic introduced. Question posed on what they know. Safety issues are so important to include.
	2	Was the introduction creative and within the context of the planned learning content?		✓		
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?		✓		
TEACHING AND LEARNING ACTIVITIES – Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?	✓			I really enjoyed the mini-poster and the mini-SASS activity. Just ensure enough linking occurs between activities and topic.
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?	✓			
	3	Did emphasis and consolidation of learnt material occur continuously?	✓			
	4	Were learners continuously assessed and given appropriate support?	✓			
	5	Were learning activities appropriate and relevant?	✓			
	6	Was feedback given consistently on the learning activities?		✓		
TEACHING AND LEARNING ACTIVITIES – Conclusion	1	Was new knowledge clearly summed up?		✓		Sum up and conclude the major points learnt during the lesson. Give a follow up activity.
	2	Were the set lesson objectives used as basis for planned learning?		✓		
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?			✓	
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?	✓			Just ensure that rules are given and followed. Work on your time management.
	2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
	3	Was communication between learners promoted?	✓			
	4	Attitude towards learners.	✓			
	5	Was self-directed learning motivated in learners?	✓			
	6	Were suitable learning and teaching aids used effectively?	✓			
	7	Quality of student's classroom management?		✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)			✓	Fill in daily reflection and daily/weekly forecast reflections.

45%

Remarks: Thank you for the lesson - a few things to improve but it was a sound lesson.

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

Univ. Tutor/School Mentor: Name (in full): G. Heath Signature: _____

F.L 55%

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Classroom management strategy

Assessor: G. Hall Date: 13.08.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

			CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON		1	Have the lesson goals been correctly formulated?		✓		Orient the lesson around a specific CMS - the strategy has to be the focus. Essential to give the UT a copy of the worksheet - assessment
		2	Are the core questions correctly aligned with the general objectives and the specific content?		✓		
		3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
		4	Is the assessment strategy aligned with the above?			✓	
		5	Was the lesson fully planned?			✓	
		6	Is relevant preparation material available?			✓	
TEACHING AND LEARNING ACTIVITIES	Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		objectives of the lesson have to be oriented around a specific CMS.
		2	Was the introduction creative and within the context of the planned learning content?		✓		
		3	Did the introduction spur the learners on to further learning?		✓		
		4	Were the goals of the lesson clear to the learners?			✓	
	Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?		✓		Case study of the Buffalo given. Learning activities have be oriented around a CMS
		2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?	✓			
		3	Did emphasis and consolidation of learnt material occur continuously?	✓			
		4	Were learners continuously assessed and given appropriate support?	✓			
		5	Were learning activities appropriate and relevant?			✓	
		6	Was feedback given consistently on the learning activities?	✓			
	Conclusion	1	Was new knowledge clearly summed up?		✓		A good conclusion
		2	Were the set lesson objectives used as basis for planned learning?		✓		
		3	Were the lesson objectives reached?		✓		
		4	Were homework and follow-up activities clear and achievable?		✓		
STUDENT'S TEACHING SKILLS		1	Does the student have sufficient subject knowledge?			✓	Please improve on subject knowledge. Your classroom management is OK but can be improved - late coming and noisy boys
		2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
		3	Was communication between learners promoted?	✓			
		4	Attitude towards learners.	✓			
		5	Was self-directed learning motivated in learners?		✓		
		6	Were suitable learning and teaching aids used effectively?			✓	
		7	Quality of student's classroom management?		✓		
ADMIN		1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)	✓			A good and efficient file

Remarks: You have some very pleasing teaching qualities but I would like you to repeat this lesson as a CMS - the learners have to understand what a strategy is. Explain what a CMS is in class.

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

Univ. Tutor/School Mentor: Name (in full): G. Hall Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: [redacted] Subject: Geography CRM Grade: 12

Course: PGCE Lesson theme: Impact of people on ecosystems

Assessor: G. Heath Date: 30 · 08 · 16 07

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?			✓	Be absolutely sure of what you need to teach – the lesson has to revolve around the subtopic Understand the content and subtopic
	2	Are the core questions correctly aligned with the general objectives and the specific content?		✓		
	3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
	4	Is the assessment strategy aligned with the above?		✓		
	5	Was the lesson fully planned?			✓	
	6	Is relevant preparation material available?			✓	
TEACHING AND LEARNING ACTIVITIES – Introduction	1	Did the introduction include learners' experience and prior knowledge?			✓	Next time spend more time keeping the introduction.
	2	Was the introduction creative and within the context of the planned learning content?			✓	
	3	Did the introduction spur the learners on to further learning?			✓	
	4	Were the goals of the lesson clear to the learners?			✓	
TEACHING AND LEARNING ACTIVITIES – Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?			✓	I liked what you used but please arrange learning activities around a content goal and PLAN next time
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?		✓		
	3	Did emphasis and consolidation of learnt material occur continuously?		✓		
	4	Were learners continuously assessed and given appropriate support?			✓	
	5	Were learning activities appropriate and relevant?			✓	
	6	Was feedback given consistently on the learning activities?		✓		
TEACHING AND LEARNING ACTIVITIES – Conclusion	1	Was new knowledge clearly summed up?		✓		Conclusion reasonable but just focus on the overall purpose of the lesson next time.
	2	Were the set lesson objectives used as basis for planned learning?		✓		
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?			✓	
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?		✓		Verbal communication fine but address non-verbal. Address time in your next time
	2	Quality of the communication (verbal/non-verbal) with the learners.			✓	
	3	Was communication between learners promoted?		✓		
	4	Attitude towards learners.		✓		
	5	Was self-directed learning motivated in learners?		✓		
	6	Were suitable learning and teaching aids used effectively?			✓	
	7	Quality of student's classroom management?		✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)			✓	A lot more work needs to go into your file – forecasts, reflections 40%

Remarks: This was a borderline lesson but there is very pertinent advice for you next time. Much more planning needs to go into the lesson.

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

Univ. Tutor/School Mentor: Name (in full): G. Heath Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Importance of catchments

Assessor: G. Heath Date: 13.08.16

55%

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?		✓		Some good aspects like IKS but please rewrite lesson plan: Socio-economic activity, and include mini-SASS as part of body.
	2	Are the core questions correctly aligned with the general objectives and the specific content?	✓			
	3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
	4	Is the assessment strategy aligned with the above?		✓		
	5	Was the lesson fully planned?		✓		
	6	Is relevant preparation material available?		✓		
TEACHING AND LEARNING ACTIVITIES – Introduction	1	Did the introduction include learners' experience and prior knowledge?	✓			A fine introduction
	2	Was the introduction creative and within the context of the planned learning content?	✓			
	3	Did the introduction spur the learners on to further learning?	✓			
	4	Were the goals of the lesson clear to the learners?	✓			
TEACHING AND LEARNING ACTIVITIES – Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?	✓			Please indicate marks on activity sheet. Also improve sentence and expression of activity. Reasonable poster. Sheet but use blue for rivers & indicate Tugela Falls
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?	✓			
	3	Did emphasis and consolidation of learnt material occur continuously?		✓		
	4	Were learners continuously assessed and given appropriate support?	✓			
	5	Were learning activities appropriate and relevant?	✓			
	6	Was feedback given consistently on the learning activities?	✓			
TEACHING AND LEARNING ACTIVITIES – Conclusion	1	Was new knowledge clearly summed up?	✓			A fine conclusion but giving homework is a very good idea.
	2	Were the set lesson objectives used as basis for planned learning?	✓			
	3	Were the lesson objectives reached?	✓			
	4	Were homework and follow-up activities clear and achievable?			✓	
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?		✓		Just be absolutely sure of the terms you use such as "industry". Please stipulate safety instructions on work sheet.
	2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
	3	Was communication between learners promoted?	✓			
	4	Attitude towards learners.	✓			
	5	Was self-directed learning motivated in learners?		✓		
	6	Were suitable learning and teaching aids used effectively?		✓		
	7	Quality of student's classroom management?		✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)		✓		Please include reflections reports and proper planning for the field trip, i.e. Letter to Head.

Remarks: A good lesson with some planning aspects. What can be improved are the lesson plan, activity sheet, and the other points mentioned above. 55

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

48%

Univ. Tutor/School Mentor: Name (in full): G. Heath Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

52%

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Human impacts on catchment basins

Assessor: G. Heath Date: 06.08.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?		✓		Specify exact grade, and the exact lesson objectives
	2	Are the core questions correctly aligned with the general objectives and the specific content?		✓		
	3	Are the teaching and learning activities aligned with the lesson's objectives?	✓			
	4	Is the assessment strategy aligned with the above?	✓			
	5	Was the lesson fully planned?	✓			
	6	Is relevant preparation material available?	✓			
TEACHING AND LEARNING ACTIVITIES — Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		A reasonable introduction
	2	Was the introduction creative and within the context of the planned learning content?	✓			
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?		✓		
Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?	✓			Good groupwork activity - just consider size and participation for next time.
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?		✓		
	3	Did emphasis and consolidation of learnt material occur continuously?	✓			
	4	Were learners continuously assessed and given appropriate support?	✓			
	5	Were learning activities appropriate and relevant?	✓			
	6	Was feedback given consistently on the learning activities?	✓			
Conclusion	1	Was new knowledge clearly summed up?		✓		Just make the conclusion - the main points learnt - more explicit at end
	2	Were the set lesson objectives used as basis for planned learning?		✓		
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?		✓		
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?		✓		Just focus on time management and full preparation for next time consider giving out a worksheet to be completed during the field
	2	Quality of the communication (verbal/non-verbal) with the learners.		✓		
	3	Was communication between learners promoted?	✓			
	4	Attitude towards learners:	✓			
	5	Was self-directed learning motivated in learners?	✓			
	6	Were suitable learning and teaching aids used effectively?		✓		
	7	Quality of student's classroom management?		✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)			✓	Reflection reports, not daily forecasts, not 42 found. The file needs to be "full"

Remarks: A good lesson but just focus on the issues to be improved for next time.

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

Univ. Tutor/School Mentor: Name (in full): G Heath Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Catchment Management - Section 17

Assessor: G. Heath Date: 19.08.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?			✓	Please be more sure of lesson materials for a field trip. Also reference lesson objectives to a CMS. T+L activities need to be aligned to a CMS
	2	Are the core questions correctly aligned with the general objectives and the specific content?			✓	
	3	Are the teaching and learning activities aligned with the lesson's objectives?			✓	
	4	Is the assessment strategy aligned with the above?			✓	
	5	Was the lesson fully planned?			✓	
	6	Is relevant preparation material available?			✓	
TEACHING AND LEARNING ACTIVITIES – Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		Some relevant aspects but please align goals to a prior CMS.
	2	Was the introduction creative and within the context of the planned learning content?		✓		
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?			✓	
Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?			✓	Thank you for the worksheet but please align to a CMS. Good activities for human impacts but please re-align to a macroscale for a CMS
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?		✓		
	3	Did emphasis and consolidation of learnt material occur continuously?		✓		
	4	Were learners continuously assessed and given appropriate support?		✓		
	5	Were learning activities appropriate and relevant?			✓	
	6	Was feedback given consistently on the learning activities?		✓		
Conclusion	1	Was new knowledge clearly summed up?		✓		Case study given to learners - please give the UT a try.
	2	Were the set lesson objectives used as basis for planned learning?			✓	
	3	Were the lesson objectives reached?			✓	
	4	Were homework and follow-up activities clear and achievable?		✓		
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?		✓		You have some pleasing teaching competencies.
	2	Quality of the communication (verbal/non-verbal) with the learners.		✓		
	3	Was communication between learners promoted?		✓		
	4	Attitude towards learners.	✓			
	5	Was self-directed learning motivated in learners?		✓		
	6	Were suitable learning and teaching aids used effectively?		✓		
	7	Quality of student's classroom management?		✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)			✓	Your file needs to be better organised.

48%

Remarks: Please focus on safety - lightning and trees - and always do research on the lesson topic and country where you have fieldwork.

EXCEEDS STANDARD ☐ MEETS STANDARD ☐ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☑

45-0%

Univ. Tutor/School Mentor: Name (in full): G. Heath Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Impact of people in vulnerable areas

Assessor: G. Heath Date: 6.8.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?			✓	Reformulate lesson plan and use a properly considered and prepared work sheet next time.
	2	Are the core questions correctly aligned with the general objectives and the specific content?			✓	
	3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
	4	Is the assessment strategy aligned with the above?		✓		
	5	Was the lesson fully planned?			✓	
	6	Is relevant preparation material available?			✓	
TEACHING AND LEARNING ACTIVITIES — Introduction	1	Did the introduction include learners' experience and prior knowledge?			✓	Make the introduction more explicit and inclusive of what the learners know.
	2	Was the introduction creative and within the context of the planned learning content?			✓	
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?		✓		
Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?			✓	Remember to have a framework to work from for fieldwork next time. A properly planned worksheet is a good example of this.
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?		✓		
	3	Did emphasis and consolidation of learnt material occur continuously?		✓		
	4	Were learners continuously assessed and given appropriate support?			✓	
	5	Were learning activities appropriate and relevant?			✓	
	6	Was feedback given consistently on the learning activities?		✓		
Conclusion	1	Was new knowledge clearly summed up?			✓	Remember to sum up key knowledge at the end next time.
	2	Were the set lesson objectives used as basis for planned learning?		✓		
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?		✓		
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?			✓	Your classroom management can be improved — you need to take control of your own lesson. Also improve your knowledge of CAPS process
	2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
	3	Was communication between learners promoted?		✓		
	4	Attitude towards learners.		✓		
	5	Was self-directed learning motivated in learners?			✓	
	6	Were suitable learning and teaching aids used effectively?				
	7	Quality of student's classroom management?	✓	✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)		✓		Please do daily forecasts for next time.

Remarks: I would like you to repeat this lesson showing clear planning and preparation for a fieldwork exercise.

EXCEEDS STANDARD ☐ MEETS STANDARD ☐ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☑

Univ. Tutor/School Mentor: Name (in full): G. Heath Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

51 0/0

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Human impacts on ecosystems

Assessor: G. Heath Date: 20.08.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?		✓		A reasonable lesson plan but be careful of using words like "urbanisem" where no such feature exists. Good poster for introduction
	2	Are the core questions correctly aligned with the general objectives and the specific content?		✓		
	3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
	4	Is the assessment strategy aligned with the above?		✓		
	5	Was the lesson fully planned?		✓		
	6	Is relevant preparation material available?	✓			
TEACHING AND LEARNING ACTIVITIES — Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		A good introduction with creative aids.
	2	Was the introduction creative and within the context of the planned learning content?	✓			
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?	✓			
Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?		✓		A good section but please understand the number of human impacts: dams, IBT (mostly negative). It is also very important for learners to [illegible]
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?	✓			
	3	Did emphasis and consolidation of learnt material occur continuously?	✓			
	4	Were learners continuously assessed and given appropriate support?		✓		
	5	Were learning activities appropriate and relevant?		✓		
	6	Was feedback given consistently on the learning activities?		✓		
Conclusion	1	Was new knowledge clearly summed up?		✓		A sound conclusion
	2	Were the set lesson objectives used as basis for planned learning?		✓		
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?	✓			
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?			✓	Please improve content knowledge on key terms such as urbanisem, road mine drainage, and the role of people in different areas
	2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
	3	Was communication between learners promoted?	✓			
	4	Attitude towards learners.	✓			
	5	Was self-directed learning motivated in learners?		✓		
	6	Were suitable learning and teaching aids used effectively?		✓		
	7	Quality of student's classroom management?		✓		
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)		✓		Please ensure all daily forecasts are done

58 0/0

Remarks: Please do more research on the human impacts on ecosystem areas. Examples must be absolutely sure of what they are doing. Some planning aspects though.

57 0/0

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

Univ. Tutor/School Mentor: Name (in full): G. Heath Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Impact of people on catchment areas

Assessor: G. Hearn Date: 12.08.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?		✓		Lesson plan good but do not confuse sub-topic's : concept of catchment area belongs to importance of c. area subtopic. Write out in pen next time.
	2	Are the core questions correctly aligned with the general objectives and the specific content?		✓		
	3	Are the teaching and learning activities aligned with the lesson's objectives?	✓			
	4	Is the assessment strategy aligned with the above?	✓			
	5	Was the lesson fully planned?		✓		
	6	Is relevant preparation material available?	✓			
TEACHING AND LEARNING ACTIVITIES — Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		A good introduction. Good that you explained what a catchment area is.
	2	Was the introduction creative and within the context of the planned learning content?		✓		
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?	✓			
Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?	✓			Give marks or mention in classroom for assessment activity. Also give more organising details on it. Admire sketch map - just show route next time. Put organising details on worksheet.
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?	✓			
	3	Did emphasis and consolidation of learnt material occur continuously?	✓			
	4	Were learners continuously assessed and given appropriate support?		✓		
	5	Were learning activities appropriate and relevant?	✓			
	6	Was feedback given consistently on the learning activities?	✓			
Conclusion	1	Was new knowledge clearly summed up?	✓			Just ensure positive and negative aspects covered. Also ensure that exercise is completed for homework.
	2	Were the set lesson objectives used as basis for planned learning?	✓			
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?			✓	
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?		✓		Please ensure clipboards or hardcovers are used to write on. Also improve on classroom management : involvement of boys and where they should stand in groups.
	2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
	3	Was communication between learners promoted?	✓			
	4	Attitude towards learners.	✓			
	5	Was self-directed learning motivated in learners?		✓		
	6	Were suitable learning and teaching aids used effectively?		✓		
	7	Quality of student's classroom management?			✓	
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)		✓		Good reflection - but indicate dates. Also 60% lesson forecast sheet.

Remarks: It is important to inform the Head of the Fieldwork in writing; and organise the Fieldtrip so that proper organisation occurs.

EXCEEDS STANDARD ☐ MEETS STANDARD ✓ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

Univ. Tutor/School Mentor: Name (in full): G. Hearn Signature: _____

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF EDUCATION
EDGEWOOD CAMPUS, PINETOWN

55%

FORMATIVE ASSESSMENT OF LESSON (B.Ed and PGCE)

Name: _____ School: _____

Student number: _____ Subject: Geography Grade: 12

Course: PGCE Lesson theme: Importance of managing wetland areas

Assessor: G Heath Date: 20.08.16

Key: 1. EXCEEDS STANDARD 2. MEETS STANDARD 3. DOES NOT MEET STANDARD

		CRITERIA	1	2	3	REMARKS
PLANNING AND PREPARATION OF LESSON	1	Have the lesson goals been correctly formulated?		✓		Good and precise lesson plan but ensure that objectives of lesson revolve around main theme – importance of managing wetland areas.
	2	Are the core questions correctly aligned with the general objectives and the specific content?		✓		
	3	Are the teaching and learning activities aligned with the lesson's objectives?		✓		
	4	Is the assessment strategy aligned with the above?		✓		
	5	Was the lesson fully planned?	✓			
	6	Is relevant preparation material available?	✓			
TEACHING AND LEARNING ACTIVITIES – Introduction	1	Did the introduction include learners' experience and prior knowledge?		✓		A sound introduction.
	2	Was the introduction creative and within the context of the planned learning content?		✓		
	3	Did the introduction spur the learners on to further learning?		✓		
	4	Were the goals of the lesson clear to the learners?	✓			
Teaching and learning phase	1	Were appropriate teaching strategies used to make the new content clear to the learners?		✓		Good worksheet but at least 5 or 6 questions are needed. Emphasise that wetland areas don't give us all the oxygen we need. Also integrate the activity mini-SASS with the topic.
	2	Were opportunities created for the learners to apply the new knowledge (in individual and /or group context)?		✓		
	3	Did emphasis and consolidation of learnt material occur continuously?		✓		
	4	Were learners continuously assessed and given appropriate support?		✓		
	5	Were learning activities appropriate and relevant?		✓		
	6	Was feedback given consistently on the learning activities?		✓		
Conclusion	1	Was new knowledge clearly summed up?		✓		A reasonable conclusion but try not to use "I think" which indicates you are still thinking of whether or not the lesson has ended.
	2	Were the set lesson objectives used as basis for planned learning?		✓		
	3	Were the lesson objectives reached?		✓		
	4	Were homework and follow-up activities clear and achievable?		✓		
STUDENT'S TEACHING SKILLS	1	Does the student have sufficient subject knowledge?		✓		Only 2 out of 42 learners arrived for the lesson – please report this to the Head. Please repeat this lesson in class to the non-attendees.
	2	Quality of the communication (verbal/non-verbal) with the learners.	✓			
	3	Was communication between learners promoted?	✓			
	4	Attitude towards learners.	✓			
	5	Was self-directed learning motivated in learners?	✓			
	6	Were suitable learning and teaching aids used effectively?		✓		
	7	Quality of student's classroom management?			✓	
ADMIN	1	Does the student show clear evidence of all necessary documentation? (Daily forecast, timetables, class lists, lesson plans, school information, etc.)		✓		You need to ensure that daily forecasts are totally completed. 58%

Remarks: This lesson has not met the standard but please repeat the lesson to the whole class in a more coherent and holistic (i.e. the whole wetland) way. Also include IKS in how to manage wetland areas.

EXCEEDS STANDARD ☐ MEETS STANDARD ☑ DOES NOT MEET STANDARD – THE LESSON MUST BE REPEATED ☐

58%

Univ. Tutor/School Mentor: Name (in full): G Heath Signature: _____

LESSON PLAN

Subject:	Geography	Grade:	11 12
Date:	30/07/2016	Duration:	55 min
Content:	River and Catchment Management		
Sub-topic:	Importance of managing drainage basin & Catchment		
Lesson objectives:	Learners must be able to: *Understand the importance of managing drainage basins and catchment areas. *Understand the impact of people on drainage basins		
Materials:	*Chart *Equipments for doing a MiniSASS		

	Teacher activity (with time)	Learner activity (with time)
Introduction	*Explain the purpose of the field trip - Aims & objectives *Explain the main concepts - Catchment area - Drainage basin *Brief Learners on safety measures and movement along the river.	*Learners listen to explanation and ask questions when they dont understand or make comments.
Body	*Explain the importance of managing drainage basins & catchment areas. *Explain the impacts of people on drainage basins and catchment area.	*Learners to listen to the explaination *Learners must describe the other impacts that the human have on catchment area and in drainage basin.

Conclusion

Conclusion	* Compare the results of different groups and give a feedback the learners. * Conclude by allowing learners to comments or add on the lesson.	* Allow learned to express their views or make comments
Assessment	* Divide learners into 5 groups, then allow them to do the activity on MiniSASS.	* Learners must do the MiniSASS activity in group.
Reflection		

Name of teacher: [redacted]

Sign: [redacted]

Date: 30/07/2016

Mentor: UT

Sign: _____

Date: _____

LESSON PLAN

Subject:	Geography	Grade:	12
Date:	13/08/2016	Duration:	~~55 min~~ 1hr 30 min
Content:	Catchment and River Management		
Sub-topic:	Catchment area management strategies		
Lesson objectives:	Learners must be able to identify problems in a catchment area. *Learners must be able to carry out the strategies to reduce the problems *Learners must understand the effect of problems in the catchment area.		
Materials:	*Map sketch *Mini-SASS equipment		

	Teacher activity (with time)	Learner activity (with time)
Introduction	*Explain the purpose of the lesson to the learners. *Brief learners with safe measures. *Brief learners with the objectives of this field trip. *Give learners the prac sheet.	*Learners must listen
Body	*Recap on previous lesson or field trip by mentioning the aim. *Explain to the learners what is a case study. *Allow one learner to read a case study and explain it relating to the surrounding environment. *Group learners into five groups to do an activity. *~~Allow learners to~~ present their answers. *Give feedback to the learners. *Before answering questions on a worksheet allow learners to do a Mini-SASS. *Compare the results and give a feedback to the learners.	*Learners must listen and take down some notes *Learners must ~~start~~ question 1 and 2 on the activity (worksheet). *Learners must do a Mini-SASS activity

Conclusion	Conclude lesson by highlighting the main aim of the field trip and how it is related to the activities. Allow learners to ask questions.	* learners must ask questions.
Assessment	Finish off question 3 at home.	Do question 3 at home (homework).
Reflection		

Name of teacher: _____ Mentor: Mr Heath

Sign: _____ Sign: _____

Date: 13/08/2016 Date: 13/08/2016

LESSON PLAN

Subject:	Geography	Grade: 12	
Date:	30 July 2016	Duration:	60 min
Content:			
Sub-topic:	catchment river management / Human Impacts		
Lesson objectives:	to understand the importance of our rivers and catchment area. to be able to identify activities taking place in a catchment to be able to come up with strategies to manage catchment		
Materials:	Different textbooks		

	Teacher activity (with time)	Learner activity (with time)
Introduction	Introduce the topic by first looking at where river get their water. what makes up a drainage system and a catchment area. Introduce the focus of todays lesson which is catchment and river Management.	listen, participate and ask questions
Body	The main issues facing catment and river manage are erosion & pollution. - look at precipitation as a natural agent of erosion - Laminar flows & Turbulent flows; heavy rains.	Listin participate and ask questions Learners can add information from their own experiences with the river.
	- Human induced activities - overgrazing, deforestation - development, exploitation of natural resources. - Pollution	

Conclusion	- How is the catchment of river cripping with Pollution - What has the community lost because of poor river management. - What can be done to improve the catchment area and quality of water	- Learners can participate and ask questions and seek clarity or even add their views.
Assessment	- Questionnaire - Identity sheet with score	- observe the environment and be able to see evidence of pollution degradation and erosion. - Activities taking place in the catchment?
eflection		

of teacher: _____ Mentor: _____

_____ Sign: _____

30 July 2016 Date: _____

LESSON PLAN

Subject:	Geography	Grade:	12.
Date:	13 Aug 2015	Duration:	55 min
Content:	Catchment River Management		
Sub-topic:	Importance of Catchments		
Lesson objectives:	- What are catchments socio-economic - Importance of catchments and rivers (socio-economic) - Identification of activities taking place in a catchment		
Materials:	- Different text books - Intanet and Otha Reading, Indegenous knowledge.		

	Teacher activity (with time)	Learner activity (with time)
Introduction	What are Catchment areas? How are they formed? How do rivers get their water? The lesson will focus on the observing the natural environment and looking at its beauty and what it offers to us ~~look at~~ understand where rivers get their water.	learners are to listen and ask questions. They will also get a chance to speak or discuss what they see. and to answer questions.
ody	- Catchments provide a whole range of activities and they allow humans and nature to experience the best of life. - Everything relies on water. • Industry • Agri • Business • Development • Settlement - Rivers provide for socio-economic activities. - the importance of dams as part of the river systems	listen and Participate by asking questions and filling in their worksheets

Conclusion	looking back at what rivers provide for us as humans and other natural inhabitants The importance of these rivers. looking out keeping them useful	Participate in the Mini SASS. and be able to understand how the importance of a clean river system
Assessment	Work Sheet with Questions Mini SASS Study	Able to follow instructions
Reflection		

ame of teacher:

gn:

te: 13/aug/2016 Date: 13/08/2016

25

LESSON PLAN

Subject:	Geography	Grade:	12
Date:	06 August 2018	Duration: 3 hours	35 min
Content:	Catchment and drainage basins		
Sub-topic:	Human impacts on catchment areas		
Lesson objectives:	Learners will understand the positive and negative human impacts on catchment areas.		
Materials:	handouts, charts and pictures		

	Teacher activity (with time)	Learner activity (with time)
Introduction	* Summarise the field rules * outline lesson objectives * introduce the topic on positive and negative human impacts on catchment areas	* listen * apply prior knowledge * ask question
Body	starts with negative impacts * Overgrazing / poor cultivation * Removal of vegetation * Soil erosion * Urbanization * loss of wetlands * Eutrophication * Water pollution	

Conclusion	Alien species Positive impacts - Increased water storage - Ecotourism - Basic needs such as drinking water	
Assessment	Soil erosion experiment observational activity	will observe and discuss in small groups. answer questions
Reflection	The lesson was fully planned and learners did learn alot from this lesson.	

Name of teacher _____ Mentor: _____

Sign: _____ Sign: _____

Date: 06 August 2018 Date: _____

(25)

[redacted]

LESSON PLAN

Subject:	Geography	Grade:	12
Date:	19 August 2016	Duration: 3 hours	[redacted] min
Content:	Catchment and River management		
Sub-topic:	Catchment Management Strategy		
Lesson objectives:	Learners will learner how to conserve, control, manage and rehabilitate water resources and land		
Materials:	Textbook, worksheets and notes		

	Teacher activity (with time)	Learner activity (with time)
Introduction	Will explain what is a catchment management Strategy * Will ask question to check learners prior knowledge * Summarise Field trip rules * Outline lesson objectives	Will answer questions
Body	* how to control alien species * How to manage land pollution * Importance of ground water and to conserve ground water * Veld management * Overgrazing	observe discuss ask question

Conclusion	Soil erosion land degradation Poor road development Summarize the fieldtrip	
Assessment	Completion of worksheet will do miniSASS	Discuss in groups and answer the worksheets
Reflection		

Name of teach _____ Mentor: _____

Sign: [redacted] Sign: _____

Date: 19 August 2016 Date: _____

LESSON PLAN

Subject:	Geography	Grade:	12
Date:	20/08/2016	Duration:	60 min
Content:	Catchment and River management		
Sub-topic:	The impact of People on catchment and drainage basin		
Lesson objectives:	• Be able to identify and understand the positive and negative impacts that people have on drainage basins and catchment areas.		
Materials:	work sheet, Charts		

	Teacher activity (with time)	Learner activity (with time)	
Introduction	• Explain the purpose of the Fieldtrip. • Tell learners about objectives of the lesson. • Ask learners what they know about the concept of drainage basin and catchment area. • Tell learners that the impact may be negative as well as be positive.	• Communicate their existing knowledge.	15 min
Body	• Take learners to different sites in the field that show examples of human impact on catchmen areas. • Removal of vegetation - Overgrazing - Pollution (Eutrophication) - Urbanization - wetland destruction • Positive impacts of people on drainage basins	• move to different sites and complete their work sheets at each site.	

Conclusion	- Give learners a summary of all the positive and negative impacts that People have on drainage basin and catchment areas.	- Participate by answering questions posed to them.	15 mins
Assessment	• learners will be assessed by completing the worksheet they are provided with - they are working in groups of 5.	• Form groups and discuss in their groups the impacts that they see and fill in their work sheets.	
Reflection			

Name of teacher

Sign:

Date: 20/08/2016.

Mentor: _____

Sign: _____

Date: _____

School Name:

Date: 12/08/2016

Subject: Geography

Grade: 12

Number of learners: 25

Duration: 1hr 55 min

Strand: Geomorphology

Topic: Impact of people on catchment areas

Lesson objectives:

- Learners should understand the concept of catchment area
- Learners should understand how people negatively and positively impact catment areas

Assessment(s): Filling in worksheet and discussions

Extended opportunities: Discussions on strategies to deal with particular issue.

Resources required: Text book; Worksheets; Sketches (Posters); Watch

Lesson Details

Section	Educator	Learner	Time (min)
1. Introduction (10 min)	• Introduce the topic of the fieldtrip and lesson objectives to learners.	• Listen to the explanation.	03
	• Ask learners about what do they know about catchment areas?	• Respond to the question by providing information on what they know.	02
	• Give-out handouts with a catchment area in order to explain it and adding information provided by learners (if any).	• Listen to explanation, ask questions and respond to questions asked by the educator	05

2. Body (1hr35min)	• Explain the negative impacts of people on catchment areas - Removal of vegetation - Overgrazing - Water pollution - Eutrophication - Destruction of wetlands • Explain positive impacts of people on catchment areas - Dam buildings - Removal of aliens invasive species - Construction of stonepacks • Let learners discuss and present what they learnt in small groups.	• Listen to explanation • Ask questions • Respond to questions asked • Discuss each impact and fill in a worksheet provided • Discuss and write down what they learnt in the fieldtrip	50 min 30 min 15 min
3. Conclusion (10 min)	• Collect papers from learners and read out what they think they learnt in this fieldtrip • Summarise the important aspects that were covered in this fieldtrip	• Submitt their papers in groups on what they learnt • Listen to the summary and respond to some questions asked.	5 5

Reflection

School Name: ,1 Date: 20/08/2016

Subject: Geography Grade: 12

Number of learners: 25 Duration: 90 minutes

Strand: Geomerphology Topic: The importance of managing catchment areas.

Lesson objectives:

- Learners should understand the concept of catchment area.
- Learners should know how important catchment areas are.
- Learners should understand the importance of managing catchment areas.

Assessment(s):

- Filling in worksheet and Discussion.

Extended opportunities:

Resources required: Text book, Worksheet, Sketch (Pester); Stop watch

Lesson Details:

Section	Educator	Learner	Time (min)
Introduction (10 min)	• Introduce the topic of the fieldtrip and the lesson objectives to learners.	• Listen to the explanation given by the educator.	02
	• Acquire learner's pre-knowledge about catchment areas	• Provide information they have / know about catchment areas.	03
	• Use a handout with a catchment area to explain it and adding information given by learners	• Listen to explaination, ask some questions and respond to questions asked by the educator.	05

2. Body (75 min)	• Explain the importance of catchment areas to people. • Explain the importance of managing the catchment areas. • Explain to learners what is a minisass and conduct it together with learners. • Let learners discuss and present what they learnt in small groups.	• Respond to questions and ask questions. • Discuss the importance on managing catchment areas in small groups & fill in worksheet. • Conduct the minisass in two points to determine health of the river. • Discuss in small groups and present what they learnt to other learners.	10 15 30 10
3. Conclusion (05 min)	• Conclude the lesson by summarising what was learnt during the whole fieldtrip.	• Listen to the summary and respond to some questions asked.	05

Reflection

- The lesson went well, however some learners were behaving as if they are not in a lesson.
The group discussions were very helpful to all learners and it was showing the understanding of the content learnt.

(25)

LESSON PLAN

Subject:	Geography	Grade:	12
Date:	26/08/16	Duration:	55 min
Content:	Catchment and River management		
Sub-topic:	Catchment management Strategy		
Lesson objectives:	learners will learn how to overcome problems associated with catchment of upper Thukela		
Materials:	Textbooks, Illustrations on the chalkboard and charts.		

	Teacher activity (with time)	Learner activity (with time)
Introduction	Explain what is a Strategy. * Explain what is a CMS * link it with the previous lesson	ask question discuss
Body	* Explain CMS in a macro scale level * Explain how to use Plans such as conservation, Zoning management control and development in a catchment	ask questions discuss

Conclusion	Summarise the topic	ask questions
Assessment	open small group discussion about how to overcome local issues related to water and catchment as a whole	discuss
Reflection	The lesson went well learner know how to overcome local issues such as pollution and macro issues that affect the the Uthukela catchment	

Name of teacher: _____ Mentor: _____

Sign: _____ Sign: _____

Date: 26/08/16 Date: _____

Field Trip report 1

Topic: Catchment and River Management

Sub-topic: Importance of catchment area and drainage basins

What went wrong?

Preparation of lesson does not meet the standards since there was a confusion of sub-topics. The lesson was supposed to evolve around one sub-topic. This results in the lesson plan which was not relevant to what happened during the lesson. There no follow up activity or homework that was given to the learners to help learners to refresh their mind about what was happening in the field. The feedback was not clear to the learners; the major points were not mentioned. Classroom management was not good at all. The teacher was supposed to give learners safety majors before everything started. In terms of administration, there were some documents that were missing on the file such as daily forecast and reflection reports.

What went well?

The teaching and learning activities were aligned with the lesson objectives. The activity that was given to the learners went as teacher planned. The teaching strategies that a teacher used encourage learners to be passionate with the lesson. And that result in a good communication between a teacher and learners. The participation of learners was perfect; learners were answering questions very well and ask relevant questions. All the relevant materials were available.

What can be done in order to improve?

A lesson must focus on one sub-topic to avoid confusion to the learners and also to the teacher. Safety measures must be always mentioned or given to the learners. Follow up activity or homework is very important, it helps in testing learners and refreshing their minds on what they did during the lesson. Feed backs also must be clear to the learners.

Field Trip report 2

Topic: Catchment and River Management

Sub-topic: Catchment Management Strategy

What went wrong?

Planning and preparation of the lesson was good, however there was a misunderstanding in the strategy and strategies. The lesson was supposed to orientate around one strategy in a catchment. This results as if the lesson was not fully planned. The relevant preparation materials were not available. The objectives did not orientate around a specific catchment management strategy. The goals of the lesson was not clear enough of which confuses some of the learners. There was a lack of subject knowledge in the learners and in the teacher as well. This was because the topic that the lesson was all about has not covered yet on their grades since the learners are from grade 11 and 10 and the misunderstanding between the strategy and strategies. The activity was not appropriate due to the misunderstanding of the sub-topic. Suitable learning and teaching aid were not used effectively. The weather also play a role in the lesson, there was a wind of which result in other learners to lack focus and a teacher to try by all means to do the lesson as she planned.

What went well?

The introduction of the lesson spurs the learners to further learning. Communication between a teacher and learners was good. The attitude of a teacher towards the learners was also perfect. The teacher encourages leaners to participate during the lesson. The feedback that was given to the learning activity was consistent. Learners were given support during assessment. There was a good communication among learners. Classroom management was perfect. In terms of administration, the file was good and had all necessary documentation.

What can be done in order to improve?

The lesson must be orientated around a specific catchment management strategy. The strategy has to be the focus. Objectives of the lesson have to be orientated around a specific catchment management strategy. Case study given to the learners has to be orientated around

a catchment management strategy. Subject knowledge need to be improved. The lesson must be repeated on a classroom in order the learners to understand what a strategy is.

Grade 12 Catchment River Management

Geography: Human impacts in the catchments

Field trip: 30 July 2016

The field trip was held on the 30 July with the grade 12 learners. The trip was well prepared for and pre site inspection was conducted to make sure that it relates to the planed lesson. The site that I chose clearly showed the human induced impacts that our catchment and river systems face. There was evidence of pollution, erosion, mining and mis-utilization of the riparian zone.

The information that was given to students was well researched and they had the evidence to see for themselves along the river site. By the end of the lesson learners had the chance to fill in a questionnaire about activities that take place in the catchments. This questionnaire was to give learners a clear picture of how the community has damaged the environments of the river banks and have impacted on the water quality and the state of the natural environment.

The things that did not go so well is that there were a fewer learners who were taking part in the field trip and this had a negative impact on delivering the lesson as planned and caring out the activities that were planned for the day. The trip ended up taking less time.

Next time I should make sure that I get to school early so that I can give my learners motivation to take part in the trip.

Geography Grade 12 lesson

Importance of river catchment (Indigenous knowledge systems)

The field trip was arranged and focused on the raising awareness of the importance of river catchment area. The lesson was to focus on using indigenous knowledge and also extracting the knowledge that the learners carry with them in terms of protecting and preserving the rivers.

The lesson was well planed and learners were taking part in the lesson. We were using content from the textbook as a guide but largely focused on what we have learnt through our families and communities.

The lesson began with identifying activities that take place in a catchment. In the area of the upper uThukela there are a lot of tourism, industry and farming activities taking place. So by identifying these activities was the first step to identifying the importance of catchments. Catchments are important socially, economically and ecologically.

What went well?

The lesson went very well as learners were able to actively participate in the lesson, they were asking questions and giving information that they have been exposed to in their homes and community. We further moved down to the river and that is when we looked at the river itself and we performed a mini sass. The aim was to show that even though our rivers and catchments are important to us but they are not protected as they are polluted. The mini sass was to help us determine if the river was healthy or of poor quality.

My learners were very happy about this activity and enjoyed it as they were looking for the different animals in the river. They were very disappointed by the result as they showed that the Thukela River was not healthy.

The learners were then to answer a questionnaire with regards to the importance of catchments and the indigenous knowledge that they have used and that can still be used to protect rivers. The learners were to come up with ways to involve the community to take part in protecting the rivers.

What went wrong?

In my perspective the challenge was to make sure that the learners were safe while we were in the river because the learners were jumping on the rocks.

06 August 2016

Reflection report

Topic: Human impacts on catchment areas

Duration: 3 hours

Grade 12

Geography Class Fieldtrip

On the 6th of August 2016 I took my Geography learners at high school to an excursion. The fieldtrip began at the gate of the school where I outlined the fieldtrip rules and safety measures. The main aim of this field trip was to teach by showing learners about both negative and positive human impact on catchment areas.

The lesson was fully prepared and well organized. I thought my learners very well; visible signs of negative and positive impact of humans were evident during our fieldtrip. During our trip, we observe land pollution, alien plant species, all forms of erosion, poor cultivation methods, poorly managed wetlands, overgrazing and overstocking, water pollution. Learners were fully involved they participated by answering and asking, making comments, generalize the factors that contribute to positive and negative impact of humans. I managed my time well because we finished the lesson on time.

I have sufficient subject knowledge and I have the ability to project my voice. I have the ability to maintain momentum of the lesson. We conducted an experiment that showed the relationship or importance of vegetation cover.

I gave my learners an activity. The main purpose of the activity was to check their understanding with regard to human action on catchment areas.

What I need to do in my next fieldtrip is to give learners worksheets and sketch maps before we embark on the trip.

19 August 2016

Topic: Catchment management strategy

Duration: 3 hours

Grade 12

Geography Class Fieldtrip

On the 19th of August 2016 I took my Geography learners at High school to an excursion. The fieldtrip began at the gate of the school where I outlined the fieldtrip rules and safety measures. I handed out worksheet and sketch maps.

In this field trip I had 49 learners. Our first point was on Alien invasive plant species. What are alien species , how they affect our catchment and most importantly how to overcome them. These are the issues I discussed with the learners.

Point number two was on land pollution. The type of pollutant we observed was the broken bottles, nappies and plastics lying next to Busingatha River. I explained ways of combating these issues. Then we moved to point number 3 which was on neglected springs, the spring was not even recognized by members of the community hence I thought my learners ways of conserving and managing springs.

I could not finish my lesson on the trip because there were unforeseen circumstances. It rained a lot hence I had to finish my lesson in classroom. I carried on with my lesson in the classroom. I could not show the learners how to rehabilitate gullies and I could not show them how to do minisass.

It had been pointed out that I should have not thought catchment management strategy from a local, micro-point of view. I should have provided with a strategy that would manage the whole catchment not the small areas of a catchment.

Therefore I had to repeat the lesson. On the 26th of August I repeated the lesson in class showing them different charts and worksheet. The main purpose was to teach the catchment management strategy from macro point of view. Like for instance zoning, dividing the catchment for different purposes, the upper uThukela is zoned for conservation not for heavy industries while the areas next to Amajuba are zoned for heavy, light industries, formal and informal human settlement.

The things that I need to pay attention to next time, is weather I have to ensure that it does not become a problem. Decentralize power or authority. For instant if learners are over abundant, I should choose class leaders that would assist me in the trip.

Reflective report

Date: 6 August 2016

Name

On the 6th August I taught the impact of people on catchment and drainage basin to the grade 12 learners at High school. This lesson did not go well because that was my first time conducting a fieldtrip lesson. I feel like I didn't do enough and appropriate preparation for the fieldtrip. During the lesson I failed to keep all my learners in what was happening during the lesson. I failed to introduce the lesson in a way that arouses learner's curiosity about the topic. The form of assessment I used also failed to engage all my learners. I then have to repeat the lesson so that my learners will understand well about the topic we covered. Next time I have to improve in all the aspects that did not go well in my lesson

Reflective report

Date: 20 August 2016

Name

On the 20th August I taught the impact of people on catchment and drainage basin to the grade 12 learners at High school, this is because my first lesson was not good enough. My lesson today went very well the lesson was planned appropriately; I manage to introduce the lesson very well in a manner that engaged all my learners. I taught the lesson very well using small group teaching and I facilitated what was happening amongst the groups. The learners were fully involved in the lesson even though I had two students who were dunked, but manage to keep classroom management. What made the lesson to be good is that what was being taught to learners is something that was around the environment. During the lesson learners were fully engaged in group discussion and completing their worksheets.

Reflective Reports

Lesson Theme: Impact of people on catchment areas.

Date: 12 / 08 / 2016

On the 12 of August 2016 I took geography grade 12 learners from High School to a fieldtrip. In that fieldtrip I taught them about the impacts of people on catchment areas. Learners seems to be enjoying the fieldtrip because they were asking questions and engaging very well with what was being taught. They were participating in every task that was done and they asked question they did not understand from the worksheets I gave them. The worksheets required some improvement because they did not have marks for each question asked and some organising details such as date and duration of the fieldtrip. However, some aspects of classroom management were not well facilitated because there were few learners that were not displaying good behaviour during the fieldtrip. This fieldtrip was successful although it needed some more organisation and informing the whole school stakeholders, including the security guards.

Lesson Theme: Importance of managing catchment areas.

Date: 20 / 08 / 2016

On the 20 of August I conducted a second fieldtrip for geography grade 12 learners from High School. In this second fieldtrip, the lesson taught was about the importance of managing catchment areas. In this fieldtrip only two learners were able to come and one thing that might have negatively influence attendance of learners can be a weather since it was cold and showing signs of rainfall. The fieldtrip continued successfully because it was linked with previous fieldtrip and the learners understood the importance of managing catchment areas because they were able to answer questions. Together with learners we conducted a mini-sass to test the health of some stream and the learners enjoyed this task. However, the mini-sass activity was not well integrated with the theme of the fieldtrip. This fieldtrip lesson had to be repeated in the classroom because there was little attendance.

Geography Lesson
The impact of people on catchment areas

Introduction
- Humans impact catchment areas through their activities.
- Human / anthropogenic activities have both negative and positive impacts on catchment areas.
- However, human activities seems to be negatively impacting catchment areas often compared to positively impacting them.

Body
- Negative impacts of people on catchment areas are as follows:
  (a) Removal of vegetation / plant cover
  (b) Overgrazing
  (c) Water pollution / contamination
  (d) Eutrophication
  (e) Destruction of wetlands

Removal of vegetation
- Leaves bare soil, which will be vulnerable to soil erosion (removal of soil particles by water, wind and ice from one point to another).
- Removal of vegetation will decrease infiltration of water after rainfalls, thus that will increase surface runoff.
- Surface runoff will erode soil particles and transport

- Soil particles greded to the river will affect water quality* and @ water quantity* in the river.

Overgrazing

- Occurs when grass is intensively grazed for long period of time without enough recovery period
- Overgrazing results to removal of some vegetation or plant cover then that leads to erosion of soil particles since soil is left bare or uncovered.
- Overgrazing reduces native lindigineous plants in an area and leaves uncovered patches of soils that may be invaded by alien invasive species.
- Then alien invesive species will consume a lot of water that will negatively impact water quantity on the catchments
- Cattle trampling will also compact soil then they will cover infiltration rate and increase surface runoff.

Water pollution

It is caused by human activities such as dumping rubbish (plastics) that will contaminate water in water catchments and affect aquatic

Another human activity that will contaminate w determing particular rituals such as slaughter ats and burning candles and dumping them in river

Eutrophication

- Occurs when chemicals such as fertilisers and pesticides are washed and deposited to the catchment
- This deposition of these chemicals will encourage growth of algae and other plants in the catchment / River
- Plant will compete for space and oxygen till oxygen levels decrease in the river and some aquatic species such as fishes will die and decline in abundance.

Destruction of wetlands

- Wetlands store and filter water to clean it.
- Water passes through a number of wetland systems before reaching catchments and dams
- Wetlands are destructed by overgrazing, pollution, road building, drained for pastures and crops.
- Destruction of wetlands negatively impact both water quality and quantity within the wetland and in the catchments.

Positive impacts of people on catchment areas

~~as follows~~

~~(a) Dam building~~

~~(b) Removal of alien invasive species~~

~~(c) Construction of stone packs~~

~~Dam~~

Dam building

~~helps to~~ store water to be supplied to people domestic use since South African rainfall is liable and irregular.

~~y~~ are a good strategy to prevent flooding in the

catchment areas.
- Dams are also used to produce Hydroelectricity which ensures good and sustainable supply of electricity.

Removal of alien invasive species

- This increases water quantity in the catchments by lowering the amount of water consumed by these species.

Construction of stone packs

- Stone packs prevent soil erosion, thus lowers the amount of soil particles eroded to the streams.
- This will improve water quality and water quantity in the catchments river.

Dear Principal

I am writing this letter to ask for permission to take Grade 12 learners on a field trip that will take place on 20 August 2016. The fieldtrip will take place down near the river and it will start at 12:00 and finish at 15:00. The aim of conducting this fieldtrip is to teach learners about the **importance of managing catchment areas**. My university tutor will also observe this lesson on fieldtrip. I would be glad if my request is accepted.

Yours faithful

Geography Grade 12 lesson

The importance of managing catchment areas

Introduction

- Catchment areas are the supporting system for millions of people
- Catchment areas are important and thus they require appropriate management

Body

Why catchment areas are important?

- Supply water for agricultural, industrial, domestic and recreational purposes
  - * Rivers form important source of water
  - * Dams helps to store water since South African rainfall is low and unreliable
  - * Dams also prevent flooding effects on catchment areas

- Promote eco-tourism

Eco-tourism is the responsible travel to natural areas that conserves the environment and sustains or even improves the well-being of local people

Eco-tourism is important because it improves the life lives of local people and contribute to the economy of the area/country

- Provide grazing ground for cattles
  * Cattles get space to graze on and also obtain water for drinking in the rivers.
- Provide grass for making brooms and for roof thatching.
- Provide space for human settlements
  * Humans get space to build their houses in the catchment areas
  * They also get space to practice agricultural activities, especially on flood plains, which contain fertile soil.

Importance of managing catchment areas

To ensure water supply even to areas having shortage of wa
To prevent or reduce flooding effects
To increase and maintain income generated by the eco-tour
To ensure provision of employment to local people by eco-tour
To protect wildlife and plants (including aquatic plant spec
To improve livelihoods from good recreation and getting
To increase or improve agricultural activities, which
also improve food production

Catchment and River Management (CRM) Fieldtrip

Date: 20 August 2016

Geography Grade 12

The importance of managing catchment areas

Duration: 12:00 – 15:00

- **Catchment areas** are life-supporting system for millions of people.
- Catchment areas require appropriate management.

Catchment areas are important to:

- Supply water for agricultural, industrial, domestic and recreational purposes.
- Promote Eco-tourism
- Provide grazing camps for cattles.
- Provide space for human settlements.

1. Why do you think it is important to manage catchment areas? **5 marks**

2. How does management of catchment areas ensure water quality and water quantity? **5 marks**

3. How does effective management of catchment areas reduce floods on catchment areas? **5 marks**

- Destruction of wetlands

Positive impacts of people on catchment areas:

- Dam building
- Removal of alien invasive species
- Construction of stone packs

How do the following positively impact catchment areas:

Dam building

Removal of alien invasive species

Construction of stone packs

Impacts of people on Drainage basins and catchment areas

Date: 20 August 2016

Time: 3 hrs

Marks: 30 marks

- *The purpose of this field trip is to teach about the impacts of people on drainage basins and catchment areas.*
- *Goals/Objectives:*

-learners must be able to understand negative and positive impacts of people on Drainage basins and catchment areas.

-learners must also understand the consequences associated with the impacts on the landscape and also to the people downstream.

- *Safety measures :*

-Learners must be aware of the dogs that we may come across as rabies is a deadly disease.

-Learners must make sure that they do not kill any creature that we may come across in the field.

-learners must make sure that they walk in groups and follow the orders of the teacher, when we have to cross the roads or move to different sites.

- **The negative impacts of people on drainage basins and catchment areas.**

-Removal of vegetation (for building houses, roads, schools, etc.)

-Overgrazing

-Pollution (Land and Water)

-Urbanization

-Wetland destruction

-Eutrophication

- **The positive impact on drainage basins and catchment areas.**

-Construction of dams

-Stone packing and gabion baskets

-Removal of alien plants along the river (working for water programmes)

1. **Removal of vegetation**

- Give at least three reasons that lead to the removal of vegetation. (3)

1.2 What are the possible consequences of the removal of vegetation on drainage basins and catchment areas? Consider consequences on land as well as on rivers. (5)

1.3 What effect does siltation of dams have on the water quantity of the people downstream/ downlands? (2)

2. Overgrazing

2.1 Discuss the consequences that are a result of overgrazing on catchment area and drainage basin (5)

3. Pollution (Land and Water)

3.1. Discuss the effect of pollution on land as well as on aquatic ecosystems (4)

3.2 Name two diseases on humans that are caused by drinking polluted water (2)

4. Urbanization

4.1 Explain how urbanization impact on drainage basins and catchment areas (3)

Impacts of people on Drainage basins and catchment areas (Memorandum)

Date: 20 August 2016

Time: 3 hrs.

Marks: 30 marks

- The purpose of this field trip is to teach about the impacts of people on drainage basins and catchment areas.

- **Goals/Objectives:**

-learners must be able to understand negative and positive impacts of people on Drainage basins and catchment areas.

-learners must also understand the consequences associated with the impacts on the landscape and also to the people downstream.

- ***Safety measures :***

-Learners must be aware of the dogs that we may come across as rabies is a deadly disease.

-Learners must make sure that they do not kill any creature that we may come across in the field.

-learners must make sure that they walk in groups and follow the orders of the teacher, when we have to cross the roads or move to different sites.

quality and quantity
* Reduced water quantity effect many people downstream

3 What effect does siltation of dams have on the water quantity of the people downstream/ downstreams? (2)

Siltation of dams will lead to the reduction of water quality for the people that are further downstream

2. Overgrazing

2.1 Discuss the consequences that are a result of overgrazing on catchment area and drainage basin(5)

* Reduction in biomass cover/grass (loss of Palatable species)
* The land become vulnerable to soil erosion
* Land degradation is likely to occur
* Alien plants can get opportunities to be established on the degraded land
* Cattle die because of the shortage of Palatable grasses

3. Pollution (Land and Water)

- **The negative impacts of people on drainage basins and catchment areas.**

-Removal of vegetation (for building houses, roads, schools, etc.)

-Overgrazing

-Pollution (Land and Water)

-Urbanization

-Wetland destruction

-Eutrophication

- **The positive impact on drainage basins and catchment areas.**

-Construction of dams

-Stone packing and gabion baskets

-Removal of alien plants along the river (working for water programmes)

1. Removal of vegetation

- Give at least three reasons that lead to the removal of vegetation. (3)

deforestation for fire wood,
for agricultural purposes
for building houses
for infrastructure developments such as roads, schools, clinics

1.2 What are the possible consequences of the removal of vegetation on drainage basins and catchment areas? Consider consequences on land as well as on rivers. (5)

* increased surface run-off leading to risk of flooding
* disturbed areas lead to alien invasive plant impacting the land
* Dam silitation due to increased soil erosion
* Aquatic ecosystems are degraded due to reduced water

3.1. Discuss the effect of pollution on land as well as on aquatic ecosystems (4)

* Reduction of Soil Fertility
* degradation of land
* waste products get into the river and reduce oxygen levels in the water.
* Aquatic ecosystems are destroyed by the reduction of oxygen levels and mechanical injuries from solid waste

3.2 Name two diseases on humans that are caused by drinking polluted water (2)

* diarrhoea
* Cholera
The disease affect mostly people down stream

4. Urbanization

4.1 Explain how urbanization impact on drainage basins and catchment areas (3)

*Concrete surfaces reduce the rate of infiltration this lead to the increased risk of flooding during heavy rainfalls, all waste products that are thrown by people get collected along with water down to our rivers.

5. Eutrophication

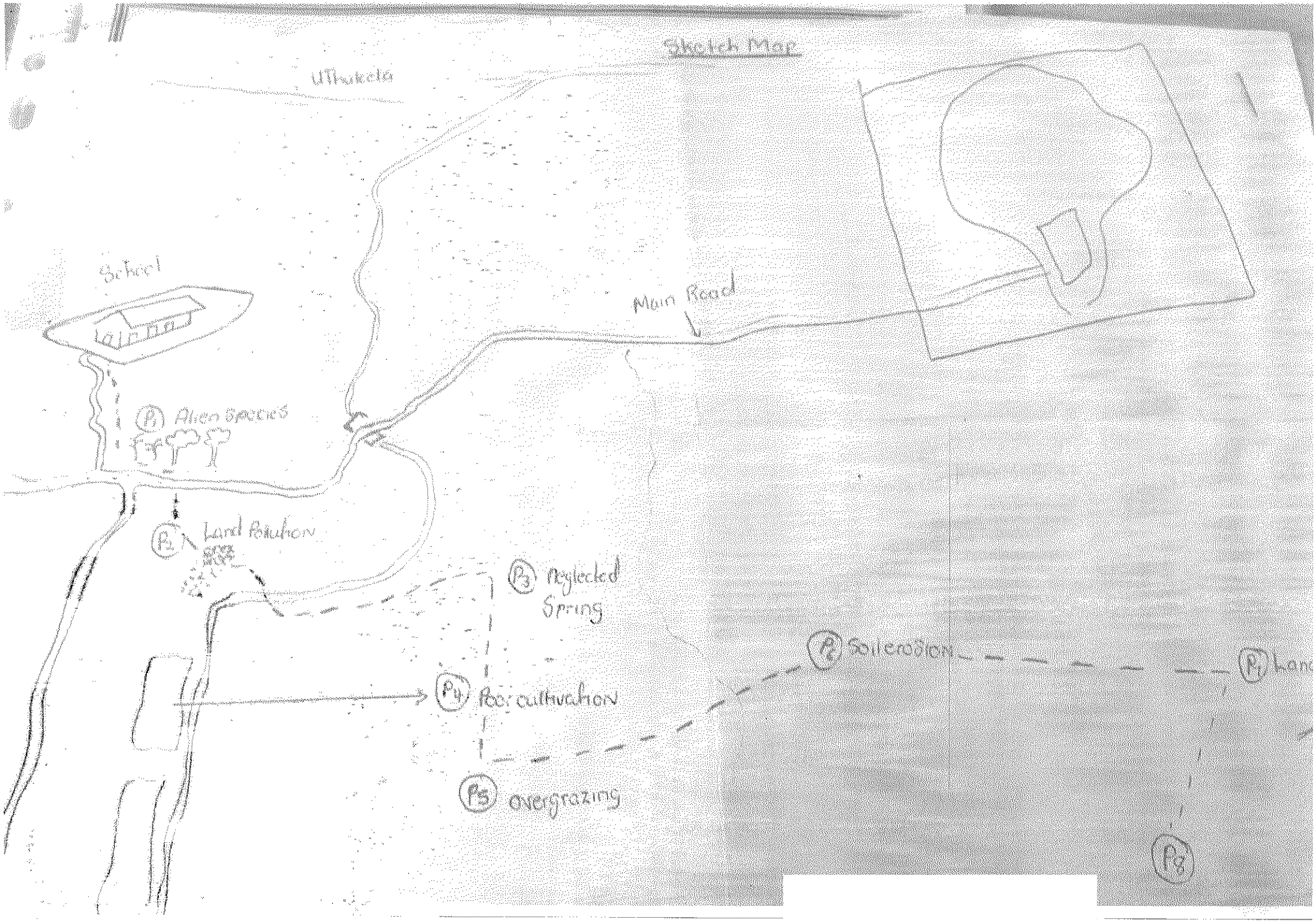
Explain the concept of Eutrophication and how does it affect the aquatic ecosystems (4)

*Eutrophication refers to the washing away of fertilizers, pesticides, insecticides and chemicals from agricultural activities to our water bodies in the rivers.
* This cause reduction to oxygen levels and the algae

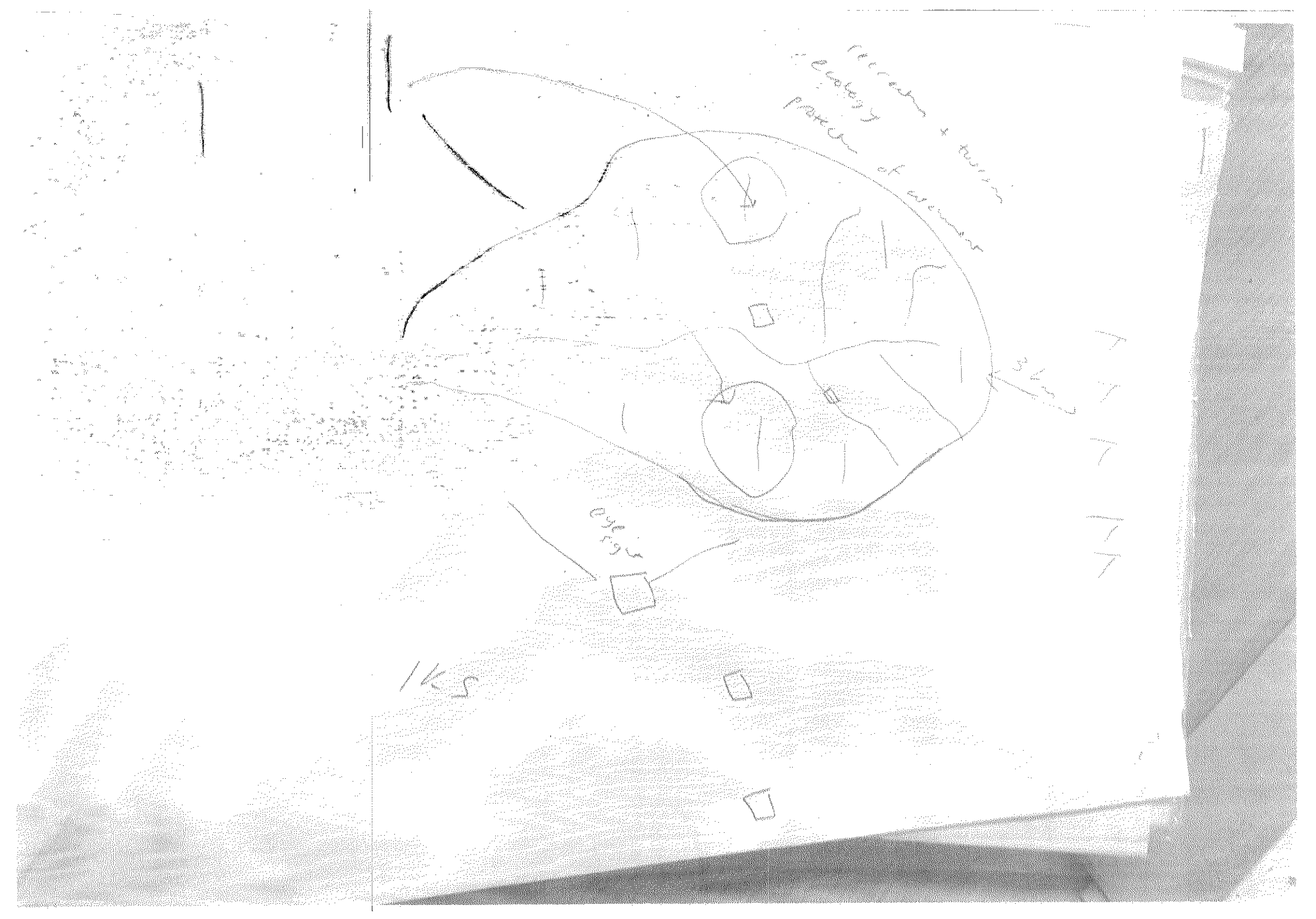
grow extremely, this lead to destruction of aquatic ecosystems (fishes, Amphibians and aquatic birds.

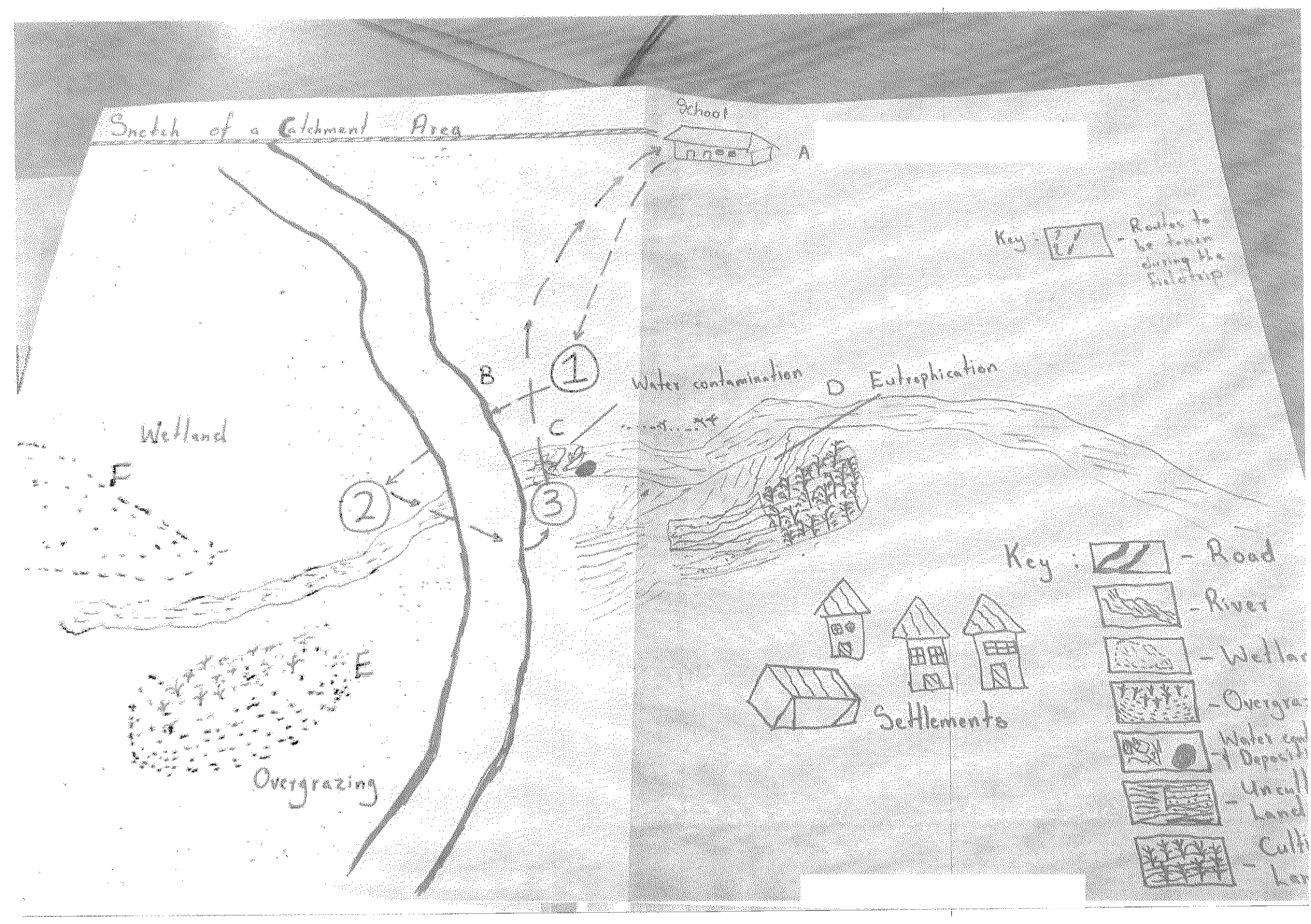
6. **What are the positive impacts that people have on drainage basins and catchment areas? (2)**

*building of dams and water transfer schemes
* Removal of alien invasive plants (working for water programmes)
* Stone packing and building of gibion baskets


Sketch Map
uThukela
School
Main Road
P1 Alien species
P2 Land Pollution
P3 Neglected Spring
P4 Poor cultivation
P5 overgrazing
P2 Soil erosion
P1 Lan
P8

The sketch map




Sketch of a Catchment Area
School
A
B
C
1
2
3
Wetland
F
E
Overgrazing
Water contamination
D Eutrophication
Key - Routes to be taken during the fieldtrip
Key : - Road
- River
- Wetlan
- Overgra
Water
Depos
Unsuit
Land
Cult
Lan
Settlements

LESSON PLAN

Subject:	Geography	Grade:	12
Date:	26 Apr '16	Duration:	35 min
Content:	Catchment and River Management		
Sub-topic:	Catchment management strategy		
Lesson objectives:	learners will learn how to overcome problems associated with catchment of upper reaches		
Materials:	Textbook, Worksheet, the daily news and charts		

	Teacher activity (with time)	Learner activity (with time)
Introduction	Explain what is a strategy. Explain what is a CMS Link it with the previous lesson	ask questions discuss
Body	Explain CMS in a simple scale level Explain how to use Physical Qualities (Construction, Zoning Improvement controls and development in catchment	ask questions discuss

Assessment	Open small group discussion about how to overcome local issues related to water and catchment as a whole	discuss
Reflection	The lesson went well learners knew how to overcome local issues such as pollution and macro issues that affect the the attitude to catchment	

Name of teacher:

Sign:

Date: 26/08/16

Mentor: _____

Sign: _____

Date: _____

SERIES OF LECTURES ON CATCHMENT AND RIVER MANAGEMENT

1. Introduction to catchment and river management, and participatory integrated water management (13 May 2016)

The regular Postgraduate Certificate in Education lectures had ended for the first semester and both lecturer and students were available to attend these extra lectures. To introduce this section, I went through the key lessons of the first phase of research, namely the curriculum analysis:

1. That there are notable differences between educational policy and the implementation thereof in KwaZulu-Natal, especially regarding physical geography. The teaching of especially physical geography needs major motivation, quality control and encouragement to ensure discipline integrity.
2. That catchment and river management teaching will have to lead towards teachers being retrained especially in regards to the teaching of the "importance of managing drainage basins and catchment areas" (Department of Basic Education, 2011, p. 43), given that there has been blurring and some confusion in previous curricula. In addition, most catchment management agencies are not yet operational, despite many years in the making.
3. That the inclusion of teaching catchment management agencies' catchment management strategies may be seen as putting the cart before the horse, given that not one catchment management strategy is presently operational.
4. That the necessary teaching of fieldwork is going to have require significant resourcing of schools, so as to teach physical geography and catchment and river management adequately.

I also informed the student of the key catchment and river management knowledge in the CAPS curriculum. The three key subtopics to be taught were:

Catchment and River Management (3hrs) (Under Geomorphology, Gr 12 in Term 1)

- *Importance of managing drainage basins and catchment areas;*
- *Impact of people on drainage basins and catchment areas;*
- *Case study of one catchment area management strategy in South Africa* (Department of Basic Education, 2011, p. 43).

Students were informed (orally and in writing) of the following critical information to teach:

1. Teach the importance of catchment and river management; this will comprise, *inter alia*, the importance of watershed or catchment basin management (including drainage basins). You will have to consider upstream and downstream, uplanders and downlanders, economic activities along the river (traditional economic arteries), and many other issues.
2. Teach whatever impact or impacts people have on these areal units. Are the effects good or bad, sustainable or unsustainable? Should people be completely banned from catchment areas, or do the authorities have to work with them?
3. What is a case study? What is a catchment area management strategy? Does the latter even exist yet? How do we teach the strategy, using a case study approach?

Having dealt with the preliminaries the following lecture was given. I took the effort to explain the geographical context of the information throughout.

There is a growing body of research into watershed or catchment management worldwide but most is European- or North American-centred, with some interesting research coming out of Asia, especially the foothills of the Himalaya (Hamilton and Bruijnzeel, 1997; Bandyopadhyay et al., 1997; Hamilton and McMillan, 2004; Achet and Fleming, 2006). Recently the Dushanbe Forum of Mountain Countries in Asia (Mountain Partnership, 2105) has reiterated the importance of integrated water management. South Africa too has an emerging tradition of IWRM with most such research being supported by the Water Research Commission and by new policy developments that established participatory structures for integrated catchment management under the National Water Act of 1998 (Lotz-Sisitka & Burt, 2006).

Catchment management has been earmarked as the most important method of land management (World Meteorological Organisation, 1994; Bandyopadhyay et al., 1997; Easter and Dixon, 1986; Davies and Day, 1998) and a number of models of catchment management have been identified in the literature, and these have relevance to this study, in particular with the systems thinking and complexity theory imperatives (Gregersen et al., 1988; Hufschmidt, 1986; Falkenmark, 2004; Ives et al., 1997). Easter and Dixon (1986) maintain that water management cannot be undertaken successfully without a commitment to interdisciplinarity, a trend that is also observable in South African water sciences (Rogers et al., 2000). Catchment and river management practices inherently contain a need for interdisciplinary

fieldwork techniques and the development of sustainability competencies which emerge in and through engagement with the complex social-ecological systems thinking necessary for catchment management (Wiek et al., 2011, Project WET Foundation, 2014; UNESCO, 2010; Rogers et al. 2000). This has implications for pedagogy, which I discuss in more detail below.

Watershed or catchment management is also one of the cornerstones of the new science of Montology, a body of work that is not well known in South Africa. Mountains belong in the peripheral areas of South Africa, and knowledge and techniques to manage them are not well known, or ignored. The significance of this is that mountains form the upper reaches of all catchments, and are therefore a key feature of catchment management.

Catchment and River Management Models

Hufschmidt (1986) conceptualized a "generalized watershed management system in physical output terms" which would show the very intricate man/ environment interface required in the system (the "natural inputs and management inputs, the watershed management system and natural systems effects, and outputs") (Hamilton and Bruijnzeel, 1997, 345). It is thus crucial to understand CRM as a system, with inputs, the body of the system itself, and outputs. Human agency is incredibly important to CRM- the management inputs have to be wise and judicious, and the watershed management system sustainable to both human and natural actors.

"Watershed management as a process involving separate but closely linked stages of planning and implementation; watershed management as a planned system of management measures and implementation tools applied to a watershed through a set of institutional and organisational arrangements; (and) watershed management as a set of linked activities for which specific management tasks are involved" (Hufschmidt, 1986, p.17).

The second deserves further explanation: watershed management is seen as "a planned system of (1) *resource management* actions including land uses, on-site resource utilizations and management practices; (2) *implementation tools* for putting management measures into effect through public and private actors; and (3) a set of *institutional and organizational arrangements* within which implementation proceeds (Figure 2.2, p.19)".

Hufschmidt's generalised watershed management (WM) system in physical output terms is worth elaborating upon (I ensured the diagram of the model was explicated to the students):

1. Natural inputs (land and water resources, climate) feed into, and indeed create the system.
2. Then the management input (from humans) also affects the system. This includes "labor, materials, energy, equipment, and management skills for planning, design, installation, operation, and maintenance."
3. Both inputs affect the watershed maintenance system which comprises a) resource management actions, b) implementation tools, c) institutional and organizational arrangements.
4. This creates natural systems (NS) effects, both on-site and off-site. On-site include "changes in the state of the system as a result of mass wasting, soil and nutrient losses, and changes in water-yielding capacity". Off-site include "changes in time pattern of streamflows and ground-water flows; channel and reservoir sedimentation, channel degradation; water quality."
5. The water management system and natural systems effects together create outputs which include "agricultural crops, forest products, livestock products, minerals, fish, recreation, and water." (p. 22).

Regarding how to "do" watershed management, Hufschmidt (1986) proposes three major activities of water management, under three panels (Table 2.1, p.24):

The first panel comprises dividing the watershed into major land uses such as "agriculture (irrigated and rain-fed); grazing; horticulture; agroforestry; forestry (commercial, mixed use, preservation); mining; transportation; urban; lakes, reservoirs, streams, channels, and wetlands."

His second panel involves developing a "set of resource utilization and management practices for each operating unit within each major land use" using three major categories ("irrigated agriculture, commercial forestry, and agroforestry"). Under irrigated agriculture, this involves "types of crops; rotation of crops; quantity and timing of water, fertilizer, pesticides, labor, animal power, and machinery inputs; methods of tilling (e.g. contour ploughing); methods of application of water, fertilizer, and pesticides; installation and maintenance of buffer strips, grassed waterways, terraces, and on-farm check dams." Regarding commercial forestry, this includes "types of tree species; rotation and spatial distribution of tree crops; quantity and timing of inputs; methods of tree planting, thinning, and fertilizing; (and) harvesting methods, erosion control practice, road siting,

construction and maintenance." Lastly, under agroforestry, this involves "types, spatial distribution, and rotation of tree and row crops; quantity and timing of resource inputs; methods of application of water, fertilizers, and pesticides; installation and maintenance of erosion control measures and road siting, construction and maintenance."

The third panel is about developing "a set of downstream management practices" which involve the following: "stream bank protection by reserve buffer strips, revegetation, and riprapping; debris removal; channel dredging; harbour, estuary dredging; treatment of intake water; wastewater treatment; check dams" (Hufschmidt, 1986, p. 24).

As can be seen from the tables, water management is a pure science, with skills and competencies required by differently skilled people at different times, all acting in unison and synergy. This calls for properly educated people driving the process. Interestingly, under Table 2.2 (Examples of watershed management tasks required at the planning stage, classified by management activities and management system elements), "planning for education" is specified under "implementation tools" for all three major management activities ("land-use assignments; on-site resource utilization and management practices; (and) off-site management practices") (Hufschmidt, 1986, p. 27).

Proper catchment and river management can be a long process- the Mae Chaem Watershed Development Project (northeastern Thailand) was preceded by seven years of planning (Hufschmidt, 1986, p.19).

This diagram (Land use and physical linkages within a watershed) illustrates the following changes from land use decisions within a watershed (upstream to downstream respectively): reforestation (water yield decrease, water quality increase); fuelwood cutting, deforestation (water yield increase); improper cultivation and overgrazing (productivity decrease, erosion increase); roads, mining, (erosion increase, sediment increase); reservoir storage (decrease), hydropower (questionable change); irrigation (decrease); irrigation return flow (decrease); water yield (increase/ decrease), water quality (questionable change) (Figure 1.2, Gregersen et al., 1988). This shows how carefully human-induced change must be (especially the damaging effects of roads and primary economic activities), and that deforestation and fuelwood cutting are critical to increasing water yield, the most important product from a watershed or catchment (as shown from the ground-breaking Cathedral Peak, Drakensberg experiments in the 1950s).

This very important diagram (Social, institutional and economic linkages in a watershed) shows socio-economic factors (from upstream to downstream) and the resultant consequences (increase, decrease, questionable change), and institutions (from upstream down to downstream) operating within a watershed. The former comprises shifting cultivation (population increase, productivity decrease, income questionable change); deforestation (fuelwood increase); goods and services (flows between them and deforestation), settlements around reservoirs (flows between them, and goods and services); migration (flows back and forth around settlements); fisheries (income questionable change); lowland cultivators (income questionable change); urban centres (employment questionable change). The latter comprises forestry agencies, community-owned lands; agencies (hydropower, irrigation, flood control); private landowners; city governments) (Figure 1.3, Gregersen et al., 1988).

"In the catchment, the challenge is to find a proper science-based balance between land use and water and between man and ecosystems" (Falkenmark, 2004, p. 277, Figure 1). Green (water that infiltrates the soil) and blue water flows (natural runoff minus environmental flow requirements) have thus to be understood. This was a critical concept that the students appeared to understand.

Catchment and river management also has an economic imperative- "investing in land management becomes a water augmentation and an economic development intervention" (MDTP, 2007, p. 100). I explained to the students a brief history of catchment management attuned to economic development, from the Tennessee Valley Authority of the 1930s in the United States of America.

Rivers, which have been historically used to divide regions, provinces and even countries, are contentious instruments of division between regions or administrative areas, as both banks share the river and have an equal stake in it. Rather it is the watershed between the river basins that makes more sense for regional planning. Watershed management also includes the continuum concept where the upstream and downstream, and the wilderness to the urban, or the ecocentric to the anthropocentric (Shroyer and Blignaut, 2001) are integrated. This is also the basis of "socio-ecological zoning" (Blignaut 2000), which is integral to proper catchment basin and river management. This means that the riparian zone is fully protected (the core area), with a buffer area alongside (where mutually complementary activities are

allowed), to a transition area abutting the buffer zone, where activities of more impact area allowed. The intention is to absolutely protect the key ecological artery or channel, the river and its banks

Bandyopadhyay et al. write about the usefulness of "watershed assessments" and go on to write about the increasing currency, as in 1997, of watershed management including at the World Bank (Bandyopadhyay et al., 1997, p. 150). In their very influential article, Hamilton and Bruijnzeel posit eleven reasons for watershed management (Hamilton and Bruijnzeel, 1997, pp. 340-341). This has also been affirmed by Hamilton and Bruijnzeel (1997) where they write that "watersheds provide a viable framework for approaching sustainable development" (Hamilton and Bruijnzeel, 1997, p. 366).

Bandyopadhyay et al. (1997) furthermore write about France and Spain using river basins "as the basic unit of analysing water resource administration" (Bandyopadhyay et al., 1997, p.147). They write that in this way integrated and continuous system management can take place. Körner et al. (2006, p.17) point out the effects of particular land uses in highland areas on the "forelands". The concept that the correct protection of water resources should be rewarded can be seen in Bandyopadhyay et al. (1997) where they write that "reinvestment of some of that value in the lands that generated the water is a rational means of maintaining the water wealth of the highlands" (Bandyopadhyay et al., 1997, p.153). This is also reflected in Hamilton and McMillan (2004) where they write about "water rights, values and markets" (Hamilton and McMillan, 2004, p.38). Interestingly Quito City (in Bolivia) gives a payment to the Condor BioReserve for high quality water (Hamilton and McMillan, 2004, p.38). Hamilton and Bruijnzeel (1997) write that "*high quality water is not a free resource* and this must be acknowledged" (Hamilton and Bruijnzeel, 1997, pp. 365-366). Thus, there is precedent for reciprocal rights and rewards for transfer.

It is not just through payment for water supply that more benefit can be accrued from the correct utilization of that precious resource. Inversin (1986) has graphically illustrated the installation of micro-hydropower (Schweizer and Preiser, 1997, p. 162). This installation is reasonably environmentally-friendly and modest, and is being used in developing countries in Asia. One can furthermore contend that the benefits that could be accrued from the environmentally astute placing of a number of sites down selected Drakensberg rivers, in the buffer or transition zones, would outweigh their costs (both financial and environmental).

The Western Cape Government specifically prohibits development in mountainous areas and steep slopes. Criteria such as erosion potential and stability, and water resources (e.g. presence of springs, river catchment area), cumulative environmental impacts are used to forestall unwise and environmentally-damaging development (Western Cape DECAS, 2002, p. 9).

"4. a. Development on steep slopes (i.e. steeper than 1:4) will be strongly discouraged as such areas are subject to erosion and instability; b. development on the crest of a mountain, hill or ridge will be strongly discouraged; development in an area, which has been declared a mountain catchment area in terms of the Mountain Catchment Areas Act, Act 63 of 1970 will be strongly discouraged. c. Development in locations on mountains, hills or ridges that serve as a source of water (e.g. spring, seep, river or stream source) will be strongly discouraged" (pp. 9 and 10). The Mountain Catchment Areas Act is still law and acts as very influential legislation regarding mountainous areas.

National law in South Africa also prohibits unwise and unsustainable development, and enshrines the preventative principle. According to the National Environmental Management Act (South Africa, 1998) [section 2 (4) (a) (viii)], "…negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimized and remedied." Proper and sustainable environmental management is stipulated thus: [section 2 (4) (r)], "Sensitive, vulnerable, highly dynamic or stressed ecosystems…require specific attention in management and planning procedures, especially when they are subject to significant human resource usage and development pressure."

In addition, Hamilton and Bruijnzeel (1997, p. 365) call for "cumulative impact analysis" and "undisturbed, or largely undisturbed, *riparian buffer zones"*. Rivers flow through traditional zoning schemes and there is much merit for treating the river as a continuous system, with a riparian zone alongside its banks.

As educators and graduates, we cannot forget that catchment and river management is intricately tied up with ethical conduct. Both humanity and the environment have to be protected ethically. "Catchment management oriented to sustainability has to be based on ethical principles: human rights, international conventions, sustaining crucial ecological goods and services, and protecting ecosystem resilience, all of which have water linkages" (Falkenmark and Folke, 2002, p.1).

There are also deeply held beliefs regarding catchment and river management, and these have to be understood. Care should be taken to ascertain whether or not indigenous knowledge systems (IKS) have a role to play in understanding catchment and river management. "Belief networks explicitly recognise the complexity of environmental systems and allow consideration of all key system variables together with their impacts on the environment. Importantly, this can be done in a descriptive manner which supports stakeholder participation and provides the potential to help resolve conflicts between stakeholder groups. As such, they provide a means by which comprehensive environmental plans can be developed dynamically so that they might realistically be expected to contribute to better management of natural resources" (Cain et al., 1999, p. 132).

Participatory Integrated Water Management (PIWM)

The South African Department of Water Affairs and Forestry's definition of integrated water resource management is "a philosophy, a process and a management strategy to achieve sustainable use of resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits" (DWAF, 1998) (Schulze, 2007, p.270). Here the term "all stakeholders" is key, and has both related constraints and opportunities in a differentiated and fractured society as South Africa.

However, integrated catchment management, ICM, is defined by UNESCO (1993) as "the process of formulating and implementing a course of action involving natural and human resources in a catchment, taking into account social, economic, political and institutional factors operating within the catchment and the surrounding river basins to achieve specific social objectives" (Schulze, 2007, pp. 270-271). In this definition, taking into account is the key phrase, to be undertaken by trained professionals. "Stakeholders" are not specified in this definition, only a course of action. However, the "course of action" still has to take a number of factors into consideration to achieve "social objectives."

As Hurni (1997, p. 212) writes, "For whom will SLM (sustainable land management) be realised, for what, by what means, and with what impact?"

The theory and key concern of participatory planning groups has therefore to be included. In Hurni's model (Intervention levels and activities in sustainable mountain development and resource management, Figure 19.4), he lists "participatory watershed management" as an activity (and intervention) to occur between the national and community levels (Ives et al., 1997, p. 461). This is what the post- Apartheid South African government has stated must happen between national policy and community implementation. However, there are bound to be issues in the implementation of sound policy, which has happened in innumerable spheres since the inception of democracy in 1994.

Achet and Fleming (2006) have devised an integrated watershed management framework, which has been "devised as an eight-step flowchart that embodied three checklists for watershed processes, participation and program planning analysis…." (Achet and Fleming 2006, pp. 691-692). This is where integrated water resource management planning translates into key lessons applicable to other watersheds and countries.

The authors devised a program area entitled 'Promoting Integrated Watershed development and alternative livelihood opportunities', whereby a framework was established for linking:

(1) The development of appropriate land-use planning and management for both arable and non-arable land in mountain-fed watershed areas to prevent soil erosion, increase biomass production and maintain the ecological balance;
(2) The promotion of alternative income-generating activities, such as sustainable tourism, fisheries and environmentally-sound mining;
(3) The improvement of infrastructure and social services in mountain areas, to protect the livelihoods of local communities and indigenous people; and
(4) The mitigation of effects of natural disasters related to watershed mismanagement through hazard-prevention measures, risk zoning, early-warning systems, evacuation plans, and emergency supplies" (Achet and Fleming, 2006, p. 679).

The parallels between these points and those in Hufschmidt (1986) and Gregersen et al. (1988) (in respect of catchment and river management) are evident.

Key principles were formulated by Achet and Fleming (2006, p. 686). "Based on the main lessons learned from watershed management experience in Nepal…the following operational principles can be applied in future program planning and implementation:

(1) managing watersheds based on a 10-25km² subwatershed as a management unit;

(2) building on local users groups' experience on successful participatory watershed management;
(3) a gradual shift from government management to facilitated local empowerment;
(4) management of both public and private land based on community consensus;
(5) supporting local user groups in preparing local conservation plans; and
(6) Institutionalizing watershed planning and local user groups' mobilization as a one-step procedure."

The 10-25km² subwatershed approximates the quinary catchments that comprised the study areas (V11A and V11C, appendix six).

These six steps show the importance of scale (i.e. sub watershed dimensions), building on existing success, successful public and private land management, local empowerment and conservation, and simplifying and unifying procedure.

Achet and Fleming (2006, p.692) further explain, that by "using a procedural IWMF approach, the confirmatory evidence on an ecosystem-based approach and local participatory adaptive watershed management, practice-based project evaluations could be applied to suit a local context throughout the developing world as well". Here it can be seen that Achet and Fleming's advice ties in with the central ideas of adaptive management, participatory IWRM and socio-ecological systems; and that the key lessons are transferable to the rest of the developing world.

The key issues of planning, and identification of stakeholders are to be prioritised. "More *planning* should be done on a watershed basis and , where necessary, existing groups, power structures, organizations, and management units should be identified as most likely candidates of *implementation*, and be involved in the action" (Hamilton and Bruijnzeel, 1997, p.341). It is thus evident that a lot of thought has to go into the identification and placement of key and existing people and organisations/ agencies to be involved in implementation. It cannot be a case of a *laissez faire* approach towards stakeholders but that a proper and inclusive identification process to ensure success must be implemented. Dani and Campbell (1986) state that watershed management projects must "*…build on upland residents' existing motivations* for sustaining their upland environments through increasing the value, renewability, security, manageability, and equity of resources" (Hamilton and Bruijnzeel, 1997, p. 365). If the uplanders lose out, the downlanders and downstreamers will surely lose out too. If upland residents were adequately compensated for looking after their nationally

important treasure i.e. clean water, motivation (in the form of payment) would already be a key factor. It has been identified that there is a need for bottom up development in mountainous areas. Hamilton and Bruijnzeel (1997, pp. 363-364) have reflected the work of Rao (1988) who shows the "process by which the rural poor are able to organize themselves…" Rao writes of the Asian context that bears some similarities, but also differences, with the South African one.

Under lessons learned regarding participatory integrated water management (Easter and Dixon, 1986, pp. 224-226), six major components are listed (interdisciplinary work, participation, external policies, politics, economic analysis, and people). All these lessons (the dimensions of interdisciplinarity and participation, and proper socio-economic-political structures required) need to be understood and proper analysis done of all six components before successful participatory integrated water management is undertaken. If just one is not properly researched and implemented, a project could fail. The approach (and solution) outlined by Easter and Dixon (1986, p. 227) "stresses people and the political-social-economic-institutional dimension as much as the biophysical." The 'lesson' (from a developing country/ country' context in Asia and the Pacific) bears remarkable resemblance to the situation in South Africa regarding uplander participation, "…the upland farmers are usually suspicious of government programs and people from outside" organization" (ibid, p.225). Regarding external policies, tiers and level of government have to act in synergy, not at cross-purposes for participatory integrated water management to succeed, as the authors say, "carefully designed plans for watershed management can be disrupted by other economic and farm policies…" (ibid, p.225). "Political factors, as an extension of the socio-cultural situation…, are more frequently a source of problems for watershed management than the solution. The upland-lowland, centre-periphery feelings…are commonly manifested in political actions. To counteract this top-down tendency it is necessary to educate political leaders at the center of the intimate interactions among government policies, private land-use decisions, and physical effects" (ibid, p.226). Here, this comment is pertinent as the study area is at least 200km from the centre of political power (Pietermaritzburg), and it has always been a peripheral area, both under colonialism/ Apartheid and still now. People consuming water in the Durban functional region rarely have any idea of where their water precisely comes from, nor of who the people are who live in mountainous areas.

The importance of economic analysis (sound and scientific) is given in the following quote: "If watershed management is seen as serving two goals-decreased soil erosion and reduced negative, downstream physical effects as well as improved economic and social well-being for watershed inhabitants- economic analysis is imperative for analysing alternative management options" (ibid, p.226). Payment for Ecosystem Services (PES) is a management option that has been studied, and will have to be considered strongly to introduce incentives to safeguard the quality and quantity of water emanating from the upland areas. "Due to the high value of the water resource supplied from the Maloti Drakensberg, and the growing scarcity of water in South Africa, there is an emerging need to incentivise mountain catchment management by paying mountain communities to supply ecosystem services, and in particular, water related services" (MDTP, 2007, p. 95). The *MDTP News* (2008, pp. 6 and 7) shows a model for payment for ecosystem services.

Regarding the people in the watershed, Easter and Dixon (1986, p.226) write that "people do count and are part of the solution as much as they are part of the problem…watershed management…has to work with people as much as, or even more than, with trees and soil. People use their resources to meet felt needs, and these needs have to be understood to develop reasonable, realistic management options." With water set to gain increasing currency in the future, the people living in these vitally important catchments cannot just be ignored, as in the past. In a very real sense, they act as guardians and custodians of what is set to become the country's most vital resource: water.

The complexity of integrated water resource management is further complicated and nuanced by micro- and macro- levels of scale. People running or managing catchment areas have to aware of the intricacies and levels of scale, of which there are many. "Catchment processes take place across a range of spatial and temporal scales, as do land use practices, socio-economic processes and levels of governance. The scale at which waterrelated integrated management should take place is, therefore, not one with a straightforward answer (Frost, 2001). As a general statement, however, experience in southern Africa shows that the appropriate temporal and spatial scales of operation in integrated water resource management are those scales at which the policy makers, catchment managers and stakeholders of an integrated water resource management plan believe that they can achieve their set(s) of objectives, depending on the problem(s) at hand (Schulze, 1999; Frost, 2001)" (Schulze, 2007, pp. 273). Therefore, according to this quote, the understanding of these temporal and

spatial scales is absolutely critical to the success or otherwise of participatory integrated water management. It is clear then that only trained ecologists, hydrologists and regional planners (all who have an excellent understanding of physical geography, in particular geomorphology, hydrology and climatology) should have a leading role in the decision-making capacity of integrated water resource management processes. This level of understanding (and necessary expertise) is further underscored by the following quote: "IWRM has to take cognisance of all, or some, of global scale issues (e.g. water conventions, climate change, El Niño-Southern Oscillation or ENSO scale events); international scale problems (e.g. international river agreements); national issues (e.g. national water management agendas); catchment scale issues; local government scale initiatives; community scale issues; and in poorer countries also household scale problems (which there may include household food security and/or household water poverty). Spatial scale issues in integrated water resource management often reflect the level of development" (Schulze, 2007, p.274). Thus, only people who have completed and passed a formal atmosphere science course at university will even begin to understand the intricacies and implications of El Niño-Southern Oscillation events. In fact, this course is a *sine qua non* for understanding the temporal and spatial scales of participatory integrated water management. To understand and indeed to manage these different scales (from the global to the household scale) will thus not only need people with master's degrees in physical geography to drive the process, but also graduates with 'people skills' willing to listen to, and learn from, communities and households. Here teachers and student teachers can play a critical role.

The critical and different scales at which integrated water resource management should operate, and indeed do operate, is explained thus: "A number of types of time scales are identified and need to be considered in juxtaposition with one another in IWRM (Schulze, 1999). These include *climate scales* at intra-seasonal, inter-seasonal and decadal (re. climate change) time frames, which 'drive'

- *river flow scales*, which for surface water issues range from high flow/drought "cycles" related to ENSO at multiple year scales; and the inter-seasonal variability associated with that; the seasonality and concentration of streamflows within a year; intra-annual variability; the forecastability of river flows from the near real time, through a lead time of days and up to a season ahead; and studies on extremes such as floods; on the other hand, for groundwater the temporal recharge patterns and water table fluctuations are of importance;

- *aquatic habitat time scales*, which are determined by magnitudes, variabilities, frequencies and durations of low and high flows as biological triggers, and which are highly influenced by upstream land use management as well as by in-stream reservoir management;
- *agricultural time scales*, where for crops the intra- and inter-seasonal timeframes are important whereas for forestry, inter-seasonal to decadal timeframes are of greater significance;
- *economic time scales*, ranging from longer term international to national, to regional, local and to shorter term individual rural subsistence household time scales;
- *political time scales*, which need to distinguish between essentially stable government structures vs potentially unstable government structures and inter-election time scales for national to local governance structures;
- *management and planning time scales*, often of the order of 10–20 years; and
- *wealth/development level time scales*, where wealthy countries tend to have longer term planning horizons while for poorer countries they tend to be shorter (Schulze, 1999)" (Schulze, 2007, pp. 274-275).

To manage these complications and synergies of differing and multiple scales will take highly educated hydrologists, ecologists and regional planners, as said before, to be in charge of the process, not governing body members with no appropriate education at all. It is key that widespread education initiatives, in the local vernacular and led by local experts, will be necessary to drive this message home. The necessary and delicate fusion of expertise is further underscored by this quote: "What is quite evident, in conclusion, is that for IWRM to be effective, a 'tripartite alliance' between policy-maker, stakeholder and scientist is required for IWRM to be truly 'some, for all, for ever'" (Schulze et al., 2004, p. 343).

A note of caution regarding idealistic views (particularly from the North) regarding the possibility of integrated water resource management succeeding without any impediments in deeply imperfect and undeveloped societies is expressed by Schulze (2007): "IWRM is an ideal that is difficult enough to realise and effect in developed countries with their high levels of existing infrastructural development and maintenance, high quality data, abundant levels of scientific and administrative skills down to local levels, strong mixed economics, long term planning perspectives, relatively high stakeholder involvement and their desire to pursue issues surrounding quality of life and of the environment…in many countries of the 'South',

which do not have the economic foundation and human capacity of many of the above-named attributes of the 'North', the realisation of IWRM which embodies systems, integration, management, stakeholder, participatory and sustainability approaches often appears a far-off dream…by necessity in LDCs, space scales of IWRM as well as time scales, are smaller and shorter than in the 'North'" (Schulze, 2007, p.292). Thus, it is clear that developing countries (of which South Africa is a part) must invest considerable energy and funds into enabling systems to support effective integrated water resource management.

During a memorable lecture I attended on water resource management in arid lands, Dr Ihab Jnab from the ACSAD (Arab Centre for Studies of Arid Zones and Dry Lands) pointed out that hafeers/ hafirs, stone bunds, terraces, gabions, and check dams can alleviate flash floods drastically (35mm in one hour event, and a flood volume of 190 000m^3 estimated reduced by 50%). Therefore soil and water safeguarded (Jnab, 2010). Fascinating how people in arid lands safeguard their utterly precious sources of water.

There are numerous publications and programmes that are beginning to provide useful pedagogical guidance informed by complex social-ecological systems thinking. For example, UNESCO (2010, p. 152) provides useful practical guidance on mountain water management systems. Chapter 3 (preserving water resources) is especially relevant for catchment and river management, in particular the following sections and activities:

-01 force, flow and transparency: water in mountain areas (pp. 130-138)

-02 the water cycle (pp.140-148)

-03 a paneled mural on mountain water management systems (pp. 152-161)

- Survey the landscape for stone constructions designed to catch runoff water and humidity (p. 152)
- Focus on the anti-erosive structures…(p. 154)
- Study the use of terraces in the landscape and identify them as a method of surface-water management (p. 156)
- Create the second panel…and include details of a surface-water management system (p. 159) (you will be producing your own surface-water management system out there)

- Show on the …the synergy achieved between erosion prevention, reforestation and good water management (p. 161) (damage to water supply from commercial forestation- show how indigenous forests are protected, mapped and how riparian zones are instituted in your area).

Sometimes paths, tracks and even roads can cause serious erosion, once heavy rains come. The Department of Nature and Environmental Conservation (South Africa, n.d.) (the former Cape Provincial Administration) has published key lessons on how to build tracks, especially on how to combat drainage through the use of drainage dips and outslopes, and water bars. Slope is an incredibly important factor to ascertain when building paths. As the author, Jaynee Levy, says, "trails should follow the natural contours of the land wherever possible. Acceptable slopes depend on the terrain (soil structure and ground cover). Areas that are not susceptible to erosion can withstand steeper grades." Advice on how to build retaining walls is also very pertinent [Department of Nature and Environmental Conservation, n.d., 3.4 (Drainage), 3.6 (Slope) and 3.9 (Retaining walls)].

In Wiese (1990, p. 385), Figure 2 shows an education leaflet, attuned to African countries, for mountain conservation. Figure 3 (Wiese, 1990, p. 386) shows a multiple land use concept for the Mt Michuri conservation area near Blantyre, Malawi.

Mountain zoning and current compatibility:

A mountain zoning synopsis is given in Fuggle and Rabie (1992, p. 640, Table 24.2). In Table 13, categories of mountain zoning are given, with three as having immediate relevance to the study area. The first is the "multiple-use catchment zone", which needs (under management objectives) "comprehensive management needed to achieve minimum degradation of natural resources"; and the second is the "transitional management zone (buffers)" which requires "to promote the flexible transition of objectives between zones, or used as a buffer." The "indigenous settlement zone" is the third, which has "through education and example to promote sustainable land-use practices, to prevent erosion and to conserve water sources" as its management objective.

Socio-ecological zoning:

This occurs from the ecocentric to the anthropocentric. Here the study area would fall under the IUCN categories: V11 (anthropological zone [Mountain peoples]) and V111 (multiple use zone). Both need sustainable mountain development (wise use for V111 and optimum use

for V111), but it also signals the start of degradation of natural systems (Blignaut and Shroyer, 2003, p. 27, Figure 1).

2. Reality of catchment and river management and participatory integrated water management in South Africa (20 May 2016)

The Department of Water Affairs and Forestry defines integrated water resource management as "a philosophy, a process and a management strategy to achieve sustainable use of resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits" (Pollard and du Toit, 2008, p.671). This ambitious challenge to do justice to both nature and humanity is a tall order, with nature possibly bound to lose out to the competing and fractious demands of multiple stakeholders.

"The situation becomes more interesting than this however, because it is not only the availability of water that is a constraint, but also the allocation of it. In this regard South Africa has allocated around 98% of the national water resource at a high assurance of supply (NWRS, 2004)" (Turton, 2008, p.2). South Africa's water crisis has also been detailed by Davies, 1986.

South Africa has an ever-expanding population; in 1900 there were approximately 4 million people, in 2011 that figure had escalated to 52 million. Dams not also not always the solution: The Three Gorges Dam, China has been marked by multiple controversies (siltation, displacement of thousands upon thousands of people).

Most of our major rivers have already been dammed; 50% of our wetlands have been lost; industrial and domestic pollution increasing; and an estimated overall increase in demand of some 52% over next 30 years is predicted (DEAT, 1999).

Interbasin transfers also break down natural biogeographical barriers- organisms taken from one basin and introduced to another. Consideration has to be taken of the 18 biogeographic zones in SA, and that aquatic bioregional zones naturally differ from one another (Davies, 1999). The continuum concept has to be understood to address these concerns.

Surface water exhibit clear patterns: watersheds (which are also significant visual edges in the landscape) define river basins/ systems, and the drainage pattern and density reflect the nature of crustal materials and the degree of landscape dissection. The quantity, reliability (seasonality), and the quality of water in the basins is of central importance to its resource significance (Gasson, 1999).

Rivers are four dimensional ecosystems: Longitudinal-within channel; vertical- between channel and hypotheus; lateral-between channel and riparian zone; time-rivers lead to landform sculpting (Davies, 1999). It is essential to understand these four dimensions, for they are critical to understanding and conceptualising the river. These dimensions are ever changing and dynamic, and have the potential to either nourish the banks surrounding the river, or bring great harm through floods.

Reality of participatory integrated water management in South Africa:

Catchment and river management has also moved through eras in South African history, from when governments thought they could dam every valley to innovative but problematic inter-basin transfers, to the new emphasis on participatory integrated watershed management (PIWM) (Macleod et al., 2007). The emphasis on participatory integrated water management has led to South Africa promulgating catchment management agencies (CMAs) but these are either not working optimally or not at all (Ashton, 2000; Versfeld, 1995; Malzbender et al., 2005). This has implications for the teaching of catchment and river management because teachers in local areas should work with, indeed take guidance from, catchment management agencies but as the literature points out, the very authorities are not working properly. Lotz-Sisitka and Burt (2006) argued that a key issue affecting the effective functioning of catchment management agencies in South Africa is a lack of attention to social learning and agency of people in the catchment, offering a strong rationale for giving more attention to catchment management education at all levels in South African society, including in the formal schooling system.

As can be seen, integrated water resource management is the new conceptual guiding framework for catchment and river management. However, the theory of integrated water resource management in South Africa is oftentimes fundamentally different to the practice, as noted above in relation to the actual functioning of catchment management agencies. This calls for careful critical engagement with such concepts in teaching and pedagogy, and for

supporting teachers-in-training to develop practically oriented critical understandings of such concepts, hence my interest in fieldwork.
Pollard and du Toit (2008, p.677) state that complex environment strategies acknowledge that "multiple drivers, multiple outcomes and feedback loops are all realities."
Bourblanc (2012, p.637) has shown that catchment management agencies "are essentially political arenas", and that the managerialist approach (inherent in a catchment management agency) "can sometimes be at odds with the struggle for social transformation in South African water issues" (p.646). In addition, the catchment management agencies were capable of mutating and displacing "the stated end goals of the organisation by developing policies of their own that ultimately generated advantages of individual actors rather than local communities" (p.646).

"Politics are also at play concerning the designation of individuals who are to represent the interest groups (in the Governing Body). It seems that very often the designation of such personalities involves political games" (p. 640). A former Pietermaritzburg-based hydrologist, Chris Dickens "spent 4 years working with the EU to develop Adaptive Management for water resources (for the then Maloti Project- my words), as part of IWRM. I found this really fascinating but the biggest problem is that government believes that they implement this but in reality, do not. They have a long way to go" (Pers. Comm., Dickens, 2009). Regarding the Maloti Drakensberg Transfrontier Park study on payment for ecosystem services (2007), it was stated that the catchment management agencies are "either developing or proposed at this point in time, they should be involved but are not in a position to implement" (MDTP, 2007, p.99).

In a well-remembered lecture in Sweden, a noted South African hydrologist described integrated water resource management thus: "Time scales- many; political- big promises, no action; spatial scale considerations; IWRM a dream, not a recipe" (Schulze, 2010). This quote is borne out by Schulze's article (2007, p.292). The following are useful references for the development of the said agency:

- Business Case for the Pongola-uMzimkhulu Catchment Management Agency, Department of Water Affairs, November 2012. https://www.dwa.gov.za/io/Docs/CMA/Businesss%20Case/Business%20Case%20for%20Pongola-Umzimkhulu%20CMA.pdf

- Proposal for establishment of said catchment management agency, 8 November 2013, *Government Gazette*.
- Establishment of said catchment management agency, 23 May 2014, *Government Gazette*.

In a telephone conversation I had with Mr Nkosinjani Mkhize (pers. comm.) of the Department of Water and Sanitation, he informed me that originally there were three water management areas in KZN, namely the Umhlatuze, uThukela, and the Umvoti-Umzimkulu. In 2009 this was rationalised to one water management area, the Pongola-Umzimkulu. Today there is the Pongola-Umzimkulu proto- catchment management agency, which has been gazetted. Government approval for the governing body is currently pending. In the next three years the catchment management strategy will be instituted. I commented on the diversity and challenge of the catchment management agency, to which Mr Mkhize replied that "we are equal to the task."

3. Catchment management strategies (CMS) (27 May 2016)

What is a case study? Yin (2009) defined case study research as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the phenomenon and content are not clear.

Only in the next three years (i.e. 2019) will the Pongola-uMzimkhulu catchment management strategy be instituted (Mr Mkhize, pers.comm.). This does sound rather ambitious given that the catchment management agency is not up and running yet. One of the issues emerging is that this date may be too late to gather sufficient momentum to deal with the inherited and burgeoning (as we speak) issues of the past and present.

The National Water Act states (Section 8) that a "catchment management agency contemplated in Chapter 7 must, by notice in the Gazette, establish a catchment management strategy for the protection, use, development, conservation, management and control of water resources within its water management area" (Pollard and du Toit, 2008, p.674). There is thus a continuum of actions from looking after the water and the land, to using and controlling it. Given that many of these six terms are mutually contradictory, and no guidance is given as to how these mutually incongruous concepts be reconciled, this Act may be completely impractical to implement. Indeed, the only proper way to conserve is to

proclaim a conservation area, something that shuts out the other aims (e.g. use, development, etc.). Very careful guidance will thus be needed.

The Department of Water Affairs and Forestry guidelines attempt to define a catchment management strategy thus: "a set of medium- to long-term action programmes to support the achievement of sustainability, equity and efficiency through integrated water resource management" (Pollard and du Toit, 2008, p.674). Here again, these three noble aims are difficult to reconcile- and no indication is given as to which one must be prioritised, as will happen in reality.

The authors (2008, p.674) go on to describe the catchment management strategy as comprising a suite of sub-strategies which provide the basis for business and operational plans. A number of core strategies have to be included in the catchment management strategy, irrespective of where it is. Strategies will be considered work in progress as strategy development is iterative in nature; and provision is given for different scales (such as for sub-catchments) and time in drafting the catchment management strategy. Essentially a catchment management strategy will have to follow the precepts of integrated water resource management in South Africa, which is conceptualised as four clusters or parts. Part A deals with important foundational information; part B with water resource management sub-strategies; part C with facilitating sub-strategies; and lastly part D with the integration strategy and the need for co-operative governance (Pollard and du Toit, 2008, pp. 674-676). Figure 2 (p.675) is a very useful diagram for illustrating these four parts, and will be explained in detail to the students.

The key issue of vulnerable and poor people cannot be ignored in a catchment management strategy, indeed these people need to have "special attention is given to water" for them (Pollard and du Toit, 2008, p.677). These two authors round off their very useful paper by stating that "self-organisation and identity of stakeholders", and the concept of "embeddedness" and collaboration with other "plans and processes" are critical to "building resilience with catchment systems."

Key questions and discussion in class:

What is a strategy?

How does one design a catchment management strategy?

What are the results one wants?

4. The importance of the Drakensberg/ Maluti water system (3 June 2016)

The Drakensberg's importance as a producer and provider of water is encapsulated in the following quote by the writer of the first policy statement (Drakensberg Policy Statement) for the Drakensberg region: "the successful development of a land and its people in large measure depends on an assured supply of potable water" (NT&RPC, 1976, p. 6). Water from the Drakensberg even supplies the Port Elizabeth area via the Orange and Fish rivers, besides its key role in supplying much of Johannesburg's and Pretoria's industrial areas (Stone, 1992, p.32).

Nänni (1975) has also outlined the cardinal importance of the Drakensberg to the country's rainfall, especially the eastern half of it. Nänni also found that the 1400 m contour was critical in that a disproportionately large proportion of runoff occurred above it. Therefore, the contour stands in for proximity to the main escarpment, and that catchment area (above that contour) was critically important for water production. "Run-off is increased eightfold when annual rainfall doubles from 800 mm to 1 600 mm" (Nänni, 1975, p.72). Clearly areas receiving this kind of rainfall should be prioritized for run off and hence water production, and are at the moment, with the glaring exception of the Mnweni and the far southern Drakensberg (towards Ongeluksnek). He goes onto to say that "small isolated pockets probably have as much as 2 000 mm (rainfall) annually" (Nänni, 1975, pp.71-72).

It has been found that "the Maloti Drakensberg is a strategically important watershed, supplying 25% of South Africa's water" (MDTP, 2007, p.2). Furthermore, "the rivers rising on the South African side contribute over 8000 million m^3 in mean annual runoff (MAR) to systems within the region" (MDTP, 2007, p.3). The same organisation has earmarked the Upper uThukela Catchment Conservation Area as a biodiversity priority area (KwaZulu-Natal Priority 3) (MDTP News, 2008, pp.4 and 5).

The study area falls within the buffer zone for the Ukhahlamba Drakensberg Park World Heritage Site, something that was deemed a requirement for the establishment of a world heritage site (Forster et al., 2007, p.1). The authors stipulate that activities existing within the buffer zone do not "inhibit the achievement of the core values", of which one is "water production" (Forster et al., 2007, p.7). Moreover, the authors include "sustaining water production and other life support systems" as a "protected area purpose to be extended through intervention in the Buffer Zone" (Forster et al., 2007, p.9).

Van der Zel (1981) found that water production was the most beneficial land use applied to mountains, from a cost/ benefit analysis of different landuses. "Mountain catchments, so defined, occupy 12% of Southern Africa, but deliver 53% of the runoff" (van der Zel 1981: 75). Blignaut (1994) writes that mountains are "the major providers of unpolluted, unsilted water (van der Zel, 1981a; van Wilgen, 1991; Buthelezi, 1993) to the country. Furthermore, regarding the country, about 70% of the land is dry and relies on an irregular rainfall, and to exacerbate the problem, there is a limited storage capability (countrywide) (Huntley, 1989)" (Blignaut, 1994, p.2).

A Pietermaritzburg-based hydrologist, R.E. Schulze, has written extensively on the rivers of the Drakensberg, and on the necessity for judicious water resources management. "In a country not endowed with an abundance of water, the Drakensberg as South Africa's major inland source of water supply with large annual and seasonal supplies available to augment deficits elsewhere, is a region where careful water resources management deserves particular attention" (Schulze 1979, p.168). "The wetland systems of the (Drakensberg) area are extremely important to the hydrological cycle: they maintain river flows during the winter and reduce flood peaks during the high rainfall period (Bainbridge et al., 1991)" (Stone, 1992, p. 31).

Schulze in his very influential 1979 study showed the dimensions, reliability and water production rates of Drakensberg rivers. These rivers do not flow at the same rates year after year, instead variability is a key factor. "A general inverse relationship between CV (coefficients of variability) and rainfall was noted. Thus, the planners of one of South Africa's prime water production regions still have to contend with unreliable rainfall totals" (Schulze, 1979, p.169).

In the following table, the significance of the uThukela system can be clearly seen. Of the six Drakensberg rivers, it can be seen that the uThukela has the highest mean annual streamflow and mean annual catchment rainfall. Significantly, the mean annual streamflow compared to mean annual catchment rainfall is 39.8% compared to Umzimkhulu that is 33.4%, and the Umzimvubu at a very weak 12.7%. The importance of this is that despite the relatively high catchment rainfall, mean annual streamflow is relatively good, showing that a significant amount of water is not infiltrated into the soil, unlike the Umzimvubu especially. It is the fourth most variable river, showing relative reliability, and the most significant river in evapotranspiration loss.

River	Mean annual streamflow in mm (MAR)	Coefficient of variability in %	Mean annual catchment rainfall in mm	Mean annual actual evapotranspiration in mm
Tugela	475.3	49.6	1192	742.1
Mooi	378	54	986	608
Bushmans	93	63	745	
Umkomaas	336	29.5	1123	
Umzimkulu	359	34.7	1073	714
Mzimhlava/ Mzimvubu	108	52.2	850	686

Adapted from Table 8.2 (Schulze, 1979, p. 112), using an average of the selected gauging weirs, from Mean Annual Streamflows, Coefficients of Variability, Catchment Rainfalls and Actual Evapotranspiration amounts in the Drakensberg Catchments.

In a more recent study by Blignaut et al. (2010), a useful physical geographic synopsis as well as a socio-economic status has been given. "The Upper-uThukela catchment in northwest KwaZulu-Natal forms the northeast border with the Royal Kingdom of Lesotho…. The catchment comprises 1876.19 km² and is made up of nine Quaternary Catchments (QC) …. This topographically rugged area ranges in altitude from ~1150 m in the east to ~3300 m along the northwest to southeast trending top of the Drakensberg mountain range in the west. The subdelineations of the QCs have mean sub-catchment slopes ranging from 3.8% to 52.1%. Mean Annual Precipitation (MAP) varies from 745 mm to 1660 mm in the mountainous sub-catchments, mostly between October and March. Natural vegetation in this area belongs to the grasslands biome and comprises tall grasslands in the east, short sourveld in the foothills with alpine type grasslands in the high Drakensberg. The high rainfall over the summer period has both led and contributed to erosion along the slopes (Everson et al., 2007). The area comprises a mixture of rural communities and commercial farmland. The rural communities rely heavily on natural resources and practice subsistence agriculture which includes both livestock and crop farming" (Blignaut et al., 2010, p.1314). The diversity, both in terms of hydrology and geography, has also been typified by Schulze

(2007). "The Thukela, on the east coast of KwaZulu-Natal province in South Africa and one of the UNESCO-HELP catchments, covers 29 036 km2 with the main river rising in the Drakensberg mountain range at >3 000m altitude in the west and flowing eastwards for ~180 km before entering the Indian Ocean (Figure 4). It is a highly diverse catchment, physiographically as well as climatically and socio-economically (Dlamini and Schulze, 2004a). Hydrologically the Thukela has been delineated into 113 interlinked, cascading, mesoscale operational subcatchments (SCs) (Schulze, 2007, p. 279). Ironically in such a catchment, water poverty, both now and into the future especially, is indeed a factor. "Water poverty is acute in many meso-scale catchments and is likely to be exacerbated by global warming (again, a case study from the Thukela catchment) …" (Schulze, 2007, p. 269).

Problems in the Drakensberg/ Maluti System:

Irresponsible development is however affecting the streamflow of some Drakensberg rivers, certainly the Sterkspruit in the Champagne Castle Valley. "The Sterkspruit could not be relied on and water shortages are already experience (sic) in the Valley" (*Bergwatcher*, 2008).

Tyson et al. (1976, p.76) in their study on the Drakensberg's climate, emphasize that "very careful ecological management" will be required for the area's "full recreational resource potential" to be realized. Furthermore, policy changes at the drop of a hat, and areas that were earmarked for no development, such as the upper reaches of the Mnweni, are now seeing development, especially roads at higher and higher contours even although there is policy, and zoning, applicable to that area under the Special Case Area Plan for the Drakensberg (T&RPC, 2001). It has been shown that the 1400m contour is significant for doubling the rainfall. According to a student in the class, socio-ecological zoning is routinely ignored and an attitude of laissez faire prevails concerning where and when development should occur. The lower reaches of the Mnweni have however been earmarked as a key development node by the Special Case Area Plan (T&RPC, 2001, p. 83), as it "occurs in a high intensity section."

Communal farming and tenurial rights are other challenges, especially evidenced by the situation in the Mnweni (close to the study area). "Traditional systems of land tenure and cultural and religious attitudes towards livestock contribute to land deterioration in tribal areas of South Africa…" (Stone, 1992, p.34). Hamilton and Bruijnzeel (1997) also call

attention to "*greater tenurial security"* where "land or water rights are uncertain" (Hamilton and Bruijnzeel, 1997, p.365). Pearce (2006, p. 350) writes of the impact of the "Locations", especially the Upper uThukela, upon the water supplies of the Drakensberg. "Not only are they hopelessly overcrowded, there is a huge animal population and gross over-utilization of the veld. Today there is the most appalling erosion in these areas. The land is serrated and seamed with huge dongas, there is bad sheet erosion especially on the hillsides, and there are huge areas where the ground has turned sour and where grass no longer grows. The effect of all of this on the water supplies emanating from the Drakensberg is tragic."

The Upper uThukela, also known as the Mnweni, breaks many continuities in the Drakensberg, namely protected area status, biodiversity counts, recreational opportunities, and even law enforcement. However, it must be remembered that the Mnweni situation is an inherited case of colonial social engineering where people were moved into the Drakensberg to act as a buffer between newly arrived settlers and the Bushmen (San). Sandwith puts this historical environmental injustice in geographical and economic terms: "The {historical} conflict also initiated a system in which black communities were confined to specific locations, which were, in most cases, of insufficient size or productivity to enable any sustainable form of land use. This resulted in the general degradation and lack of development. Those areas adjacent to the mountains are among the most poverty stricken in present day KwaZulu-Natal, leading to transboundary conflict over access to resources" (Sandwith, 2003, p.153). This social engineering in an extremely sensitive mountain environment has also been borne out by passages in Wright and Mazel (2007, pp. 81-82, 141). Everson and Morris (2006) have written about the lower biodiversity counts (to the measurement of 71% of the protected area count) in the communal rangelands of the Mnweni. "In the communal rangelands of Mnweni, a biodiversity study showed that species richness in 100 square meter plots was significantly lower (35) than in adjacent conserved areas (49)" (Everson and Morris, 2006, p.290). At present there is no conservation statute governing activity in that critical area, especially the higher reaches, and the landscape is being degraded daily.

"The human footprint in the Thukela consists of a complex (largely historical) juxtapositioning of developed and underdeveloped areas, with large tracts of former segregated "Homelands" mainly in the north and east suffering from severe water poverty at meso-scale levels …" (Schulze, 2007, p. 279). Thus it can be clearly seen that the fabric of

the uThukela region is disjointed, discontinuous and that it suffers from water poverty in a number of areas.

5. **Useful teaching and learning resources for catchment and river management (10 June 2016)**

FIELDWORK TECHNIQUES AND CATCHMENT AND RIVER MANAGEMENT:

Fieldwork and practical work is mentioned as a key skill in the Curriculum and Assessment Policy Statement (Department of Basic Education, 2011, p. 16). Under Grade 12, Fieldwork (time permitting) has the following skills mentioned:

- *Collecting and recording data using a variety of techniques*
- *Processing, collating and presenting fieldwork findings* (Department of Basic Education, 2011, p.16).

The key proviso is "time permitting" (which can be construed as ambiguous) but it is expected that teachers will find the time to conduct field work to teach catchment management, as fieldwork is a critical mechanism for conceptual understanding of such a body of work.

"Such is the significance of fieldwork to learning at the undergraduate level that the UK Quality Assurance Agency benchmark statement ES3 states, 'it is impossible for students to develop a satisfactory understanding. . . without a significant exposure to field-based learning and teaching and the related assessment' (QAA 2007, 7)" (Fuller, 2012, p.8). Two Australia-based authors have shown the clear value of fieldwork in teaching catchment management. In Ballantyne and Packer's (2002, p. 219) article, primary and high school pupils were taken to a catchment area.

Dummer et al. (2008) reiterate that fieldwork is a good methodology for teaching catchment management concerns. These authors explained how and why "deep learning" as evidenced in diaries takes place during fieldwork. (Students will keep a diary for the whole 6 weeks of TP, on their own teaching and learning of catchment and river management in the upper uThukela. Date, record of your own experiences, even conversations, geolocate everything-sketch maps of interesting phenomena and even routes). Moreover, another author cites Dummer et al. (2008) in explaining the skills engendered during fieldwork: "The field provides a place to contextualise learning in real world settings, acquire and develop

technical and life skills, and it is a place to enjoy (Fuller 2006; Dummer *et al*. 2008)" (Fuller, 2012, p.12). Furthermore Kent et al. (1997) maintain that "field studies provide the opportunity to experiment with a wide variety of different modes of course delivery and have a valuable role as a vehicle for the integration of many theoretical and practical concepts taught within a geography degree…." However the methodology is neglected particularly in poorer countries. Gerber and Chuan's book (2000), and in particular Vallega's chapter, represents a re-emphasis of a critical skill in Geography and an alignment of fieldwork with complexity. As Vallega says, "the complexity-based approach emphasises the role of geography as a science able to make representations of spatial realities thereby building up models in an epistemological sense , i.e. as non-objectivist representations establishing interaction between the individual realities and a general model" (Vallega, 2000, p. 235). Newson (1988) emphasizes fieldwork as integral to physical geography, however Cook (2008) cautions that fieldwork cannot be seen in isolation and that broader issues impinge on the pedagogy (students will determine those issues-poverty, isolation, etc.). Fieldwork has a major influence on producing autonomous and independent thinking in learners, as well as producing resilient and resourceful practitioners (Newson, 1988; Vallega, 2000). There is also very interesting progression in technology use during fieldwork, from clipboards to personal digital assistants (PDAs), and digital cameras/ voice recorders. For catchment management, altimeters (as on digital watches) will also prove very useful. The Royal Geographical Society, on its webpage, lists interesting fieldwork techniques drawing on new forms of technology.

The beginner teacher competencies and collective roles (as enunciated in the Policy on Minimum Requirements for Teacher Education Qualifications, Appendices C and A [Department of Higher Education and Training, 2011]) of teachers will also have a bearing on the teacher education programme, and especially its interest in developing the disciplinary, practice and pedagogical knowledge of teachers-in-training.

The publication *Teaching Water* (Khan et al., 2014) was given out to the students.

Fieldwork:

Catchment and River Management (3hrs) (Under Geomorphology, Gr 12 in Term 1)

- *Importance of managing drainage basins and catchment areas;* {definitely fieldwork}

- *Impact of people on drainage basins and catchment areas;* {definitely fieldwork}
- *Case study of one catchment area management strategy in South Africa* {Possible visit to a catchment management agency} (Department of Basic Education, 2011, p. 43).

Dimensions and locations of current erosion: I advised students to obtain global positioning system (GPS) units from Brice Gijsbertsen at the Pietermaritzburg campus geography department. Students were recommended to do mapping on 1: 50 000 maps and GoogleMaps (they were also advised to learn how to do a GoogleMap, and even to have produced a GoogleMap of their catchment and river management fieldwork by the end of teaching practice). This was not done however.

Methods to combat erosion:

Students were referred to Ezaza (1990, p 116, Fig. 6) which shows the development of gullies (dongas) from footpaths. I emphasised that footpaths cannot be constructed anywhere but have to follow sound environmental management principles, such as respecting the force of water and trying to follow contours.

Students were told about the following mountain-based development and conservation initiatives in South Africa:

- Mnweni Donga Erosion Reclamation Project by Mnweni Community Trust (no effort was made to contact this project, despite it being so close, i.e. the next valley).
- Working for Water Project (knowledge of this project did not come across in the students' work)
- Zululand Trail Project (Blignaut and Shroyer, 2003, p.28).

The three objectives of the (Mnweni) project were to "1) enhance the capacity of the people of Mnweni to manage their natural resources through the development of institutions, training in rehabilitation and monitoring, and environmental education; 2) plan and implement interventions to reduce rates of land degradation through the following conservation measures: i) Physical structures (e.g. contours, stone lines, stone packs, etc.) ii) Vegetative measures (e.g. planting of vetiver grass…indigenous grasses and trees, brush packing, etc.) iii) assess the species-level diversity of plants in grazed and protected areas" (Everson and Morris, 2006, p.287).

Regarding the clearance of alien vegetation, the Working for Water programme was established by the then Department of Water Affairs and Forestry in 1995. Mostly active in the Western Cape (where the need is greatest), this programme has been active in KwaZulu-Natal.

Zunckel (2003) has written how community involvement in the Mnweni area has helped combat *donga* or gully erosion by the building of gabions. There is also increasing clarity and valuing of the importance of the potential of ecosystems services that emerge from and in the Drakensberg area, which stretches from the Eastern Cape to the Cathedral Peak areas (MDTP, 2007) for national development, water security and the wellbeing of people and enterprises in the catchment.

Importance of fieldwork:

The United Kingdom Geographical Association, regarding Advanced (A) level reform, stipulates a minimum of four fieldwork days to A level as from 2016.

Mini-SASS- research macroinvertebrates. Stream assessment scoring system/ South African scoring system.

An Australian initiative, Streamwatch, contains many useful pedagogical and other suggestions on how to take care of streams and rivers (Streamwatch, 2012). In South Africa, the MiniSASS programme has developed social learning pedagogies that enable adaptive catchment management via citizen science (Vallabh et al., 2016).

Students were informed of the following references: Project WET and the Maloti Drakensberg Transfrontier Project's *MDTP News* (2007).

Video taping

There is also potential for participatory video techniques to educate and galvanize local communities. This was used for a project labelled NORMA that took place in the Himalaya: "At NORMA's core was to the use of participatory video techniques for the purpose of enabling the local communities, non-governmental organizations (NGOs) and grassroot organizations to communicate their views and ideas themselves-directly to scientists, senior policy makers and donors" (Insight et al., 2005).

Other technologies: "Mobile technology can be defined as portable (handheld) computers, typically with global positioning system (GPS) capability (e.g. personal data assistants (PDAs), smartphones). The possible benefits for learning from the use of mobile technologies are thought to be especially pertinent for field-based subjects such as hydrology in that they permit greater locational flexibility in terms of where learning takes place… In particular, the possibility for situated and context-aware learning, such as through the use of GPS, has the potential to provide a key learning tool. This is because the importance of field-based learning for facilitating "active learning" (i.e. learning by doing), and as such the potential to integrate theories, concepts and skills in a practical environment…." (Kingston et al., 2012, pp.1281-1282).

"The skills gained from using the GPS-enabled PDAs for field mapping are directly applicable to other hydrology field exercises (for example, mapping precipitation, soil moisture or river networks). Competence with such modern technology is an important transferable skills needed by hydrologists to be effective in a changing and increasing spatially and temporally complex world" (Kingston et al. 2012, p. 1286).

The following reference on fieldwork, albeit from a UK perspective, was given to the students: Maskall, J. & Stokes, A. (2008). *Designing effective fieldwork for the environmental and natural sciences.* GEES Subject Centre Learning and Teaching Guide.

6. Complex Adaptive Systems (lectures on 6 -7 and 14 June 2016)

It has been shown that it is impossible to facilitate catchment and river management without a very clear understanding of complex adaptive systems and social ecological systems. This is because catchment and river management is all about working with a dynamic system that needs constant adapting to, and because it encompasses a living socio-ecological system. Furthermore skilled practitioners need to have mastered a number and variety of key

sustainability competencies. Pollard and du Toit (2008, p.673) state that "complex systems thinking must underscore water resource management", and furthermore list the attributes of a complex system as "non-linearity, uncertainty, emergence, scale, self-organization and feedback loops."

In Figure 7.1 (Schematic representation of some attributes of self-organizing complex systems) in Favis-Mortlock and De Boer (2003, p. 138), characteristics of complex systems (defined as "emergent behaviour that cannot be simply inferred from the behaviour of the components") are listed as involving "many components, dynamically interacting, and giving rise to a number of scales, which exhibit common behaviors." The last mentioned leads to "transdisciplinary concepts (across types of systems, across scales, and thus across disciplines)." The complex system itself will comprise "hierarchies and control structures", which derive from "composites" at the base, "self-organisation and emergence."

Biggs (2008) in Pollard and du Toit (2008, p.673) postulates that the following methods are useful for thinking about uncertainty and complexity: increase the number of people thinking holistically (the whole is greater than just the sum of its parts) about the multi-faceted system and events; scenario-based planning; prudence in decision-making; 'learn-by-doing' adaptive management; and recognising that complex systems have a number of ways to arrive at the same endpoint.

In a very influential article, Dyball et al. (2005) use the mechanism of constructing mental models to appreciate complex adaptive systems, using a case study (the Macleay river catchment in Australia) that bears remarkable similarities (southern hemisphere climatological processes such as El Niño Southern Oscillation, scales, levels of trust) to the upper uThukela area (p. 48). "One of the complex issues for the environmental manager to resolve…is the mismatch between knowledge, values, economic estimates and levels of trust that are apparent between stakeholders at individual, group and intergenerational scales" (Dyball et al., 2005, p. 42). The solution is for each individual to "rethink their personal boundaries", and "generating a collaborative, shared, systems orientation to a sustainability issue", which are absolutely critical in a country such as ours with such different and fractious backgrounds for all its inhabitants. Therefore, just like the Macleay catchment, "communities (in the uThukela catchment) need to align current knowledge of trends, processes and responses in order to establish good, long-term environmental management

practices and, simultaneously, distribute the costs and benefits of change to make it personally variable to stakeholders" (Dyball et al., 2005, p. 52).

Figure 3.1 (Dyball et al., 2005, p.53) (Transition phases in the natural and anthropogenic systems) has four phases (exploitation, conservation, release, and reorganization) juxtaposed against both natural and anthropogenic processes, to show what happens, naturally and anthropogenically, in the upper and lower reaches of the Macleay catchment. Figure 3.2 (Adapting land management to the biophysical reality) on the next page (p.54) shows the (anthropogenic) adaptive land management steps in phase 1 for exploitation, conservation, release and reorganization; and phase 2 for only conservation, release and reorganization, with the clear lesson that exploitation has to be done in the initial phase, and discontinued thereafter. However, as the authors (2005, p.52) crucially say, with reference to the previous section on scales, "this variability of scale and process, with its associated variation in risk exposure and the direct experiences of different stakeholders, presents a challenge for finding the necessary common ground to start negotiations and forge learning collaborations."

To round off, "…a systems orientation encourages critical reflection on what is done and why, what structure is being maintained and in whose interest, and what parts or properties of the system are being valued or ignored in decision making processes" (Dyball et al., 2005, p. 48). If these questions are answered together and honestly, a lot of confusion and hence mistrust can be obviated. Finally Dyball et al. (2005, p. 58) write that "…the perspective of complex adaptive systems thinking can and does provide valuable insights into the process of social learning as a form of adaptive change…in so doing, it helps to highlight the dynamics of change in ecosystems, noting that different stakeholders value differing and often conflicting variables, and that such variables operate across multiple scales and with undefined boundaries. Despite this complexity, a systems perspective offers a unifying structure that makes this complex interrelationship comprehensible."

Adaptive capacity is very important in this theory and Norberg and Cumming write that "governance in SESs (social-ecological systems) that attempts to nurture adaptive capacity thus needs to recognise that 1. change and disturbance are fundamental for sustaining adaptive capacity, 2. adaptive capacity is maintained by the interplay between processes that sustain and diminish diversity, and 3. different sources of diversity may be important under different disturbance regimes" (Norberg and Cumming, 2008, p. 284). Therefore the theoretical framework has to take note of change, the interconnectedness, and a respect for

different sources of biodiversity. As mentioned above, spatial variation is another key concept within the theory, and the authors also point out that local area knowledge and indigenous knowledge systems are important to getting all communities involved (Norberg and Cumming, 2008, p. 290).

Gunderson et al.'s (2008) chapter in Norberg and Cumming's book provides a useful synopsis of how to practise adaptive management in respect of complex social-ecological systems. In particular Table 8.1 (Fostering Social Learning Through Adaptive Assessment and Management) lists nine recommendations as to facilitate social learning. These recommendations are geographically/spatially, socially and temporally integrated and inter-dependent: "embrace complexity and change, focus on sources of uncertainty, design processes to resolve uncertainty, create a 'safe to fail' system, create arenas for discourse, develop learning networks, seek peerless leaders, scale is important, invent creative solutions" (Gunderson et al., 2008, pp. 235-236).

Vallega (2000, p. 243, Table 2) describes the epistemology of complexity as (reality as consisting of): "Systems acting not as trivial machines, self-organising, passing through changing phases by interacting with their external environment, and thereby moving towards objectives." Furthermore he ascribes "conjunctive logic" as the associated Geographical logical approach. In Table 3 (p. 246) he elucidates "conjunctive logic", as opposed to disjunctive logic, (with the output of "complexity's thought") as having the following principles, which bear significant relation to this study: pertinence (describing those elements that are perceived as valid to the building up of reality's models), holism (describing reality as a unique system interacting with its external environment….), teleology (…focusing on feed-back and circular relationships…), and aggregation (selecting those elements which pertain to the building up of models representing systems as a whole according to the project they operate…). The resulting methodological attitude will be "aximotic-inductive." Complex adaptive systems (CAS) feeds into, and indeed underpins, the next section on socio-ecological systems (SES).

7. Social-ecological systems and sustainability competences, 18 July 2016, Research House, Royal Natal National Park

This day had been the first day of the students' teaching practice at the three schools and subsequently the students were a little tired. I on the other hand, after having settled the students in and bought the provisions, was enthusiastic to tell the students about the course I had attended in France on social-ecological systems.

Social-ecological system:

This term (social-ecological system) derives from Berkes and Folke (1998) who "suggested that the term social-ecological system (SES) would emphasize the integrated concept of humans in nature while not reducing any discipline to a prefix" (Norberg and Cumming, 2008, p. 278). Social-ecological systems is a rapidly emerging area of study in the sustainability sciences, and is influenced by theorists on transdisciplinarity and complexity. Regarding complexity and social-ecological systems, the analysis work will be heavily influenced by Norberg and Cumming (2008). This theory leads to sustainability competencies, which are attuned to complexity and time/ scale differences. Complexity, actors, change, scale, place and space are all integral to social-ecological systems (Norberg and Cumming, 2008).

I told the students about my trip to France and the social-ecological systems workshop.

The social-ecological system framework published by Lin Ostrom in 2005 shows the relationship between biophysical conditions, attributes, rules in use and how they lead to action situations and interactions and outcomes.

Regarding Ostrom's theory, I participated in a field trip (on the course I attended in Reims, France, 2016) on the "Analysis of the sustainability of its governance system" (Ardennes, France and Belgium). The analysis primarily looked at Resource systems (RS), Interactions (I), Governance systems (GS), Resource units (RU), Outcomes (O), Actors (A). The outcomes are linked to related ecosystems (ECO).

Sustainability competencies:

Sustainability competencies are essential to managing integrated water resource management and social-ecological system approaches, and also teaching them. The understanding of these competencies derive from Gerhard de Haan (2006, p. 22) who has written on what constitutes

Gestaltungskompetenz (or shaping competence), which is the "specific capacity to act and solve problems." There are a number of sub-competencies that are described in the sustainability competence literature that show a remarkable affinity with what students typically do on Geography fieldwork (de Haan, 2006; Wiek et al., 2011). Wiek et al. (2011, pp. 207-211) undertook a synthesis study on sustainability competences and defined a set of core *interrelated* competencies, namely "systems thinking competence, anticipatory competence, normative competence, strategic competence and interpersonal competence" as being central to the sustainability sciences. These five competences have to be posed or juxtaposed against integrated water resource management or participatory integrated water management in the upper uThukela.

This quote from Dent (2012) shows that integrated water resource management is inextricably linked up with sustainability competencies, social learning and social-ecological system awareness, and that coordination and cooperation in a number of ways are essential: "IWRM in turn demands a level of interaction between individuals, disciplines and organizations such that we can collectively, timeously, wisely and cost-effectively visit the consequences of our proposed, present and past actions. Furthermore, responsible leaders have determined that their responsibility in such circumstances will be to build multi-sector 'response –ability', this can be inferred from the CEO Water Mandate (2010) and from the Department of Water Affairs and Forestry (1997). This will mean developing the social learning crucible in which multi-stakeholder co-suspending, co-reflecting, co-sensing, co-prototyping of responses, and co-enacting is imperative for wise IWRM" (Dent, 2012, p.313). He goes on to say that "robust social-ecological knowledge creation requires robust, transparent, vibrant institutional forms and robust, transparent and vibrant engagement."

To conclude, social learning is essential to facilitate and empower human agency in catchment and river management, which resolves around a systems approach. "A systems approach takes into account multiple processes that can affect learning processes, including feedback, boundary setting, communication and uncertainty (see Table 1.1)… A system orientation allows both human and non-human elements to be included as parts of a given system, with the interaction conceived of in terms of the properties the parts possess and the constraints those properties place on each other when brought together" (Keen et al., 2005, p.10). The constraints that people bring to the interaction is key, and has to be factored into any appraisal. As the authors (2005, p. 11) say, "further complicating our understanding of

coupled human-ecological systems is the capricious behaviour of humans themselves…human reactions can vary greatly across space and time in response to changing values, contexts, incentives or understandings." This is happening in countries where people share the same language, religion and general appearance. In a country such as ours, where heterogeneity is the norm, the potential for capriciousness, and the failure to see the common good (some, for all, forever), is even more likely.

Keen et al. (2005, p.12) also list and define the key concepts employed "in a systems orientation to social learning: boundary, human communication, emergent properties, feedback, perspective, system, systems thinking, trap, tradition, and worldview." All these concepts will have to be carefully understood and considered at all times so as to produce positive and non-discriminatory results in social learning.

A note of caution is expressed by the authors when they say "our understanding of system behaviour must be contingent on incremental, experiential learning and decision-making, supported by active monitoring of, and feedback from the effects and outcomes of decisions (Jiggins and Röling, 2002)" (Keen et al., 2005, p.11). As one can see, this is extremely pertinent to the science and practice of catchment and river management itself- continual monitoring of decision making has to occur.

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Extra notes from French course (not given in lecture):

Halliday and Glaser (2011, p. 1) suggest a framework for operationalising the concept of a SES, and identify **four functional subsystems (natural, worldview, control/management, and technology).** A systems diagram (of an integrated family farm system) is shown on p. 12, illustrating the four subsystems and all the variables and factors at play. All have to be properly understood to grasp what a SES actually is, and the authors state that the term simply means "a commitment to adopt a holistic, systemic perspective towards human and non-human elements of a problem situation of interest." Of major interest to this study is the explanation of the mind- see Bateson (1970, pp. 372-373), referring to "information processing, trial and error, interconnected social system, planetary ecology." The mental capacity of the global social-ecological system has to be developed through critical systemic inquiry or more properly systemic intervention (Halliday and Glaser, 2011, p. 16)

Referring to a New Zealand study on ecosystems and human health, "the case study emphasises the importance of both horizontal and vertical connections between diverse coalitions of catchment stakeholders…both generic and location-specific examples highlight the value of participatory methods that respond to the challenge of *how* to integrate the complex social and bio-physical processes that characterize human and ecosystem health" (Parkes and Panelli, 2001, p. 85).

The SES framework published by Lin Ostrom in 2005 shows the relationship between biophysical conditions, attributes, rules in use and how they lead to action situations and interactions and outcomes.

A field trip (on the course I attended in Reims, France, 2016) was held on the "Analysis of the sustainability of its governance system" (Ardennes, France and Belgium). The analysis primarily looked at Resource systems (RS), Interactions (I), Governance systems (GS), Resource units (RU), Outcomes (O), Actors (A). The outcomes are linked to related ecosystems (ECO).

Ostrom, Elinor 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science* 325, 419-422.

For the uThukela catchment the following would be the most influential factors, I consider:

Resource systems (RS): RS1 sector (water), RS2 clarity of system boundaries, RS3 Size of resource system, RS4 human-constructed facilities, RS5 productivity of the system, RS6

equilibrium properties, RS7 predictability of system dynamics, RS8 storage characteristics, RS9 location.

Interactions (I): I1 harvesting, I2 information sharing, I3 deliberation processes (cooperation, politics, participation), I4 conflicts, I7 self-organising activities, I8 networking activities, I9 monitoring activities, I10 evaluative activities

Governance systems (GS): GS1 government organisations (ministries, local authorities), GS3 network structure (relations, power), GS4 property-rights systems, GS5 operational-choice rules (regulatory-fit, -depth, -style, -noise), GS6 collective-choice rules (decision-making, coordination), GS8 monitoring, evaluation and sanctioning rules (inter alia dispute settlement)

Resource units (RU): RU1 resource unit mobility, RU3 interaction among resource units, RU4 economic value, RU5 number of units (cows!), RU6 distinctive characteristics, RU7 spatial and temporal distribution (NB)

Outcomes (O): O1 social performance measures (e.g. efficiency, equity, accountability, sustainability), O2 ecological performance measures (e.g. overharvested, resilience, bio-diversity, sustainability), O3 externalities to other SESs

Actors (A): A1 number of relevant actors, A2 socioeconomic attributes, A3 history or past experiences, A4 location, A5 leadership/entrepreneurship, A6 norms (A6-1 norms, A6-2 trust, A6-3 capacity), A7 knowledge of SES/ mental models, A8 importance of resource (dependence/ malignancy- cows!), A9 technology available

Related ecosystems (ECO): ECO1 climate patterns, ECO2 pollution patterns, ECO3 flows into and out of focal SES

Source: URCA and SENSE (2016).

The concepts of scale (pertaining to spatial, temporal, jurisdictional, institutional, management, networks, and knowledge) and the different levels that pertain to them, as explained by Cash et al. (2006) are important to understanding human-environment interactions. In Figure 1, Schematic illustrations of different scales and levels that are critical in understanding and responding to human-environment interactions, is arranged as follows: “spatial (areas) range from globe, regions, landscapes and patches; temporal (rates, durations and frequencies) range from annual, seasonal, and daily; jurisdictional (administrations)

range from intergovernmental, national, provincial and localities; institutional (rules) range from constitutions, laws and regulations, and operating rules; management (plans) range from strategies, projects and tasks; networks (links) range from trans-society, society, kin and family; and lastly knowledge (truths) range from general and universal, to specific and contextual" (Cash et al. 2006).

Assignment 1 (Try filling out the SES framework for a site you study or work at?)

Circulating and Connecting Between Social, economic and political settings, and Related ecosystems: Resource system (uThukela)- Governance system (traditional authorities/ conservation agency/ CMA)-{farmers, people, cities between}- Users (subsistence farmers)- Interactions (clean erosion- farmers water)- Resource units (kilolitre, hectares of land, sediment levels). Interactions will connect with Related ecosystems.

Assignment 2 (which scales and levels do you address in your research or management programme?)

Which scales [Cash et al. (2006)] **do you address?**	**At which level?**	**At which extent?**	**At which grain?**	**Reflect on your choices**
Spatial	Landscapes	Small	50 * 50m	Landscape scale-specific
Temporal	Seasonal	Large	200 * 200m	General-seasonal
Jurisdictional	Localities	Small	50 * 50m	Micro-jurisdictions; kinship/ clanship
Institutional	Operating rules	Medium	100 * 100m	Medium scale-government
Management	Tasks	Small	50 * 50m	Need for local scale- specific

Network	Society	Medium	100 * 100m	Over a number of local areas- medium
Knowledge	Specific	Small	50 * 50m	Specific areas and knowledges (spatial and indigenous)

URCA and SENSE (2016).

Normative and political dimensions of your research project:

Dimensions	Description (my answers in *italics*)
Research topic: CRM in GTE- a case study of student T and L in the upper uThukela.	Reflect on the normative and political dimensions of your research project (e.g. different values, perspectives, interests). How are these dimensions relevant for your work? *Values: mine- nature, students- TP, community- wealth and status* *Perspectives: views- SES, traditional life, research-led* *Interests: long term/ short term- politics (western and traditional)*
Values and positions of research (er)	1. Personal values and standpoint: How do your personal values and standpoint (i.e. your position in society) influence your research? *Nature and lover of mountains- nature-centric, must bear in mind the socio-* 2. Values inherent in research approach: What values are inherent in your research approach and how do they influence your research?

	Think in terms of your theoretical but also your methodological approach (e.g. the condition of access to your field; the models and tools that you use) *SES values, geographic values- NORMS- holism* *Language-loaded values; science – loaded ; western science vs traditionalism*
Power structures and asymmetries	1. As external factor shaping your research project: What societal power structures might influence your research? How do you deal with this context of your work? • *NRF funding* • *Curriculum- state* • *Supervisors (balance and amelioration for all three)* 2. Between (potential) participants in your research project: what are the power asymmetries between participants in your research? (for e.g. based on access to resources). Also think about your own position as researcher in relation to other participants in the research. (actor/ translator) *Western science* *Traditional epistemology- clan/ kin/ ancestors/ river/ cattle*
Power of knowledge	What is the (potential) influence of your research project on society? What way of

	seeing and acting in SES do you make possible? • *To activate teachers* • *Get schools in deep rural areas on board* • *School agency for CRM* *Swiss catchment vs African catchment*

URCA and SENSE (2016). Courtesy of Social-Ecological Systems, Elizabeth Haber and Jetske Vaas, Summer School 2016, Reims.

Polycentricism may also be an important factor in this catchment (Liesbeth Feikema, 2015). Hybrid political orders are sure to feature in the upper uThukela- traditional, government tiers, etc.