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A framework for evaluating instructional design models resulting in a model for designing and developing computer based learning tools with GIS technologies

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Abstract

With the increasing pressures and concerns in education regarding capability, lifelong learning, higher order cognitive skills, transdisciplinary education and so on, educators are seeking fresh ways to teach and new tools to support that teaching. In South Africa, Outcomes Based Education (OBE) has identified critical outcomes (skills) across all subject areas such as problem solving, teamwork, fostering critical thinking etc. as a way of responding to these pressures and concerns. But OBE has been criticised for lacking the necessary tools to develop these critical skills and to promote cross-discipline learning. One innovative way of offering transformative teaching, instruction and learning that may foster the development of these critical skills, particularly those concerned with critical thinking, is by using geographic information systems (GIS) technologies. The scope for using these technologies in secondary education is now being realised for teaching the more generic, cross-discipline skills described whereby students are learning not only about GIS but also with GIS. This realisation provides the opportunity to create flexible, computer-based learning materials that are rooted in authentic, real-world contexts, which aim to enhance the cognitive skills of the students. If these technologies can be used in an innovative way to develop critical outcomes and skills, a model needs to be defined to aid the design and development of learning materials using these technologies for use in schools. The primary aim of this study has been to develop such a model; a model which emphasises the development of real-world learning materials that develop higher-order thinking skills in learners. Another key product of this study is the submission of a comprehensive yet flexible framework for evaluating instructional design models found in the educational literature in order to determine if these design models can be used to develop learning materials for particular contexts.

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Preface

This thesis represents the background theory for my job. At the time of writing I am involved with a small South African company which is developing the kind of learning materials detailed in this study based on GIS technologies and implementing them into a range of South African secondary schools. See Appendix C for examples of these. I am grateful for the opportunity to have a practical focus for a theoretical work such as this. In that regard I would like to thank Clyde Mallinson and his colleagues for getting me interested in GIS technologies and involved in such an innovative scheme. It has also been a perfect opportunity to blend my commercial, business experience and my academic knowledge.

I would like to thank my husband Alex (and his mother, Jessica) who looked after my son Thomas for three weeks in January so that I could complete this thesis and who gave me support and encouragement to complete it when it seemed that it would never happen.

Finally, I would like to thank my supervisor, Cheryl Hodgkinson for believing that I could undertake a purely theoretical study such as this and for being there when I needed her.

Chapter 1 Overview

1.1. Contextualisation

Globalisation, lifelong learning, higher order cognitive skills, information age, diversity, transformation, transdisciplinary education, constant change, capability …

These concepts seem to be unifying themes in education the world over (Luckett and Sutherland, 2000; Gipps, 1996; Moursund, 1995, Dhanarajan, 2000; Galbreath, 1999 and Alexander, 1999); concepts which arise partly from the demands placed on education by the workplace and partly from a general re-assessment of teaching practices (Vogel and Klassen, 2001). Due to these pressures, learners are increasingly expected to employ higher order cognitive skills such as questioning, problem solving, analysis, synthesis, creative and critical thinking, and evaluation.

Reigeluth (1995) talks about the changes in society that have driven the need for a new educational paradigm. "Now that we are entering the information age, we find that paradigm shifts are occurring or will likely soon occur in all of our societal systems, from communications and transportation to the family and workplace. It is little wonder that again we find the need for a paradigm shift in education" (1995:86). He categorises the changes between the industrial age and the information age that affect education (Table 1-1).

Table 1-1 Differences between industrial age and information age that affect education (Reigeluth, 1995:88)

Industrial Age	**Information Age**
Adversarial relationships	Cooperative relationships
Bureaucratic organisation	Team organisation
Autocratic leadership	Shared leadership
Centralised control	Autonomy with accountability
Autocracy	Democracy
Conformity	Diversity
Compliance	Initiative
One-way communication	Networking
Compartmentalisation (division of labour)	Holism (integration of tasks)

He also defines the emerging features for information age based education arising from changes in the workplace (Table 1-2).

Table 1-2 Emerging features for an information based educational systems based on changes in the workplace (Reigeluth, 1995:89)

Industrial Age	**Information Age**
Grade levels	Continuous progress
Covering the content	Attainment-based learning
Norm-referenced testing	Individualised testing
Non authentic assessment	Performance-based assessment
Group-based content delivery	Personal learning plans
Adversarial learning	Cooperative learning
Classrooms	Learning centres

Industrial Age	Information Age
Teacher as dispenser of knowledge	Teacher as coach or facilitator of learning
Memorisation of meaningless facts	Thinking, problem-solving skills and meaning making
Isolated reading, writing skills	Communication skills
Books as tools	Advanced technologies as tools

In both comparisons we can see references to the concepts in the opening paragraph of the chapter.

South Africa has responded to these challenges and forces with Outcomes Based Education (OBE). Enormous effort has been expended in the development of a conceptual framework and in the identification of critical outcomes (skills) across all subject areas that address needs such as problem-solving, team work, fostering critical thinking and preparing students to function in just such an information economy. However, in practice, OBE has been criticised for lacking the necessary tools to develop these critical skills in the learners and to promote cross-discipline learning.

Using information and computer technology (ICT) to provide computer-based learning tools is a potential way of addressing these wider and specific problems. Wadi Haddad, the editor of the US based TechKnowLogia magazine believes that the "integration of modern technologies into the teaching/learning process has great potential to enhance the … environment for learning" (2003:5). He indicates that research and experience have shown that when technologies are well utilised in classrooms, the learning process can be enhanced in many ways including fostering enquiry and exploration, and by allowing students to utilise information to solve and formulate problems.

However, it is not easy to integrate ICT into the learning process and as a result another problem emerges. To be effective in unlocking the potential of ICT, innovative ideas for the creation or design of these computer-based learning tools are required so that learners can develop the critical skills.

One innovative way of offering transformative teaching, instruction and learning that may foster the development of these critical skills, particularly those concerned with critical thinking, is by using geographic information systems (GIS) technologies. A geographic information system (GIS) is a computer-based system for managing, storing, analysing, modelling and visualising spatial information and as a multidisciplinary technology it has relevance beyond its traditional disciplinary home (Zerger, Bishop, Escobar, Hunter, Nascarella, and Urquhart, 2000).

In the USA, the Environmental Systems Research Institute (ESRI) White paper (1998) explains that when a single tool or concept can be employed in multiple educational contexts, cross discipline learning is enhanced. "With GIS, students can learn the value of exploration, wondering and questioning. They can see a single set of information being portrayed in many ways. They can develop their analytical skills, exercise integrative thinking and practice expressing their ideas

effectively to others. … In short, GIS is a tool that promotes lifelong integrated learning" (ESRI White Paper, 1998:17).

For the last twenty years GIS technologies have been used in the workplace and have more recently started being used in tertiary education. Typically this is for learning *about* GIS and achieving specific outcomes related to the job or the discipline. Broda and Baxter (2002) believe that, although the integration of GIS activities into the school curriculum (particularly in the US) is just beginning to gain momentum, the educational potential is enormous. They go on to point out that the use of GIS technologies provides natural opportunities to coordinate instruction so that educators can offer an integrated curriculum and assist learners in understanding the relationships between subjects and disciplines. The scope for using these technologies in secondary education is now being realised for teaching the more generic, cross-discipline skills described whereby students are learning *with* GIS. This realisation provides the opportunity to create flexible, computer-based learning materials that are rooted in authentic, real-world contexts which aim to enhance the cognitive skills of the students.

The creation of these learning materials could involve extending the generic, core capabilities of GIS technologies to build interactive learning materials that allow students to analyse and manipulate the underlying data sets, which will ideally be based on local data. Learning materials could be based around a real-world problem (such as an environmental issue) where the students are required to use the learning material to solve the problem or to present interpretations and judgements. In addition, the learning materials could include collaborative group work exercises, paper-based worksheets and could be used to pull together cross-curriculum project work. In this way, students could work *with* the GIS technologies to enhance their learning and thinking and enhance the capabilities of the computer – in other words as a cognitive tool. *Cognitive tools* have been put forward as a unique way of developing the aforementioned critical skills using ICT and computer-based learning tools (Reeves *et al,* 1997, Jonassen and Reeves, 1996, and Jonassen, 2000). Cognitive tools can be described as both mental and computational devices that support, guide and extend the thinking processes of their users which can be applied to a variety of subject-matter domains (Derry in Jonassen, 1996).

If this is the case and GIS technologies could be used in an innovative way to develop critical outcomes and skills, the final challenge then is how to develop these kinds of learning materials for South Africa and the OBE context, taking into account the relationship between learning, educational practice and psychological research. This leads us to the primary research question or goal for this study.

How does one design a model or framework for developing computer-based learning materials based on GIS technologies for secondary education in South Africa?

1.2. Research goals and questions

To accomplish the primary goal, a number of sub-goals present themselves. Firstly, what definitions can be found in a review of the literature to form the theoretical basis for my study? Here I am looking to define concepts such as higher-order thinking skills and cognitive tools. It will be important to set these definitions against a theoretical backdrop, so learning theories will also be reviewed. Secondly, what characteristics of GIS technologies can be enhanced to allow their use as cognitive tools in an educational setting? This will entail ascertaining the characteristics of GIS technologies and then evaluating them against some sort of criteria for cognitive tools. It is necessary to do this so that we can see some kind of educational value in GIS technologies before continuing with the study and in particular will assist in determining the kind of instruction that can be undertaken with these technologies. In order to create a new or enhanced instructional design model it will be necessary to set down criteria for evaluating instructional design models reviewed by this study. This then leads to the third sub-goal: what evaluation criteria can be selected from the literature to form the basis of an evaluation framework to determine suitable instructional design models? The models found in the literature will then need to be evaluated using these criteria and the process documented. Models that qualify for review will then need to be discussed in detail. The fourth sub-goal is therefore, what principles and guidelines arise from the models can be synthesised to form the elements of a new or enhanced model? Once these goals have been achieved, I should have a means to achieve the primary goal.

1.3. Value of research

First and foremost, by producing a model for the design of learning materials, this study will address a need to design the tools needed by South African teachers to develop the critical skills in an original, progressive and stimulating manner.

The study builds on, integrates and extends existing work on cognitive tools by evaluating GIS technologies as cognitive tools. In addition, it forges links between instructional design practice and cognitive science/psychology.

A comprehensive evaluation framework is also created as a consequence of the study. It is hoped that this will contribute to the existing research for ICT evaluations whilst at the same time being specific enough to be used in the field of instructional design.

As will be appreciated from literature discussed in section 3.2 on page 42 there is little evidence of formal, academic research into instructional design in South Africa. It is important that South Africa

adds its voice to the discipline. In this regard, the author of this study is currently working for a commercial company creating the kind of product being researched. This research will feed into that practice and will serve to make a better product for South African learners so that they can take their place with confidence on the world stage. In an *Educational Technology* journal article in 2000, Hung and Wong identified twelve fruitful areas for information and instructional technology research in Singapore. Of significance for this study and for South Africa are those of 'mind-tools or cognitive tools', 'simulation, visualisation and modelling' and 'tools for project work': this study is concerned with each of these areas. It is hoped therefore, that further papers and articles will arise from this study in the fields of GIS, instructional design and education.

1.4. Research Design and Methodology

This section identifies the underlying methodology used for this study, as well as explaining and justifying the methods, tools and data analysis methods used.

As this study focuses on creating a new or enhanced theoretical framework which is intended to be used in practice, this study will use the *developmental research method* as described by Richey and Nelson (1996). *Developmental research* is a methodology that is specific to the field of instructional design and may be unfamiliar to the broader community of educational researchers. For this reason, this section will give a little background to the topic in order to achieve some clarity.

Rita Richey and Wayne Nelson present the developmental research methodology in a chapter of the *Handbook of research for educational communications and technology* edited by David Jonassen and all references here pertain to this chapter except those specifically stated. Developmental research can be defined as "the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness" (Seels and Richey cited in Richey and Nelson, 1996:1213). Developmental research is a blend of knowledge production with the "ultimate aim of improving the processes of instructional design, development and evaluation" (p1213).

Richey and Nelson distinguish between simple instructional development and developmental research. They indicate that instructional development "typically builds on previous research" (p1216) while developmental research endeavours to "produce the models and principles that guide the design, development and evaluation processes" (p1216). In their view, there are two general types of developmental research: type 1 and type 2. The differences are shown in Table 1-3 below.

Table 1-3 A summary of the two types of developmental research (Richey and Nelson, 1996:1217)

	Type 1	**Type 2**
Emphasis	Study of specific product or program design, development and / or evaluation projects	Study of design, development, or evaluation processes, tools or models
Product	Lessons learned from developing specific products and analysing the conditions that facilitate their use.	New design, development and evaluation procedures and / or models and conditions that facilitate their use.
	Context-specific conclusions	*Generalised conclusions*

Type 2 developmental research typically addresses the design, development and evaluation processes themselves rather than a demonstration of such processes. The ultimate aim of this type of developmental research is to produce knowledge in the form of a new (or enhanced) design or development model. This study falls under type 2, which is oriented towards "a general analysis of **either** [emphasis added] design, development or evaluation processes as whole or any particular component" (p1217). Richey and Nelson go on to point out that the fundamental purpose of type 2 research is the production of knowledge "in the form of a new (or enhanced) design or development model" (p1225). In this study I will be enhancing the **design** component (analysis and planning for development, evaluation, use and maintenance) of an instructional design model. This is similar to the type of research that Driscoll terms 'model development' (1995:324) and is an attempt to implement her advice: "as learning environments grow more diverse and learners participate more in determining what they will learn, new models of instructional design or substantial revisions to old ones may be warranted" (1995:326). It is extremely important to note at this stage that this study will not attempt to carry out the full range of developmental research on this study due to the limited scope of a half thesis in a coursework masters. This study only attempts to cover the first stage[1] in developmental research and as such is a limitation of the study. This study will **not** include research into the actual process of development of the *learning material*s nor evaluation of the framework itself in a working situation.

Other key characteristics of this type of research are that:

- This kind of research does not begin with the actual development of the product but rather concentrates on previously developed instruction and / or models of instructional design
- These studies employ a great diversity of research methods and tools
- Research questions rather than hypotheses may guide these types of studies

[1] This may be extended into PhD thesis whereby the learning materials are developed, distributed to schools and used by learners and then evaluated to determine their effectiveness.

However, this particular study is context-specific in that a new framework is to be proposed for **specific** modules in South Africa; therefore it does have some characteristics of the type 1 studies. As such it will produce situation-specific recommendations and context-specific conclusions, which may, by extension be generalised to other contexts. This study is concerned with the scope and unique conditions that it operates within, as these will affect the extent to which the conclusions may be generalised.

I have situated my research within the framework employed by Richey and Nelson (1996:1226) for describing developmental research studies. (See Appendix B for a summary of the stages they suggest). The type of program or product developed in this study is a computer-based instructional module that I identify as 'learning materials'. The study focuses on the general design phase of the instructional design process. The learning materials are designed and as such will be used in the context of secondary schools. The nature of the conclusions are general with reference to some context specifics. The conclusions also pertain to a particular model not a product / programme.

For clarity, I would also like to orientate this study within another framework that is referred to quite extensively with the field of instructional design. Reeves (1995:3-4) proposes that instructional technology research studies can be classified according to six research goals:

- Theoretical--research focused on explaining phenomena through the logical analysis and synthesis of theories and principles from multiple fields with the results of other forms of research such as empirical studies.
- Empirical--research focused on determining how education works by testing hypotheses related to theories of communication, learning, performance, and technology.
- Interpretivist--research focused on portraying how education works by describing and interpreting phenomena related to human communication, learning, performance, and the use of technology.
- Postmodern--research focused on examining the assumptions underlying applications of technology in human communication, learning, and performance with the ultimate goal of revealing hidden agendas and empowering disenfranchised minorities.
- Developmental - research focused on the invention and improvement of creative approaches to enhancing human communication, learning, and performance though the use of theory and technology.
- Evaluation - research focused on a particular program, product, or method, usually in an applied setting, for the purpose of describing it, improving it, or estimating its effectiveness and worth.

Without doubt, this study falls within the '*developmental*' goal as it is focused on inventing or improving approaches used to enhance learning through both the use of theory from research literature and GIS as a technology. It is also *theoretical* in its goals as the basis is not empirical. I have found these goals a useful way of categorising what I have done when researching each of the subsidiary questions. (See Table 1-4 on page 11 to see how I have applied these categories to my study).

As indicated by Richey and Nelson in their developmental research chapter, developmental research is characterised by the use of a wide variety of research methods such as case studies, action research, evaluations, descriptive surveys, or experimental methods. This study uses primarily literature review and meta-analysis. According to Driscoll (1999), meta-analysis is a non-experimental technique that uses previously reported research findings as its 'subjects'. It can help us come to global conclusions as to whether previously research instructional technology has an effect on learning and how large the effect is (Driscoll, 1999). As indicated by Richey and Nelson (1996), the conceptual framework for this study will be found in the literature from actual practice environments as well as from traditional and commercial research literature. In the first instance, the literature was reviewed for the methodology of developmental research to form the research basis for the study. The literature has also been reviewed to reveal characteristics of effective instructional products and processes, and for factors that have impacted on the use of the targeted design process in other situations. This review feeds into the third sub-question which is concerned with forming an evaluation framework to filter instructional design models for review. Procedural models have then been examined that have relevance to this study. This is one of the core goals for this study and is concerned with extracting principles and guidelines that can be synthesised into an enhanced model.

Richey and Nelson reveal that there may be several populations or samples in developmental research projects. For this project, establishing the population and sample (in the form of instructional design models), is an integral part of the study itself, although the assumption was made in the first instance that only cognitive and constructivist informed instructional design models would make up the study population and not those concerned with the objectivist / behaviourist approach to learning. Chapter 3 forms the basis for establishing the sample, whilst the actual sample is ultimately defined in Chapter 4.

Richey and Nelson state that the research design should address both the development and traditional research facets and that the critical design and development processes should be explained along with the traditional research methodologies such as case studies, surveys etc. As stated previously, due to limited scope, this project does not report on the full range of an

instructional design project, only the design phase. However, the author of this study is currently involved in developing the learning materials described in this study. At the time of writing, the development of first set of learning materials is complete and are ready for distribution to schools. At this time, the learning materials are not being used, so the evaluation phase of the project is dependant on their implementation and acceptance by schools. When that time comes, a proper evaluation will be undertaken in conjunction with the learners, designers and teachers. The research method is purely descriptive based on the extensive literature review: a descriptive survey. As can be seem from the context, this project cannot be viewed as a case study, nor can it be seen as an evaluation.

1.4.1. Data gathering procedures

The extensive literature review drives the data collection process. Literature has been gathered comprehensively from books, journals, magazines and selectively from trusted sources on the world wide web such as forums[2] where well-known authors in this field contribute as well as papers and conference proceedings that have been made available. The goals of this project have determined the topics needed for data collection: GIS technologies, instructional design and instructional design models, learning theories (particularly those with a cognitive and constructivist approach), cognitive tools and assessment to name the most obvious.

Fortunately, due to the nature of data collection in this study, validity threats or ethical issues are of an academic nature as there are no people or institutions involved. To ensure that the data analysed is valid I have made certain that all literature is from a reliable source such as a book, peer-reviewed, moderated journal or educational magazine. As indicated with web references, these are also from identifiable and trustworthy sources. I have applied a rigorous, academic method for referencing and using other researchers work. To avoid the possibility that materials from the web are no longer available, and to facilitate the finding of these articles by examiners, these have been downloaded and copied to a CD-ROM which accompanies this thesis. These are identified in the reference chapter with a 🖫 symbol. In addition, the page numbers referred to with these articles, refer to the page number shown in a Print Preview function from either a word-processor or Internet browser. In terms of providing triangulation of data, where possible, more than one author on a particular topic has been reviewed and contrasted. In addition, the developmental work in Chapter 2 whereby GIS technologies are evaluated as cognitive tools, has been peer-reviewed by a GIS professional.

[2] For example, extensive use has been made of the ITForum (http://itech1.coe.uga.edu/itforum/) and authors such as T. Reeves, C. Reigeluth and D. Jonassen.

1.4.2. Data analysis procedures

I have made extensive usage of descriptive data presentations, qualitative data analyses using data from documentation and comparative analyses. Much of the data collected has been initially analysed in the form of matrices or tables. The data has then been examined for connections and relationships, and meta-categories have often been established from which to base comparative analyses. In Chapter 4, a weighted scoring matrix was used to apply priorities to various criteria and then to assign scores against those evaluation criteria for each instructional design model reviewed.

Table 1-4 on page 11 provides a summary of the entire research design. The research goal, method, data collection method and data analysis method are detailed for each sub-question.

Table 1-4 Summary of research design

	Subsidiary research questions	**Research Goal** **(Reeves, 1995)**	**Research Method**	**Data collection** **(Topic and type of literature reviewed)**	**Data analysis**
1	*What definitions can be found in a review of the literature to form the theoretical basis for my study? (Particularly, higher order thinking and cognitive tools)*	**Theoretical**	Literature review and meta-analysis	*Topics*: Cognitive tools Higher-order thinking Thinking Learning theories *Types*: Books Journals	Qualitative data analysis Comparative analyses
		Developmental	Establish own definition of higher-order thinking skills and cognitive tools		Descriptive data presentation
2	*What characteristics of GIS technologies can be enhanced to allow their use as cognitive tools in an educational setting?*	Theoretical	Literature review to determine GIS technologies characteristics and to find out how to evaluate as a cognitive tool	*Topics*: GIS specific literature Cognitive tools evaluation *Types*: Journals Conference proceedings	Qualitative data analysis
		Developmental	Evaluate GIS technologies against each cognitive tools criteria to provide theoretical evidence for or against		Descriptive data presentation
3	*What evaluation criteria can be selected from the literature to form the basis of an evaluation framework to determine suitable instructional design models?*	Theoretical	Literature review and meta-analysis	*Topics*: Computer-based education evaluation Computer-aided instruction evaluation Instructional design evaluation Web site evaluations *Types*: Journals Web articles Forum papers	Qualitative data analysis Comparative analyses
		Developmental	Establish evaluation framework to apply models against Establish means of prioritising criteria and scoring models Establish research sample		Descriptive data presentation Weighted scoring matrix
4	*What principles and guidelines that arise from the models can be synthesised to form the elements of a new or enhanced model?*	Theoretical	Synthesis of filtered models	*Topics*: Instructional design models *Types*: Journals Online journal papers	Descriptive data presentation
		Developmental	Creation of new or enhancing of existing model		Comparative analyses

1.5. Structure of the thesis

As this thesis is slightly different to those normally presented at masters level, the structure needs to reflect this. The thesis is structured to align with each sub-goal as is shown in Figure 1-1 below and as can be seen each sub question supports the primary research question. As a result, *Chapter 1* combines what would normally be split into two chapters and both contextualises the work and details the research methodology and design. *Chapter 2*, entitled "GIS technologies and the development of higher-order cognitive skills" deals with the first subsidiary question and explores the concepts of higher-order thinking skills and cognitive tools and underpins these discussions with a brief review of learning theories. The final, developmental part of this chapter attempts to evaluate GIS technologies as cognitive tools using David Jonassen's evaluation criteria. *Chapter 3* moves onto finding criteria from the literature that are used to evaluate technology-based learning from various sources. The chapter concludes with a new framework for evaluating instructional design models. In *Chapter 4*, the literature is again reviewed to find suitable instructional design models so that they can be evaluated against the evaluation framework. The chapter also includes a detailed description of those models that qualify from the evaluation. The research culminates in proposing an enhanced instructional design model called GIS3D in *Chapter 5*. The project is drawn to a conclusion in *Chapter 6*.

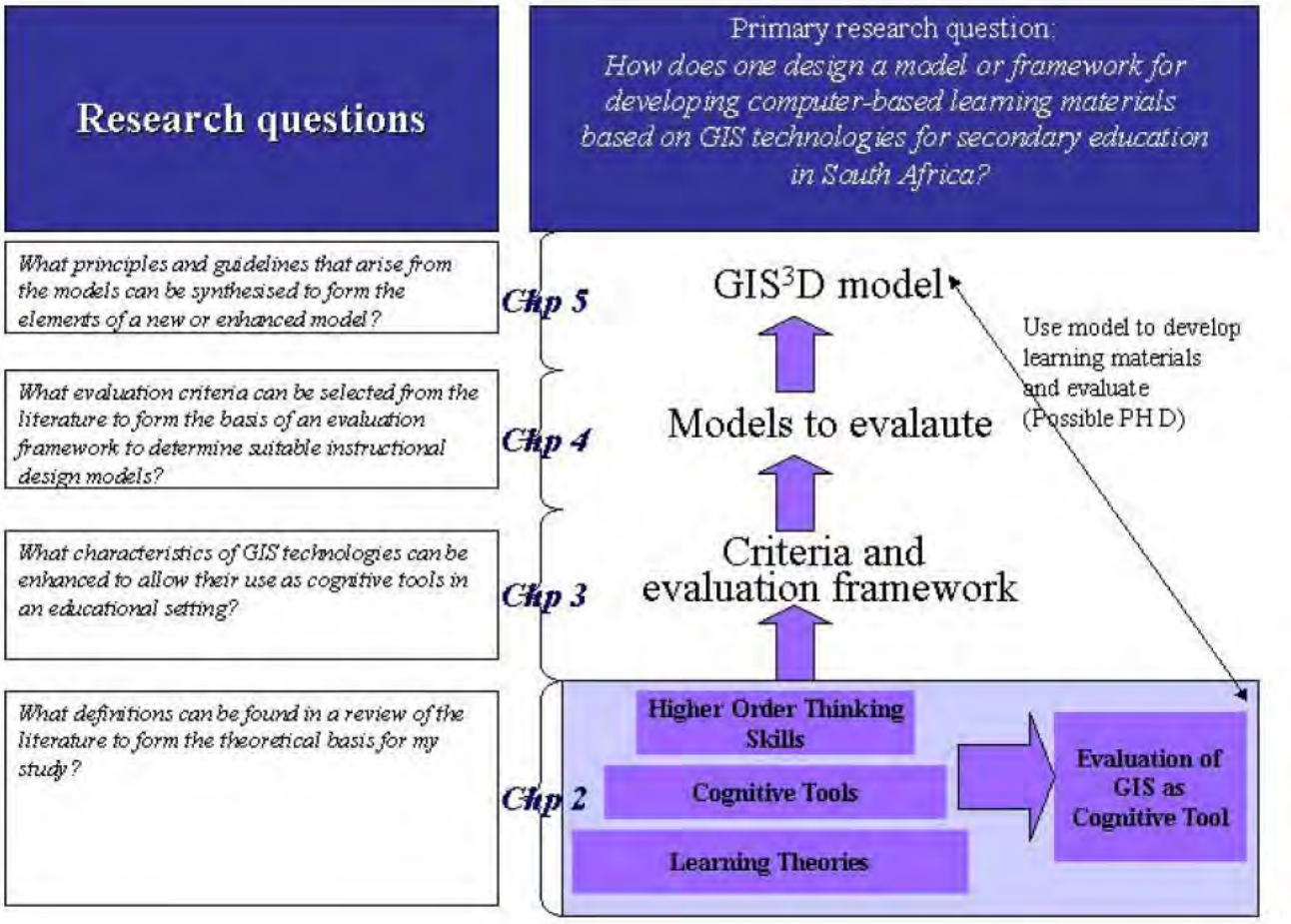


Figure 1-1 Summary of relationship between thesis structure and research goals

Chapter 2 GIS technologies and the development of higher-order cognitive skills

2.1. Introduction

The primary research question for this study is to try and determine how one designs a model for developing computer-based learning materials based on GIS technologies for secondary schools in South Africa. But why should these learning materials be based on GIS technologies?

Geographic information systems (GIS) technologies have been put forward as one new way of offering transformative teaching and learning that fosters development of higher-order cognitive skills.

This statement raises a series of questions: what are higher-order cognitive skills; why do we want to foster these skills in the first place; and does GIS really assist in fostering these skills? In other words, *to what extent can the literature provide evidence for this statement?* It is the intention of this chapter to find the theoretical evidence to support the above claim and to address these associated questions by examining the assumptions made about the links between GIS technologies, higher-order thinking (cognitive) skills, cognitive tools and learning theories in turn. As such it lays the conceptual and theoretical foundations for the remainder of this study. It also arrives at working definitions of higher-order thinking skills and cognitive tools for the purposes of this research project. The chapter makes explicit the learning theories within which these definitions of cognitive tools and higher-order thinking skills are located.

Most importantly, from a developmental research point of view, the final section of the chapter explores the characteristics of GIS technologies that could be exploited as cognitive tools and attempts to provide theoretical evidence of this using the Integrated Thinking Model and cognitive tools evaluation criteria adapted from Jonassen (1996).

2.2. Higher Order Thinking Skills

Higher-order thinking is a phrase much used in educational contexts in recent times. But what is higher-order thinking and why is it so important? This section aims to ascertain what people say about its importance and to find out what higher-order thinking actually is. It intends to define higher-order thinking skills and looks at how various researchers have created models to represent these skills. The section will also explore critical and creative thinking as two kinds of higher-order thinking skills. It is important to note that this section will not include a review of the developmental stages of thinking in children and learners, nor will it seek to create a new model of higher-order thinking skills, as this is not the objective of this research.

Why do we want learners to become good thinkers? There are many ways of answering this question, a few of which have been explored in the paragraphs below.

It may be that we want learners to be well equipped to compete in today's world; for educational opportunities, jobs etc; to be more successful (Baron and Sternberg, 1987). Baron and Sternberg emphasise, that in fact we cannot afford for our students **not** to be good thinkers as society faces many "complex and threatening problems". Dunlap and Grabinger add their voice to this concern and assert that "learning to think critically and to analyse and synthesize information to solve technical, social, economic, political and scientific problems are crucial for successful and fulfilling participation in a modern, competitive society" (1996:65).

Johnson provides us with a view of 'good thinking' from a curriculum development stance: "while our knowledge about subjects can change, fade or become obsolete, our ability to think effectively remains constant. Effective thinking strategies allow us to acquire the necessary knowledge and apply it appropriately. […] If students are to learn higher and more complex ways of thinking, and if we are to move beyond knowledge-transmission models of teaching, it makes sense that thinking skills instruction be examined as a potential tool to use in enhancing the curriculum" (2000:1).

Another perspective, provided by Vogel and Klassen (2001) is that demands placed on education by the workplace and a general re-assessment of teaching practices have made the issue of producing 'thinking' students more prominent in our minds. Galbreath (1999:19) believes that school "learning environments must focus on teaching skills and techniques [that teach] how to cope and succeed in unknown, unstable and unpredictable environments. Nothing about the knowledge age and especially the business world is stable and predictable." He goes on to say that by using new and expanded approaches in the learning environment, the critical skills needed for the knowledge age worker will be developed. Amongst others, Galbreath lists these skills as key for the knowledge worker in the 21st century: innovation and creativity, problem solving and decision-making. Vogel and Klassen (2001:104-105) are of the same opinion and indicate that learners are now being expected to apply higher cognitive skills such as analysing, summarising and synthesising and are expected to engage in creative and critical thinking. Luckett emphasises that "graduates are required to know how to acquire new knowledge and how to use knowledge as a resource" (1995:126). She points out that it is government and employers who value research, co-operative problem solving and entrepreneurial initiative skills. She also draws our attention to an Australian report on Employment, Education and Training, in which they maintain that the most compelling feature in under-graduate education should be life-long learning and that any "life-long learner should have an inquiring and critical mind" (1995:126).

It would seem then, that the skills that are required for our learners to acquire are diverse, complex and numerous. A review of the literature on this subject reveals a bewildering array of theoretical definitions and models. To begin with I will explore the concept of higher-order thinking skills itself. I will then look in some detail at critical thinking and creative thinking which are seen as two types of higher-order thinking (Fisher, 1995; Ennis, 1992; Johnson, 2000; Hawes, 1990).

2.2.1. Higher-order thinking skills

Higher-order thinking skills are "relatively complex cognitive performances, the ultimate purpose of which is not efficient use of memory but **problem solving** [emphasis added]" (Wakefield, 1996:409). Johnson (2000:5) adds that "high level thinking is any cognitive operation which is complex or places high demand on the processing taking place in the learner's short term memory." Wakefield highlights that "although there is no fixed list of higher-order thinking skills, the categories of analysis, synthesis and evaluation in Bloom's taxonomy are generally considered representative of them. These categories collectively correspond to a procedure for solving problems" (1996:409). Wakefield claims, "the nature of higher-order thinking is so actively debated among philosophers and psychologists that several overlapping categories and definitions have been created" (1996:409). Figure 2-1 shows how Wakefield categorises skills into lower and higher-order thinking using Bloom's skills categories as a basis.

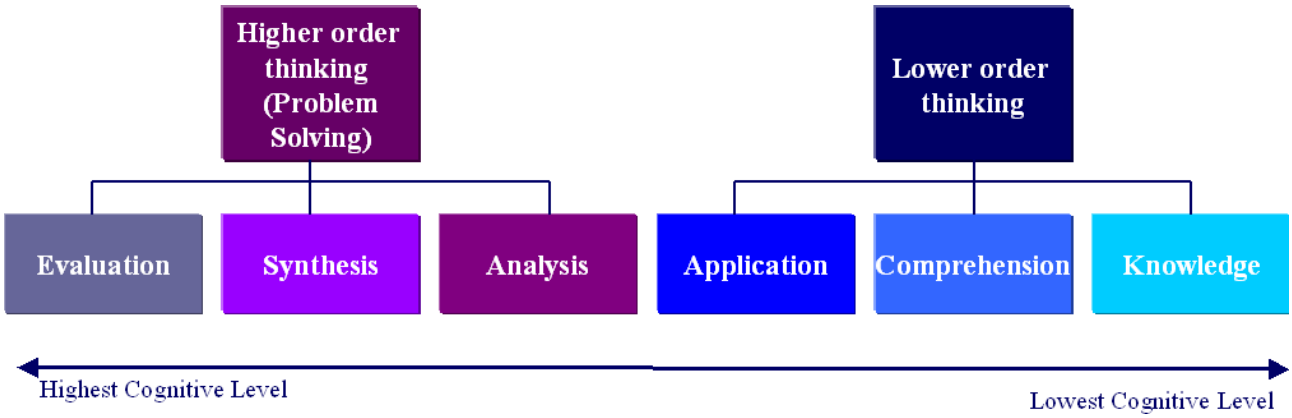


Figure 2-1 Taxonomy Categories & Higher Order Thinking (Adapted from Wakefield, 1996)

Wakefield (1996:409) points out "the outcome of higher-order thinking is now increasingly being referred to a **generative learning** [original emphasis], or the construction of knowledge. The assumption behind generative learning is that all knowledge is constructed. Process is emphasised as much as, if not more than, product. The focus of teaching shifts from content learning to cognitive skills learning. Educators agree that there is a trade-off between the two types of learning, but we can also assume that they exist in a dynamic balance that depends upon the particulars of each situation" (Wakefield, 1996:409).

Wakefield (1996:410) offers alternative terms for higher-order thinking:

Higher-order thinking	A general all encompassing term for complex thinking skills. Depending on the context it can refer to critical thinking, problem solving or metacognition.
Critical thinking	Refers primarily to evaluative skills, but these vary widely in definition.
Problem solving	Refers to a stage like process for attaining a goal. Occasionally it is still used in the narrow sense of solving a well-defined problem but, increasingly, the term refers to finding as well as solving any kind of problem – an unending process involving analysis, synthesis and evaluation. As used in this context, problem solving is functionally equivalent to higher-order thinking.
Metacognition	Refers to an awareness of one's own thought processes. It can also pertain to the skills involved in the conscious use of such thought processes. Problem solving skills are a form of metacognition, so metacognition is sometime considered to be a more inclusive term than problem solving.

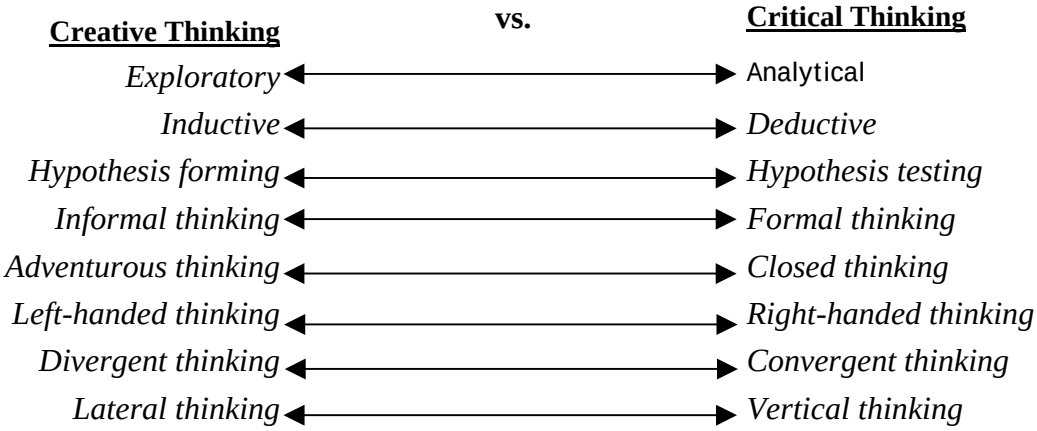
In South Africa, this kind of thinking is referred to as *reflexive competence* whereby the "learner demonstrates ability to integrate or connect performances and decision-making with understanding and with an ability to adapt to change and unforeseen circumstances and to explain the reasons behind these adaptations" (Council on Higher Education, 2001:98).

As an extension to these definitions, Jonassen provides a list of the key features of higher-order thinking originally provided by Resnick and Klopfer.

- "Higher-order thinking is nonalgorithmic. That is, the path of action is not fully specified in advance.
- Higher-order thinking tends to be complex. The total path is not visible (mentally speaking) from any single vantage point.
- Higher order thinking often yields multiple solutions, each with costs and benefits, rather than a unique solution.
- Higher order thinking involves nuanced judgment and interpretation.
- Higher order thinking involves the application of multiple criteria, which sometimes conflict with one another.
- Higher order thinking involves self-regulation of the thinking process. We do not recognise higher order thinking in an individual who allows someone else to "call the play" at every step.
- Higher order thinking involves imposing meaning, finding structure in apparent disorder.
- Higher order thinking is effortful. There is considerable mental work involved in the kinds of elaborations and judgments required" (Jonassen, 1996:26-27).

From the definitions given by Wakefield, higher-order thinking can also be referred to as critical thinking and creative thinking. Again, the literature reveals numerous conceptions or interpretations of these kinds of thinking and both have a long history as educational goals (Ennis, 1992).

Fisher (1995:32) draws these distinctions between the two as being at opposite ends of a continuum.



He points out however, that one of the misconceptions is that creative thinking is totally unrelated to critical thinking. He believes that "creativity is not merely a question of generating new solutions to problems but of creating *better* solutions" (Fisher, 1995:64). True creativity therefore requires the use of *critical* thinking.

This view is supported by Walters (cited in Jonassen, 1996) who maintains that there is a more holistic view of rationality that includes intuition, imagination, conceptual creativity, and insight. He argues that much of the bandwagon effect of critical thinking assumes that critical thinking is logical thinking. Although Walters agrees that logical inference, critical analysis, and problem solving are fundamental elements of good thinking, they are practically useful only if they are supplemented by imagination, insight, and intuition, which he considers essential components of discovery. He further believes that students will not appreciate the multiple perspectives necessary for meaningful knowledge construction if one simply concentrates only on logical thinking. Johnson (2000) states simply that critical thinking is complimented by creative thinking. This leads us to examine what researchers say about differences between critical thinking and creative thinking.

Hawes (1990) points out that there are many different meanings for *critical thinking* but attempts a broad characterisation of critical thinking as some kind of reasoned or reasonable evaluation and for describing activities that require careful judgement and "sustained reflection" (Hawes, 1990:48).

Fisher (1995:65-96) describes critical thinking as how something is being thought about. For him, learning to think critically means learning how to question, knowing when to question and what questions to ask, learning how to reason, knowing when to use reasoning and what reasoning

methods to use. Fisher (1995) believes that certain strategies can be used to foster critical thinking. He states that it is important that learners understand the purpose of their learning and thinking so that they will be in a better position to judge and understand those purposes at a later stage. Another strategy is learning the ability to evaluate, as this is fundamental to critical thinking. The process of evaluation involves developing using judgement criteria. Once criteria are distinguished, learners can be asked to judge between them. "Only by exercising critical judgement will they [learners] learn to become critical and fair-minded thinkers" (1995:74). As will be appreciated later, these strategies such as learners understanding the purpose of their learning and the ability to evaluate (reflect) are closely related to some of the core principles of constructivist learning.

Johnson (2000:28) defines *creative thinking* as a "cognitive process that leads to new or improved products, performances or paradigms. It is a quality of thought that allows an individual to generate many ideas, invent new ideas, or recombine existing ideas in a novel fashion." "Creativity seldom happens by accident; rather it is purposeful, requiring preparation, hard work and discipline" (p30). Johnson stresses that creativity is not "an event, but a process" (p30). Fisher (1995:30) defines creative thinking as "imaginative, inventive and involves the generation of new ideas" (p64). It is a way of generating ideas and developing attitudes that can in some way be applied to the world. "This often involves problem solving utilising particular aspects of intelligence, for example linguistic, mathematical and interpersonal" (p38).

What is clear from this brief review on higher-order thinking is that there is great complexity and no clear definitions of what higher-order thinking actually is and that there are many overlaps in definitions. When Jonassen (1996) wanted a single conception of critical and creative thinking as a means of comparing and contrasting the effects of using "mindtools"[3], he discovered and utilised the Iowa Department of Education's Integrated Thinking Model (Jonassen, 1996). He believes that this model is "one of the most comprehensive and useful models of critical thinking" (Jonassen, 1996:27). He goes on to explain the important aspects of this model: a system and processes. Firstly complex thinking skills are portrayed as an interactive system rather than a "collection of separate skills" (p27). Secondly, it describes the various processes that are referred to as "thinking" and their relationships to each other.

The model is made up if three basic components: content/basic thinking, critical thinking and creative thinking which are portrayed as three ellipses surrounding the complex thinking core as shown in Figure 2-2 below. This core includes the "goal-directed, multi-step, strategic processes, such as designing, decision making and problem solving. This is the essential core of higher-order

[3] These are defined in detail in the subsequent sections of this chapter, however a brief definition of *mindtools* is: computer applications that require learners to think meaningful ways in order to use the application to represent what they know (Jonassen, 2000).

thinking, the point at which thinking intersects with or impinges on action" (p27). The core makes use of the other types of thinking in order to produce some kind of outcome – a design, a decision or a solution. Jonassen describes each of the three types of thinking as follows. Due to space restrictions here, the skills are only described briefly. (Refer to Appendix A on page 123 for full descriptions and differentiations of the skills).

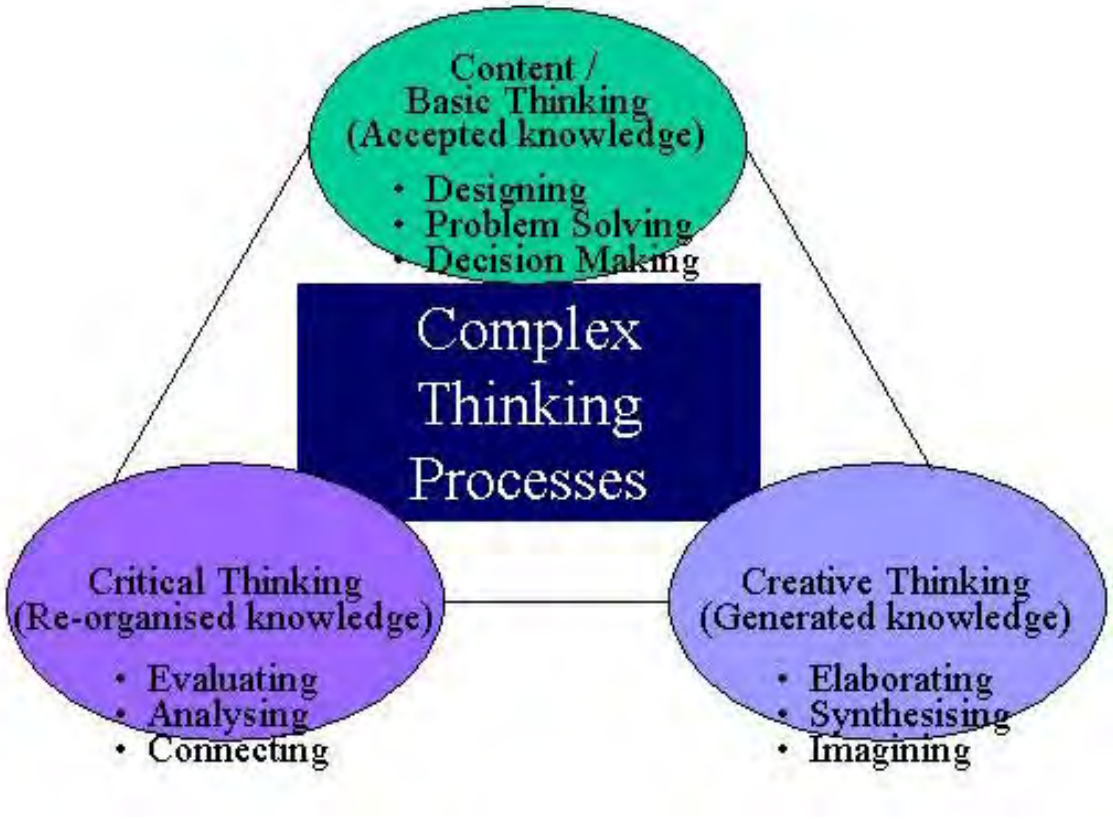


Figure 2-2 Integrated Thinking Model (Adapted from Jonassen, 1996)

- . *Content/basic thinking*

This kind of thinking includes the dual process of learning and retrieving what has been learned by representing the skills and attitudes required to learn basic academic content, general knowledge and to be able to recall this information after it has been learned. There are two important issues here. One is that that this thinking describes traditional learning and the other is that, in this model, there is constant interaction with the other forms of thinking as this thinking forms the 'knowledge base' from which learners operate (p29).

- . *Critical thinking*

Dynamic re-organisation of knowledge in meaningful and usable ways is the focus of critical thinking. Three general skills are involved: evaluating, analysing and connecting.

Evaluating involves making judgements about something by measuring it against a standard. It is not expressing a personal attitude or feeling. It involves recognising and using appropriate criteria

in different instances (p29). *Analysing* involves separating a whole entity into its meaningful parts and understanding the interrelationships of those parts, which helps learners, understand the underlying organisation of ideas (p30). *Connecting* involves determining or imposing relationships between the wholes that are being analysed. Connecting compares and contrasts things or ideas, looks for cause-effect relationships and links the elements together (p30).

- *Creative thinking*

When thinking goes beyond accepted knowledge to generate new knowledge, creative thinking happens. Critical thinking and creative thinking are closely linked. Critical thinking makes sense out of the information using more objective skills whilst creative thinking uses more personal and subjective skills in the creation of new knowledge. The major components of creative thinking are: synthesising, imagining and elaborating.

Elaborating involves adding personal meaning to information by relating it to personal experiences or building on an idea (p32); *synthesising* involves skills such as summarising, hypothesising and planning (p31); and finally, *imagining* involves intuition, fluency of thinking, visualisation, speculation and predication (p31).

- *Complex thinking skills core*

Finally at the heart of the model are complex thinking skills. These thinking processes combine the skills from the other areas into larger, action-oriented processes such as problem solving, designing and decision making, each of which involve a number of steps (p33).

Designing involves inventing or producing new artistic, scientific or mechanical products or ideas in some form. It involves analysing the need and then planning and implementing this new product (p33). *Problem solving* involves systematically pursuing a goal, usually the solution of a problem. *Decision making* involves selecting between alternatives in a rational, systematic way. It includes awareness and manipulation of objective and subjective criteria (p34).

So where does this leave higher-order thinking skills for this study? As a working definition of higher order thinking for this study, I have drawn heavily from Wakefield (1996:409) as this aligns most closely with my theoretical standpoint on learning as will be seen later in this chapter.

*For the purposes of this study, **higher-order thinking** will refer to generative learning which is thinking / learning based on the premise that all knowledge is constructed. The process is emphasised as much as, if not more than, the results and the focus of teaching shifts from content learning to cognitive skills learning.*

However, a textual definition does not provide a sufficient description for working with particular thinking skills. So, like Jonassen, I will use the Integrated Thinking Model in the remainder of this chapter. This model will be used to determine whether GIS technologies could be considered as cognitive tools. (See section 2.6.2 on page 40 and section 2.6.3 on page 42 for further details).

2.3. Cognitive Tools

Wadi Haddad, the editor of the US based *TechKnowLogia* magazine contends that the "integration of modern technologies into the teaching/learning process has great potential to enhance the tools and environment for learning" (2003:5). He indicates that research and experience have shown that when technologies are well utilised in classrooms, the learning process can be enhanced in many ways including fostering enquiry and exploration, and by allowing students to utilise information to formulate and solve problems. If these technologies are to be really effective in realising this potential, many researchers and writers believe the technologies must be employed as *cognitive tools*. As computers have become more and more common in education, researchers have begun to explore the impact of software as cognitive tools in schools (Jonassen & Reeves, 1996). The aim of this section therefore, is to understand what cognitive tools are, how they differ from other computer-based learning or media and to understand their characteristics.

Reeves (1998:18-19) reveals that cognitive tools have been around for "thousands of years, ever since primitive humans used piles of stones, marks on trees, and knots in vines to calculate sums or record events." Indeed, Bruner believes that the evolution of man can be attributed to his use of tools: "man's use of mind is dependent upon his ability to develop and use 'tools' or 'instruments' or 'technologies' that make it possible for him to express and amplify his powers" (1996:24). He asserts that it is not the tool itself but the program that guides its use that is important. "It is in this broader sense that tools take on their proper meaning as ***amplifiers*** of human capacities and implementers of human activity" [emphasis added] (Bruner, 1996:81). It is this idea of '*amplification of the human mind*' that serves as a central theme in this discussion of cognitive tools. Bruner (1996) classifies amplification tools into three classes: amplifiers of sensory capacities (microphones, hearing aids etc.), amplifiers of motor capacities (tools that bind things together, separate them etc.) and amplifiers of ratiocinative (reasoning) capacities (soft tools: mathematics, logic; hard tools: abacus, computers and animation). These classifications are significant because they show the range of human tools: those that we actually regard as tools and those that we use but don't regard as tools. The concept of cognitive tools builds on the 'hard tools' idea of amplifiers of ratiocinative capacities namely computers. Jonassen and Reeves (1996) are of the same opinion that a theoretical perspective of tools is that some are powerful without having a tangible physical substance. They point out that these are diversely referred to as: *cognitive technologies* by Pea

(1985), *technologies of the mind* by Saloman, Perkins and Globerson (1991), *cognitive tools,* by Kommers, Jonassen and Mayes (1992) and *mindtools* by Jonassen (1996).

Jonassen and Reeves (1996) offer this definition of cognitive tools:

> *"Cognitive tools refer to technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem solving and learning. Written language, mathematical notation and most recently, the universal computer are examples of cognitive tools"* (Jonassen and Reeves, 1996:693).

A complex mathematical formula or a simple shopping list can also be regarded as a cognitive tool in the sense that each allows humans to divest themselves of memorisation or other mental tasks onto an external resource.

Jonassen and Reeves believe that cognitive tools are distinctly different from other technologies, which they refer to as **media,** as these are simply communicators of information and fail to recognise that learners actively construct their own view of knowledge. "In cognitive tools, information is not encoded in predefined educational communications that are used to transmit knowledge to students" (1996:693). The technologies are taken away from the specialists and given to the learners to use as a means of expressing and representing what they know and "using the technologies for analysing the world, accessing information, interpreting and organising their personal knowledge and representing what they know to others" (1996:694). Reeves (1998) adds that computer-based cognitive tools have been intentionally adapted or developed to function as "intellectual partners to enable and facilitate critical thinking and higher order learning (1998:3). Examples of such cognitive tools include databases, spreadsheets, semantic networks, expert systems, communications software such as teleconferencing programs, on-line collaborative knowledge construction environments, multimedia/hypermedia construction software, and computer programming languages. Reeves (1998) also makes note of another important difference. "Learning '*from*' media and technology is often referred to in terms such as instructional television, computer-based instruction or integrated learning systems. Learning '*with*' technology, less widespread than the 'from' approach, is referred to in terms such as cognitive tools and constructivist learning environments" (Reeves, 1998:5).

Jonassen and Reeves (1996) caution that cognitive tools could fall victim in the same way other technology based ideas for teaching and learning have unless they have a strong foundation in theory and practical principles (1996:695). Reeves (1998) emphasises that the nature and source of the task or problem is paramount in applications of cognitive tools. He believes that "past failures of 'tool' approaches to using computers in education can be attributed largely to the relegation of the tools to traditional academic tasks set by teachers or the curriculum. Cognitive tools are intended to

be used to represent knowledge and solve problems while pursuing investigations that are relevant to users own lives. These investigations are ideally situated within a constructivist learning environment. Cognitive tools won't be effective when used to support teacher-controlled tasks alone" (Reeves, 1998:22-23).

Jonassen and Reeves' (1996:698) chapter on cognitive tools provides the detail behind the following summary of cognitive tools research.

- Cognitive tools will have their greatest effectiveness when they are applied within constructivist learning environments.
- Cognitive tools empower learners to design their own representations of knowledge rather than absorbing representations preconceived by others.
- Cognitive tools can be used to support the deep reflective thinking that is necessary for meaningful learning.
- Cognitive tools have two kinds of important cognitive effects: those which are with the technology in terms of intellectual partnerships and those that are of the technology in terms of the cognitive residue that remains after the tools are used.
- Cognitive tools enable mindful, challenging learning rather than the effortless learning promised but rarely realised by other instructional innovations.
- The source of the tasks or problems to which cognitive tools are applied should be learners, guided by teachers and other resources in the learning environment.
- Ideally, tasks or problems for the application of cognitive tools will be situated in realistic, authentic contexts with results that are personally meaningful for learners.

2.3.1. Characteristics of cognitive tools

The following characteristics of cognitive tools can be highlighted:

- "They are computer-based tools and / or learning environments that are adapted or developed to function as intellectual partners with learners in order to engage and facilitate critical thinking and higher-order learning
- They are generalisable computer tools that are intended to engage and facilitate cognitive processing
- They are knowledge construction and facilitation tools that can be applied to a variety of subject-matter domains
- They help learners construct their own representation of a new content domain or revisit an old one" (Jonassen, 1996:9-11);
- Hung and Wong (2000) point out that there is currently an important emphasis on how these tools can help students to structure knowledge. Jonassen (1996:4) suggests "when students

> work with computer technology [as a cognitive tool], instead of being controlled by it, they enhance the capabilities of the computer and the computer enhances their thinking and learning. The result of this partnership is that the whole of learning becomes greater than then sum of its parts."

Rowe (1996:2) offers these characteristics to extend those of Jonassen's:

- Cognitive tools support, guide and extend the thinking processes of their users
- Cognitive tools support active and durable learning
- Cognitive tools are external, computer-based procedures and learning environments

*For the purposes of this study, **cognitive tools** will be defined as technologies that enhance or amplify the cognitive powers of learners during the learning process and which lead to active and durable learning in the learner.*

There are explicit links between cognitive tools and higher-order thinking skills that can be made as a result of this discussion. Wakefield (1996) indicates that the outcome of higher-order thinking is the construction of knowledge. Cognitive tools have been characterised as a means for learners to construct and represent their own knowledge. Fisher (1995) points out that creative thinking results in applying ideas or attitudes to the *real* world. One of the foundations for applying cognitive tools is that they should be situated in realistic, authentic contexts. Much of the core of higher-order thinking is trying to bring about a criticality and individuality in the learners. Cognitive tools support this notion by allowing learners to build and represent their *own* knowledge rather than relying on or absorbing knowledge representations of others. Last but not least, the *essence* of higher-order thinking is about learning how to think and reflecting on how one thinks. Again one of the foundations for cognitive tools is that they support this kind of deep reflective thinking that in turn ensures more holistic, meaningful learning.

Reeves, Laffery and Marlino carried out a study in 1997 on applying computer-based cognitive tools in higher education. The results of their study indicate that higher order outcomes can be achieved via the implementation of situated learning environments in which cognitive tools play critical roles. They conclude that they have learned at least three lessons. "First, technology is best used as a cognitive tool to learn *with* rather than as a surrogate teacher. Second, pedagogy and content matter most; technology and media are only vehicles, albeit essential ones. And third, our future efforts to use media and technology in higher education must be guided by much more rigorous research and evaluation than in the past" (1997:5).

This result that cognitive tools can stimulate the learning of the highly sought after higher-order thinking skills is encouraging in many ways. Firstly, it indicates that cognitive tools are indeed linked to the higher-order thinking skills. Secondly, they show that it is possible to provide

empirical evidence that cognitive tools **amplify** these higher-order thinking skills. Finally they demonstrate that the learners **do** learn by working *with* the tools.

Having looked at higher-order thinking and cognitive tools, the next question is to determine which learning theories inform them and to establish if there are links with GIS technologies.

2.4. Learning theories

This section examines the most common learning theories described in educational literature and endeavours to establish a link between higher-order thinking skills, cognitive tools and particular learning theories. It is not the objective of this section to discuss these theories in detail, rather to contextualise higher-order thinking and cognitive tools.

Capel, Leask and Turner (1995) believe that, to ensure that effective learning takes place, it is important to have a theoretical framework of learning to provide a context in which one can develop professional practice. They indicate that the key areas in this framework should be:

- An understanding of the mental processes that are involved when someone is learning
- An understanding of how concepts are developed by learners
- An understanding of what we as teachers can learn from the psychological theories of learning that can help in the teaching environment.

Learning theories offer different versions of the way in which learners learn and think but perhaps more importantly, they also reflect the different ontologies and epistemologies of their respective practitioners. Choi and Jonassen (2000:36) support this view and state "the contemporary learning theories that justify open-ended, learner-centred environments are based on substantively different ontologies and epistemologies than traditional, objectivist foundations for learning." Romiszowski (cited in Sims, 2000) points out that one's philosophical stance will determine how learning activities are structured. For example, humanists may emphasise useful content, behaviourists will emphasis outcomes of objectives, cognitivists and developmentalists will emphasise the process and so on.

Although at times it has been difficult to differentiate between the massive amount of writing on learning theories, from my own synthesis of the literature, there seem to be three broad categories of learning theories that are evident: behaviourism, cognitivism and the more contemporary theories known as constructivism. Each of these broad categories has spawned an extensive range of related learning theories and strategies. These will not be reviewed here.

The literature abounds with writings on behaviourism, so suffice it to say that the behaviourist approach rests on the objectivist / positivist belief that there is a known body of knowledge in the world which evolves from observable facts and phenomena (Winn and Snyder, 1996).

Subsequently, the pedagogical assumption is that this knowledge is an external entity with an absolute value which can therefore be transmitted from the teacher to the learner (Bostock, 1998). The learner is rewarded for proving that they have acquired the knowledge by showing that they can give the 'right' answers. On the whole, behaviourism is concerned with stimulus-response theories that define learning as establishing an associative link between a particular stimulus and a particular response. Well known theorists in this area include: Pavlov (1849-1936), Thorndike (1874-1949), Watson (1878-1958) and Skinner (1904-1990).

2.4.1. The cognitive approach

Whilst behaviourism is concerned with external behaviour or what learners do, cognitive learning models are concerned with the mental processes involved with learning, how learners acquire what they know. Cognitive theories of learning concentrate on the cognitive processes, higher-order thinking employed and internal mental representations constructed by the learners as they acquire new knowledge and skills (De Villiers, 2001; Roblyer and Edwards, 2000). However an objectivist epistemology can also underlie much of cognitive psychology (Bednar *et al*, 1992). It is simply the focus of **how** learning takes place that has shifted (Duffy and Jonassen, 1992: Bednar *et al*, 1992).

Cognitivism is based on the writing of a plethora of theorists and is "a broad, eclectic and sometimes elusive discipline" (Winn and Snyder, 1996:113). Winn maintains that the beliefs of cognitivism are not new but date back to the "very beginnings of the autonomous discipline of psychology in the 19th century" (1996:113) and that they came back into 'centre stage' because the central stimulus-response theory of behaviourism did not account for or explain many aspects of human behaviour, particularly social behaviours that occur every day. Most prominent amongst the theorists are Piaget, Gagne, Dewey, Bruner and Bloom. It is interesting to note that some of these theorists are also central theorists in the constructivist approach discussed below. In fact, it is sometimes difficult to define exactly where they lie as many authors discuss them under cognitivism and / or constructivism. Bruner has gone as far as saying that Piaget "is often interpreted in the wrong way by those who think that his principal mission is psychological. It is not. It is epistemological. He is deeply concerned with the nature of knowledge per se, knowledge as it exists at different points in the development of the child" (1966:7)

According to Winn (1996), there are two main bodies of research in the cognitive field, although it is sometimes difficult to separate the two distinctly:

1. *Mental representations*: which deals with how we store information in our memory and how we represent it to ourselves. The learner constantly builds an internal representation of knowledge. "This representation is constantly open to change, its structure and linkages forming the foundation to which other knowledge structures are applied" (Bednar *et al*, 1992).

Winn (1996) believes that 'schema theory' is basic to almost all cognitive research. New information learned is compared to existing cognitive structures called 'schema'. Schema can be combined, extended or altered to accommodate new information.

2. *Mental processes:* This area explains the processes that operate on the representations we construct of our knowledge of the world. Three main streams are evident here: the information processing model, symbol manipulation and knowledge construction. With knowledge construction we are blurring the boundaries between cognitivism and our next learning theory, constructivism.

A cognitive approach to learning could be characterised as follows:

1. Learning is a change of knowledge state
2. Knowledge acquisition is described as a mental activity that entails internal coding and structuring by the learner
3. Learner is viewed as an active participant in the learning process
4. Emphasis is on the building blocks of knowledge (e.g. identifying prerequisite relationships of content)
5. Emphasis on structuring, organising and sequencing information to facilitate optimal processing

Cognitive learning has been concisely summarised by Cogito:

> *"The cognitive paradigm [sic] sees learning is an active and creative process. Learning involves individual meaning making, not knowledge reception. The most important element of the cognitive paradigm is the student. The cognitive focus is upon learning and thinking. The student does the learning. The student is the active player. The teacher is merely a facilitator.* (Cogito, online, undated).

If one were compare key characteristics of cognitivism with GIS characteristics, one would see clear correlations between the two.

Table 2-1 Cognitivism compared to geographical information systems

Characteristics of cognitivism	**Characteristics of GIS technologies (Derived from Figure 2-4 on page 39)**
Learning is an active, creative process.	GIS technologies encourage learners to interact with data and images in an active way. They also allow learners to create new data and images.
Emphasis on structuring, organising and sequencing information to facilitate optimal processing	Learners guide themselves, identify relationships through exploring data and so organise their knowledge Learners can also model and manipulate both spatial and relational data with GIS technologies
The focus is on learning and thinking	GIS technologies encourage learners to analyse data

2.4.2. The constructivist approach

Constructivism bases itself on the cognitive approach but develops the importance of context or environment and "provides an alternative epistemological base to the objectivist tradition" (Duffy and Jonassen, 1992:3). Constructivism is a term that can be applied to ontology and epistemology as well as a psychological theory of learning. Wilson (1997) points out that from an epistemological point of view, many strands of constructivism could be seen to fall into the post-modern view of the world, however, not all constructivists are postmodern in their orientation. He believes that one may have a constructivist view of cognition or learning while still preserving a fairly traditional, modern view of science, method and technology (Wilson, 1997). It is difficult to compartmentalise constructivism because it covers a "wide spectrum of beliefs about cognition" (Jonassen, 1991 cited in Wilson *et al*, 1995:141).

The adoption of constructivism and the renunciation of behaviourism, especially Skinner's view of behaviourism, seems to be the current trend. Marti (1997) implies that it is almost as if behaviourism is being presented as being "grossly deficient" and constructivism as being the only credible way of learning occurring for students. However, according to Marti (1997), constructivism is not universally accepted either.

Jonassen (1996:11) believes that learning theory is in "the midst of a revolution, in which researchers and theorists are arguing about what it means to know something and how we come to know it." He defines constructivist learning as:

- Active – students process information meaningfully
- Cumulative – all new learning builds on prior learning
- Integrative – learners elaborate on new knowledge and interrelate it with their current knowledge
- Reflective – learners consciously reflect on and assess what they know and need to learn
- Goal-directed and intentional – learners subscribe to the goals of learning

As with behaviourism and cognitivism, there are a variety of constructivist theories. "Constructivism comes in different strengths … from weak to moderate to extreme" (Molenda, 1991:47 cited in Roblyer and Edwards, 2000:59). Many of the theories build on the common principle that a process takes place in every learner whereby knowledge is constructed resulting in every learner having his or her own relative view of knowledge. As all constructivists share this common principle, the different theories can be viewed as "points of view" or perspectives rather than theories. Duffy and Cunningham (1996) summarise the common focus areas of constructivism as being the **construction** of new knowledge that is unique to each **person** and the **importance** of the environment in determining the **meaning of reality.** Duffy and Cunningham (1996) indicate

that the differences between the various schools of thought can be seen in how they *define* the terms *knowledge, learning* and *construction.*

Perkins (1991:20) offers another way of differentiating between the different 'brands' of constructivism. He contrasts between 'BIG (beyond the information given) constructivism and WIG (without the information given) constructivism'. In his view, with BIG constructivism, the learners are directly introduced / exposed to concepts and are then given opportunities to work through their understanding of the concepts in different ways or to engage in cognitive-related activities that require them to apply and generalise their understandings, so constantly refining them as they go along. On the other hand, WIG constructivism, "holds back on direct instruction" (Perkins, 1991:20). Rather the learners are presented with situations, phenomena and tools in the conceptual domain that they must try to explain and refine into models with scaffolding provided by the teacher. He believes that education with a balance of the two kinds of 'episodes' would be effective.

Constructivism addresses different kinds of learning needs than those supported by the behaviourist / objectivist approach. For example: by anchoring learning tasks in meaningful, authentic contexts, skills are made more relevant to the learners' backgrounds and futures; by ensuring learners play more active roles in their learning, motivation problems are addressed; by emphasising motivational, problem-solving activities, learners can acquire higher and lower-order skills at the same time and by teaching learners to work together to solve problems they can acquire co-operative, team work skills (Roblyer and Edwards, 2000). It is just these types of needs that South Africa and its outcomes based approach to education is trying to address. This is particularly evident in its list of critical outcomes, which encompass all of these needs[4]

More specifically for the GIS aspects of this study, Sarah Bednarz (1995:3) makes connections between constructivist learning theories and GIS technologies. She summarises the generic characteristics of constructivism and compares them to the characteristics of GIS (see Table 2-2 below). The links between GIS and constructivism are clear.

Table 2-2 Constructivism compared to geographic information systems (Adapted from Bednarz, 1995)

Characteristics of constructivism	**Characteristics of GIS**
Learners construct knowledge.	Learners construct knowledge through building databases, maps.
Learners discover relationships through experience.	Learners explore spatial relationships through mapping.
Learners learn in complex, authentic situations.	Learners learn from real-world data and places.

[4] For more on the topic of Outcomes Based Education, see section 2.5 on page32.

Learners manage their own learning.	Learners guide themselves, identify relationships through exploring data.
The process of learning is as important as the product.	GIS is a tool to explore.

2.4.3. Theoretical standpoint for this study

As can be seen from this discussion, learning is a complex matter. This is further complicated by the fact that every educator or researcher has implicit assumptions that reveal how the educator understands the process of learning. I believe that it is possible to take a pragmatic approach to the application of learning theories to one's teaching such as those suggested by Entwistle and Smith (2002). For example, critical thinking is not the goal of all learning interventions just as it isn't appropriate to apply problem-solving approaches to introductory learning in lower school grades. Ertmer and Newby (1993) support this view and suggest matching learning theories with the level of the learner and the content to be learned.

However, if one is to embark on the design of learning materials or learning interventions, is it important to adopt a particular epistemological view? Bednar *et al* (1992:19) state quite forcefully that "it is inconceivable to mix epistemologies in an instructional program" as it has far ranging implications for the goals and strategies used in the instructional design process.

> *"As a field we must ground ourselves in theory. Minimally, we must be aware of the epistemological underpinnings of our instructional design and we must be aware of the consequences of that epistemology on our goals for instruction, our design of instruction, and on the very process of design." "We must constantly re-examine our assumptions in light of a new findings about learning" (Bednar et al, 1992:31).*

Therefore, for this study and specific situation, the following is a basic premise: learning is viewed as an active process of knowledge construction, in which learners are involved with other learners in authentic, problem-solving situations. In order for higher order learning to take place, knowledge must be acquired by using learning strategies and activities. This knowledge can then be transformed into higher order thinking by learners participating actively in realistic, authentic, cross-content domain, socially situated and problem-orientated settings.

This predominantly *cognitive* view of learning in this project is based more on 'mainstream' constructivism (using Piaget, Vygotsky and others as a basis) rather than the more extreme radical or critical forms espoused by von Glasersfeld and others. Bednar and colleagues call this view 'constructivist cognitive science' and encapsulate my viewpoint on the underlying epistemology and ontology: "this view of knowledge does not deny the existence of the real world and agrees that reality places constraints on the concepts that are knowable, but contends that all we know of the world are human interpretations of our experiences of the world" (Bednar *et al*, 1992:21).

Listed below are the key aspects of cognitive-constructivism relevant to this study. These have been drawn from many readings and encapsulate what is key for this research.

1. Knowledge is constructed from experience
2. Learning is an active process of meaning-making based on experience
3. Learning should occur in realistic, authentic settings
4. Learning is collaborative with meaning negotiated from multiple perspectives
5. Cognitive engagement with the subject material is vital for learning
6. Opportunities for reflection generally promote learning
7. Assessment should be authentic and integrated with the task and not a separate activity
8. Learning is an intentional and intrinsically motivated activity

Oliver describes this suitably as aligning more closely with Aristotle's view of knowledge which is seen as "practical, situated in context, and built from concrete experiences rather than external abstractions and theories" (2000:5).

In closing this section, I would like to highlight a key tenet for this study inspired by Wilson. "If you think of knowledge as a person's meanings constructed by interaction with one's environment then you may think of instruction as a learner drawing on tools and resources within a rich environment (Wilson, 1995:3).

2.4.4. Intersections

Higher-order thinking and learning

For clarity at this point, it would be interesting to look briefly at whether higher order thinking aligns with a particular learning theory. If we pick out key points from the writings on higher order, critical and creative thinking we find phrases like:

- Generative learning, construction of knowledge, complex cognitive performances, problem solving (Wakefield, 1996)
- Complex, yields multiple solutions, involves application of multiple criteria, involves imposing meaning (Resnick and Klopfer in Jonassen, 1996)
- How something is being thought about (Fisher, 1995)
- Quality of thought that allows generation of many ideas, invention of new ideas etc (Johnson, 2000)

If we review the broad characteristics of the learning theories discussed earlier, we can see that perhaps higher order thinking does not sit well within behaviourism. If the learner is rewarded for providing the 'right' answers then there is little need for any of this kind of thinking. It does however, harmonise with the tenets cognitivism and constructivism. Within cognitivism, the key focus is on how learning takes place. Development of these types of thinking skills will show how

learning is taking place. Finally, within constructivism, the focus is on knowledge construction, reflexivity and multiple perspectives. With higher order thinking we see the use of problem solving, multiple solutions and criteria and the imposing of meaning.

Cognitive tools and learning theory

It now remains to locate cognitive tools within one or more of these learning theories, if possible. If we look at the characteristics of cognitive tools discussed in section 2.3.1 above we see that cognitive tools:

- assist in structuring knowledge
- assist in constructing personal representations of content domains
- support active and durable learning

These are also key principles in both cognitive and constructivist learning theories (see sections 2.4.1 above and 2.4.2 above). In his forum discussion paper on using *Technology as Cognitive Tools* in 1994, Jonassen puts forward a persuasive argument that cognitive tools promote constructive learning, which can be summarised as follows: "cognitive tools and environments activate cognitive learning strategies and critical thinking. Knowledge acquisition and integration, […] is a constructive process, so when using cognitive tools, learners engage in knowledge construction rather than knowledge reproduction (Jonassen, 1994:3). Cognitive tools align very closely with the cognitivist learning theory but they also have links with the cognitive orientated theories in constructivist theories. Reeves summaries the links between learning and cognitive tools:

> *"Constructivists seek to create learning environments wherein learners use cognitive tools to help themselves construct their own knowledge representations. Cognitive tools and the goals, tasks, pedagogies, resources, and human collaboration integral to their use enable learners to engage in active, mindful, and purposeful interpretation and reflection."* (1998:20-21)

We can see from the discussion so far that we have alignment between learning theories and cognitive tools as well as between learning theories and higher order thinking. This creates the foundation for the remainder of this chapter and for subsequent chapters in this enquiry.

2.5. Outcomes Based Education in South Africa

In order to contextualise education in South Africa, it is necessary to give a brief overview of the key drivers in South African education. Since 1994, education in South Africa has been the focus of government attention and has undergone many changes, the most significant of which are the National Qualifications Framework (NQF) and Outcomes Based Education (OBE). As there is a variety of literature describing these including government documentation, this section will describe these briefly and use them to contextualise OBE with this section on learning theories.

The NQF was established for a number of reasons but primarily because of demands for:

1. access to lifelong learning for all population sectors (learners need to 'pick up' learning and to transfer credits as well as have multiple entry and exit points)
2. accountability and transparency from education providers and qualification awarders at a national level
3. development of 'strategic' human resources driven by a need for greater national productivity and economic competitiveness in the global marketplace.

According to Strydom, Hay and Strydom (2001), the NQF is a rejection of the traditional method of structuring of curriculum and a response to the inequalities and discontent with the nature and quality of education and training in pre 1994 South Africa. It is an attempt to create an integrated approach to curriculum development which focuses on equity and redress, productivity and economic competitiveness and promotion of quality in learning. It has been seen as the major national policy initiative for the restructuring of South African higher education curricula and has changed the focus of higher educational curricula from emphasis on formal knowledge to emphasis on skills.

Dison and Pinto (2000:202) describe the NQF as a "flexible structure for articulating the various levels of educational enterprise, at a national level." They believe that it's purpose is to "provide a degree of standardisation and interchangability of educational qualifications across the country." The South African Qualification Authority (SAQA) was set up to develop the rules of the NQF and oversee the implementation of the framework. It is important to note that South Africa is not unique in this endeavour, it is simply following international trends in education such as those undertaken in New Zealand and Australia.

The other key change in South African education is the development and subsequent implementation of the Outcomes Based Education approach. Dison and Pinto (2000:201) describe the OBE framework:

> *"At any particular level, the learning experiences that are designed as part of the curriculum, as well as the assessment procedures which will measure their efficacy, are such that the statements can be made about whether or not the learner is ready to progress to the next level."* (2000:201)

With OBE the end products of the learning process are "carefully described *a priori*" (Dison and Pinto, 2000). They point out that within this framework the focus has shifted from covering a body of content to providing learning experiences, which facilitate the acquisition of pre-described competencies by the learner. To illustrate this shift in focus by the South African government, Cronje (2000) presents the criteria in a table as shown in Table 2-3 below.

Table 2-3 Shift in government focus (Cronje, 2000:2-3)

Old Educational Focus	New Educational Focus
• Passive learners	• Active learners
• Exam-driven	• Learners are assessed on an on-going basis
• Rote-learning	• Critical thinking, reasoning, reflection and action
• Syllabus is content-based and broken down into subjects	• An integration of knowledge; learning relevant and connected to real-life situations
• Sees syllabus as rigid and non-negotiable	• Learning programmes seen as guides that allow teachers to be innovative and creative in designing programmes
• Emphasis on what the teacher hopes to achieve	• Emphasis on outcomes – what learner becomes and understands
• Behavioural approach to learning and assessment	• Cognitive approach to learning and assessment
• Assessment of isolated knowledge or discrete skills	• Knowledge, abilities, thinking processes, metacognition and affect assessed.
• Individual learning and products	• Collaborative learning and products

There are a number of statements that need to be discussed. Firstly, the new focus seems to align itself with both constructivism and cognitivism. Active learning, critical thinking and a cognitive approach to learning are characteristics of the cognitive learning theory whilst ongoing assessment, collaborative learning and learning that is connected to real world situations are key tenets of the constructivist approach to learning. There are also parallels between this new focus and the features of an information age illustrated by Reigeluth (1995) in Table 1-2 on page 1.

Twelve **critical outcomes** are specified in OBE which must be covered by all subject areas in the curriculum. These include: fostering critical thinking, preparing students to function in an information economy, developing problem solving skills, preparing students to be lifelong learners and to enjoy learning and for students to be confident in using their knowledge and skills. Authentic and formative assessment is another key factor in OBE. Again, we can see correlations between these critical outcomes and the cognitive and constructivist approaches to learning as well as connections to cognitive tools. It is exactly these outcomes that this study is most concerned with, particularly those outcomes concerned with critical thinking.

Listed below are some of international trends that have lead South Africa to adopt an OBE approach to education (derived from Breier, 2001: 3-21). Some of the trends have already been stated as drivers for this study in the opening chapter. For example, lifelong learning and globalisation.

1. Globalisation (a global economy), massification (diversity of student populations, internationalisation (employment is not confined to the country of study)
2. Responsiveness to needs of the economy, broader society and communities and the need to engage with society (or stakeholders) to determine needs, actions and direction of education

3. Different forms of knowledge: local or indigenous knowledge versus international, global or 'universal' knowledge
4. Lifelong learning
5. Graduateness: the qualities expected by employers from graduates
6. Citizenship: nationally and globally learners are aware of cultural, political and moral knowledge as well as global risks, rights and duties.
7. Distance education: which may help to increase access, expand educational provision and achieve economies of scale especially in South Africa supported by technology.

OBE "questions the assumption that simply knowing or understanding disciplinary content enables a person to apply knowledge and argues instead that students actually have to be taught applications and capabilities. Learning outcomes are the things we want graduates to be able to do as a result of their learning. An outcomes based approach involves using the discipline to teach them to do these things. Merely understanding disciplinary content is not an outcome. An outcome is something else which the understanding of the content allows the learner to do" (Boughey, 2002, 10:11).

Many criticisms have been levelled at OBE. Many believe that it is premised on an outdated behaviourist psychology which assumes a certain uniformity and predictability in human behaviour. Many believe that is favours reductionism and the behaviourist approach to learning as well as marginalising content and discipline specific knowledge. As one would expect, similar criticisms are levelled at the NQF, including that the NQF is too prescriptive, it could lead to the marketisation of knowledge, registration of qualifications involves cumbersome procedures and that additional workload is placed on staff to revise modules and courses to align with the requirements (Strydom *et al*, 2001). There seems to be an inherent tension that exists in the South African curriculum in that is appears to be based on both behaviourist and constructivist assumptions. For example, working to pre-defined outcomes can be though of as clearly behaviourist whilst the ideas of creating learner-centred teaching and learning environments swings over towards constructivism. At the time of writing, however, in South Africa it is the reality that we must work within.

2.6. Geographic Information Systems as Cognitive Tools

The opening paragraphs of Chapter 1 have contextualised GIS technologies in education. But can GIS technologies be classified and exploited as cognitive tools? The purpose of this section is to use the complex thinking framework provided by Jonassen in "Mindtools" to explore this idea. Firstly, I will highlight the key features and functions of GIS technologies. Secondly, I will evaluate GIS technologies according to Jonassen's criteria for cognitive tools and thirdly model GIS technologies features against the Integrated Thinking Model.

2.6.1. Key features and functions of GIS technologies[5]

Figure 2-3 below, shows the key features and functions of a typical GIS technology. Using the definition provided by Zerger *et al* on page 1, these have been identified as *managing, storing, analysing, modelling and visualising data*. Each feature and function is extended to show the thinking skills[6] required to carry it out. In my opinion the functions of storing and managing data are very similar and require the same kind of thinking. Therefore they have been incorporated into one function for the purposes of this study.

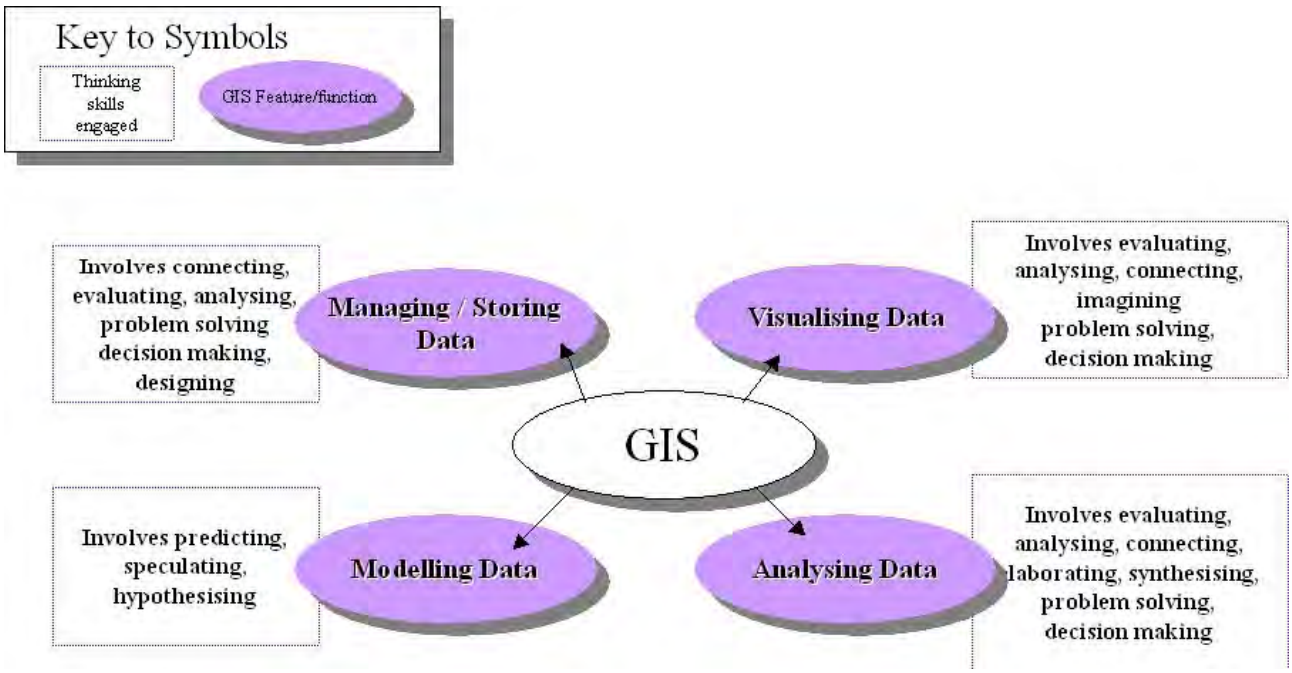


Figure 2-3 Features and functions of GIS Technologies (using the definition provided on page 1)

2.6.2. Critical, creative and complex thinking in GIS Technology usage

The authors of the ESRI White Paper claim that GIS technologies are "powerful tools that permit teachers and students to explore and analyse information in new ways, focusing students' activities in the higher order thinking skills of observation and exploration – questioning, speculation, analysis and evaluation" (Environmental Systems Research Institute, 1998:1). Broda and Baxter support this claim: GIS "activities provide a natural setting for the development of higher-order thinking skills" (2002:50).

[5] This section on GIS was kindly peer-reviewed by Marinda du Plessis who has an MSc in Geography from Rhodes University and is a lecturer in GIS at Fort Hare University.

[6] These thinking skills are fully described in Appendix A and represent critical, creative and complex thinking skills. They are also referred to in Table 2-4 on page 40.

This section draws on Jonassen's (1996:34) approach in order to describe and evaluate GIS technologies in terms of the critical, creative and complex thinking skills they engage and support in order to provide evidence that GIS technologies could be used as cognitive tools. Table 2-4 below uses the Integrated Thinking Model explained by Jonassen as a framework for indicating which features and functions of GIS technologies engage particular thinking skills.[7] In the Integrated Thinking Model, thinking skills are divided into critical thinking, creative thinking and complex thinking. Critical thinking skills involve the dynamic re-organisation of knowledge in meaningful and usable ways. When thinking goes beyond accepted knowledge to generate new knowledge, creative thinking happens. Finally at the heart of the model are complex thinking skills. These thinking processes combine the skills from the other areas into larger, *action-oriented* processes such as problem solving, designing and decision making. Further details of the model and these skills can be found in Appendix A.

It is important to note that, at this stage, this is purely theoretical evidence for using GIS technologies as cognitive tools. Further empirical research specifically using GIS technologies needs to be undertaken to support this theoretical position such as that undertaken by Reeves *et al* in 1997.

[7] These features and functions are those identified on pages 1 and 36

Table 2-4 Critical, creative and complex thinking in GIS technologies

	GIS Features and Functions				
		Visualising	**Managing / Storing**	**Analysing**	**Modelling**
Critical Thinking Skills in GIS	Evaluating				
	Assessing information		✓	✓	
	Determining the criteria		✓	✓	
	Prioritising	✓		✓	
	Recognising fallacies			✓	
	Verifying	✓	✓	✓	✓
	Analysing				
	Recognising patterns	✓	✓		✓
	Classifying	✓	✓	✓	✓
	Identifying assumptions				✓
	Identifying main ideas		✓	✓	
	Finding sequences	✓			✓
	Connecting				
	Comparing / contrasting	✓			✓
	Logical thinking		✓	✓	✓
	Inferring deductively				
	Inferring inductively	✓		✓	
	Identifying causal relationships			✓	
Creative Thinking Skills in GIS	Elaborating				
	Expanding			✓	✓
	Modifying		✓		
	Extending				✓
	Shifting categories		✓	✓	
	Concretising	✓			✓
	Synthesising				
	Analogical thinking				
	Summarising		✓	✓	
	Hypothesising				✓
	Planning		✓	✓	
	Imagining				
	Fluency				
	Predicting	✓			✓
	Speculating	✓			✓
	Visualising	✓			✓
	Intuition				✓
Complex Thinking Skills in GIS	Designing				
	Imagining a goal		✓		
	Formulating a goal		✓		
	Inventing a product		✓		
	Assessing a product			✓	
	Revising a product		✓		
	Problem Solving				
	Sensing the problem				
	Researching the problem	✓	✓	✓	✓
	Formulating the problem	✓		✓	
	Finding alternatives		✓	✓	✓
	Choosing the solution	✓			✓
	Building acceptance				✓
	Decision Making				
	Identifying an issue	✓		✓	
	Generating alternatives				✓
	Assessing the consequences	✓	✓	✓	✓
	Making a choice		✓	✓	
	Evaluating the choices	✓	✓	✓	✓

2.6.3. Evaluation of GIS technologies as cognitive tools

In order to establish if GIS technologies can be classified as cognitive tools, one must evaluate them against a set of criteria that characterise cognitive tools. Jonassen (1996:56) offers eight criteria with which to evaluate software as cognitive tools. Full descriptions of these criteria can be found in Appendix A. The tools must:

1. Be computer-based
2. Be readily available, general applications
3. Be affordable
4. Be capable of representing knowledge
5. Be applicable in different subject domains (cross-curricula or cross disciplinary)
6. Engage critical thinking
7. Encourage transferable learning
8. Offer a simple, powerful formalism
9. Be easy to learn

In the paragraphs below, GIS technologies will be evaluated against each of these criteria by drawing on GIS and other literature to provide support for the evaluation.

GIS technologies are certainly **computer-based** and are **readily available**, **general** applications. They are used extensively in commercial and government organisations for many applications such as public administration, tourism, mining, exploration, environmental science as well as the more obvious applications of cartography and surveying.

Broda and Baxter (2002:50) point out that "the use of GIS … technology provides natural opportunities to coordinate instruction" so that "students can see relationships among disciplines" and educators can offer an integrated curriculum. It follows then that GIS technologies are applicable to many different **subject domains**.

GIS packages are becoming more **affordable**. Buss, McClurg and Dambekalns (2002:1) point out that "until recently it was not feasible for educators to use this spatial data resource because the cost of the software was prohibitive and the size of the data files was too large to load on the personal computers used in most school settings. Demand from public and private sectors coupled with spiralling innovations in technology have resulted in the recent introduction of software which can be used to manipulate spatial data on personal computers." Some vendors offer fully functional free versions or bundled versions of the software for use in educational establishments.

Can GIS technologies **represent knowledge**? Many authors believe they can. GIS technologies "provide users the opportunity to exercise creative vision, to integrate information, and to evaluate endless alternatives. Its value is enhanced when the user collaborates with others, and the

technology itself facilitates such sharing of resources, understandings and interpretations" (ESRI White Paper 1998:3). Bednarz (1995) believes that GIS technologies enable learners to construct and represent knowledge through building maps and GIS databases. Broda and Baxter (2002:51) believe that by using GIS technologies, learners "are able to go beyond text-book maps and build their own representations of the world in spatial terms" and thus represent what they know. Another important aspect here is that GIS technologies allow learners to work with local data which is relevant to their own lives and which further allows knowledge to be meaningfully represented by undertaking authentic tasks based on local issues. Broda and Baxter (2002:51) believe that "rather than removing students from the real world, technology can help them explore, experience and analyse their surroundings in a direct and engaging format."

The discussion regarding engaging **critical thinking** has been presented in the section above. Theoretically, it would seem that GIS technologies would engage critical thinking. Empirically, this still needs to be established, particularly in South Africa in the light of the new curriculum requirements.

Jonassen believes that using a cognitive tool results in the acquisition of generalisable, **transferable skills** that can facilitate thinking in various fields. This criterion suggests that critical thinking developed by using a cognitive tool in a science class for example will transfer to or be applicable in language classes. The spatial component of GIS is where it's strength lies as a cognitive tool. By developing the learner's ability to relate subjects such as history and the environmental sciences to the spatial skills acquired using the GIS as a tool, learners can see in their 'mind's eye' how events and topics fit together and as a result learning becomes more alive (ESRI White Paper, 1998; Broda and Baxter, 2002 and Bednarz, 1995).

Jonassen states that a cognitive tool should have a **simple, yet powerful formalism**. For me, this is an unclear criterion and the textual description does little to clarify it for me. The Mirriam-Webster dictionary defines formalism as "marked attention to arrangement, style, or artistic means (as in art or literature) usually with corresponding de-emphasis of content" (Online, 2004) and Dictionary.com as "a method of aesthetic analysis that emphasizes structural elements and artistic techniques rather than content, especially in literary works" (Online, 2004). It seems that it is some kind of organising framework that focuses more on structure and arrangement than on content. It is still unclear to me what this means in connection with cognitive tools and as such requires further reading or direct contact with Jonassen himself. It is therefore difficult at this time to ascertain whether GIS technologies can satisfy this criterion.

Are these technologies **easy to learn**? Much of the research here is centred on the need for the teachers to learn the technology and about the required pedagogies but little is written about how

easy it is for the learners to master the technologies (Buss, McClurg and Dambekalns, 2002; Zerger et al, 2000). ESRI (1998:4) have this to say about learning these technologies:

> *"It can take a long time to learn to use these tools to their fullest extent. Fortunately, however, the vast majority of tasks that schools wish to accomplish can be handled with a reasonable number of basic operations. Students and teachers generally need just the basic features of the software and should not be concerned with learning immediately 'all there is'."*

The authors of this White Paper also point out that both learners and teachers can both be "active learners at the same time. By developing new skills and exploring new understandings of a variety of topics, teachers can model for students the process of lifelong learning" (1998:8). This fits very well into the latest work on constructivist learning and pedagogical approaches to teaching and with the notion that cognitive tools are most effective in a constructivist environment.

From Jonassen's original nine criteria, theoretical evidence from the GIS and other educational literature has been provided for eight of them. As a tentative proposal, it would seem that GIS technologies could be used as cognitive tools in educational contexts.

2.7. Conclusion

This chapter lays the theoretical foundations for much of this study. The model that will result from this research paper will provide a framework for the design and development of learning materials using GIS technologies that operate as cognitive tools, so it is important that clarity is achieved on these concepts before exploring the models themselves.

The chapter has explored the ideas and concepts behind higher-order thinking and cognitive tools and has arrived at working definitions for them both. More importantly, explicit links are made between higher-order thinking, cognitive tools and the learning theories so that readers can align higher-order thinking and cognitive tools with particular learning theories.

As GIS technologies are the core technology for this project, GIS features and characteristics have been applied to the definitions of cognitive tools in an attempt to provide a theoretical basis for employing GIS technologies as cognitive tools. It would seem that there is substantial theoretical evidence for classifying GIS technologies as cognitive tools. However, as indicated before, it will be necessary to carry out empirical research into exactly how these technologies can achieve this.

Chapter 3 Evaluation framework for instructional design models

3.1. Introduction

The core thrust of this chapter is to research and then determine the criteria that will be used to filter the instructional design models to examine in this study. This forms a facet of data collection for developmental research whereby the evaluation process is documented using procedural models from the literature review that might be appropriate for the task at hand. Before looking at the criteria, it is worth defining the concept of instructional design as seen by the discipline whilst at the same time, providing a rationale for the particular type of instructional design this study is concerned with.

3.2. Overview of instructional design

Moallem (2001:2) defines the instructional design process as "the entire process of analysis of learning needs and goals and the development of an instructional system that meets those needs. It includes development of instructional materials and activities, trial and evaluation of all instruction and learner activities. [The] instructional design process has the ambition to provide a link between learning theories (how humans learn) and the practice of building instructional systems (an arrangement of resources and procedures to promote learning)."

According to Moallem (2001), various instructional design models have been developed to help teachers, educators and instructional designers make use of fundamental elements of the instructional design process and principles. He goes on to say that the instructional design process focuses on **how** to design and develop learning experiences, while the principles focus on what learning experiences should be like **after** they have been designed and developed. "In other words, instructional design models are guidelines or sets of strategies, which are based on learning theories and best practices" (2001:2).

Anderson (1997:521) defines an instructional design model as a "step-by-step process designed to achieve a particular educational outcome." He takes a pragmatic approach and indicates that no single model will help to achieve **all** the outcomes of education. He suggests that teachers and educators must be "able to use a variety of teaching models in order to accomplish the goals of education" (1997:521). Anderson (1997) goes on to identify that each instructional design model has these characteristics: 1) it includes the learning theory that it is derived from, 2) it states the educational goals it is designed to achieve and 3) it gives evidence to support the effectiveness of the model.

The Teaching, Learning and Technology Centre (2002) observes that instructional design models originally become apparent as a result of the influence of behavioural psychology on learning

theory and instruction. These psychologists believed that the correct arrangement of stimuli, behaviours and reinforcers would cause learning to take place. This belief is still prevalent in the practice of instructional design today as demonstrated by prominent theorists such as Merrill; and Dick and Carey. The early models of instructional design were intended to be universal to all different training and educational contexts. The Teaching, Learning and Technology Centre (2002) believe that, over time, instructional design models have become more differentiated and that whilst many teachers and educators still emphasise behavioural outcomes, more attention is given to the process of how knowledge structures are built as a result of learning. This last point has implications for this study as we have seen that one of the key focus areas is learning and building of knowledge structures. If one reviews a book such as "*Instructional Development Paradigms*" edited by Dills and Romiszowski (1997), one can see that the field of instruction design has indeed expanded beyond the original behaviourist / objectivist inspired models.

Many writers believe that instructional design should move with the times and embrace the changes that are taking place in both technology and learning research. Wilson, Jonassen and Cole (1993) indicate that the instructional design (ID) discipline "has enjoyed considerable success over the last two decades but is now facing some of the pains expected along with its growth. Based largely on behaviouristic premises, ID is adjusting to cognitive ways of viewing the learning process. Originally a primarily linear process, ID is embracing new methods and computer design tools that allow greater flexibility in the management and order of design activities. In the present climate of change, many practitioners and theorists are unsure about 'what works'; for example, how to apply ID to the design of a hypertext system or an on-line performance support system" (1993:1).

One of the ways the literature on instructional design models seems to categorise models, is to align them to a particular learning theory. Tam (2000) provides support for this idea and observes that many instructional design models are either *behaviourist inspired models* or *constructivist inspired models*. She has characterised the models as shown in Table 3-1 below. Of particular note for this study is the fact that constructivist inspired models do not follow a linear design process, that planning is organic and collaborative and the learning takes place in a meaningful context. These are already features that we have seen in constructivist learning. They are also themes of this chapter and the next.

Table 3-1 Instructional Design Model Characteristics (Tam, 2000

	Behaviourist Inspired Models	*Constructivist Inspired Models*
Design Process	Sequential and linear	Recursive, non linear and sometimes chaotic
Planning Approach	Top down and systematic	Organic, developmental, reflective and collaborative
Objective Style	Objectives guide development	Objectives emerge from design and development work
Experts?	Experts with special knowledge are critical to Instructional Design work	Experts do not exist
Learning Style	Careful sequencing and teaching of sub skills are important. The goal of delivery is pre-selected knowledge	Instruction emphasises learning in meaningful context with the goal of personal understanding within those contexts
Evaluation Type	Summative evaluation is critical	Formative evaluation is critical
Valuable Data	Objective data is critical	Subjective data may be most valuable
Typical Model Type	Instructional Systems Design (ISD) typically involves 5 stages: • Analysis • Design • Production/Development • Implementation • Maintenance/Revision	None

In spite of what Anderson (1997) says, it would seem that alignment with a particular learning theory is not always explicitly stated or used as the basis for a design model. Rita Richey (1995:81) points out "while an [instructional design] model may be the over-all guide for a design project, specific design strategies are rooted in a myriad of separate principles based upon learning theory." Duffy and Jonassen (cited in Richey, 1995:81) have noted that "while instructional designers typically may not have the time or support to explicitly apply a theory of learning during a design or development task, the theory is nonetheless an integral part of the instruction that is produced." Richey (1995) goes on to indicate that there are strong concerns that many instructional design practitioners are ignoring the use of learning principles in the design process although theoretically these have always been integrated into the micro-design models such as Gagne's 'Events of Instruction' or Merrill's 'Instructional Transaction Theory'. As we have seen in Chapter 2, there are some who believe quite strongly that instructional design must be firmly rooted in a theoretical basis (Bednar *et al*, 1992). If we assume that most instructional design models explicitly or implicitly include the learning theory that they are derived from, we can safely categorise instructional design models according to the learning theory they are based on. This is an extremely important assumption for this study as only instructional design models where it is possible to ascertain which learning theory they are aligned with will be selected for evaluation.

Richey (1995:82) goes on to argue that the traditional instructional design theories and models are most effective with "highly prescribed, objective outcomes and the organisation of to-be-learned lesson content, not the largely unique and individual organisation of knowledge". This is consistent with the view of instruction as the transmission of knowledge, rather than the facilitation of learning, and "leads to the concern that the product of such instruction is surface, rather than deep learning" (Richey, 1995:82). Kember and Murphy (1995) add their support that instructional design needs to incorporate new philosophies and approaches and believe that instructional designers need to "adopt a broader and more pragmatic approach, one which is based on a constructivist paradigm and which harnesses emerging research on student learning" (1995:104). They orientate themselves with Jonassen who stresses that "educational technologies should, quite simply, teach learners to learn rather than acting as passive purveyors of information or techniques for reducing learner involvement in the learning process" (1995:104). For them, if meaningful and lasting learning is to take place, greater consideration should be given to the constructivist paradigm. Also, "specific techniques need to be devised and implemented which encourage deep learning" in learners (1995:104). As an aside, I would like to comment on Kember and Murphy's use of the word 'paradigm' here: I believe that they are referring to the learning aspects of constructivism rather than the ontological or epistemological dimensions of constructivism.

Two other important aspects of instructional design that should be considered here are that there has been a change in focus in the instructional design development process. Firstly, the next generation of instructional designers may need to be content as well as instructional design specialists (Bednar *et al*, 1992). Secondly, Richey (1995:83) indicates that "many recent theoretical developments stress the role of the learner" and this emphasis can be attributed largely to the constructivist orientation, which emphasises learner experience, learner control, as well as how the learner defines the meaning of reality. "The more prominent role of environmental variables, often as interpreted by the learner, is evident in systemic design, … and both cognitive and constructivist psychology. Applications of the new technologies are creating instruction controlled, and sometimes even developed, by learners rather than designers" (Richey, 1995:83). As will be explained later, thus study is not moving into the 'learners as designers' territory yet, but it is moving towards the idea of learners being able to adapt learning materials, to be involved in determining problems that they would like to solve and in the evaluation of learning materials.

The essence upon which much constructivist instructional design is based is captured by those comparisons made by Reigeluth in the opening paragraphs of Chapter 1. Reigeluth believes that constructivist approaches to learning and learning environment design offer "great potential to help learners acquire such qualities demanded by the information age such as initiative, responsibility, problem-solving competence, team-building, group-process skills, and communication skills. Instructional theory must be developed to … create instructional systems that support such learning

experiences. In particular, instructional theory is needed to provide guidance on creating an engaging problem space/scenario, on designing personalised, interactive skill-builders and in creating powerful tools to help learners build causal models" (1995:91).

There is a great deal of support for the move towards constructivist instructional design, but due to the nature of constructivism, practical research is needed to make the design less hazy. Wilson, Teslow and Osman-Jouchoux point out that "literature is filled with theoretical dialogue but few design models or concrete suggestions for practice" (1995:140). If this is the case, this will have implications for this study as there will be fewer models to review and discuss. Wilson *et al* (1995) maintain that:

> "*the constructivist movement is changing the way many of us think about instructional design, but theories are still somewhat vague about actual design practices. Certain fuzziness may be inevitable, since constructivism is a broad theoretical framework, not a specific model of design. Moreover, constructivism tends to celebrate complexity and multiple perspectives. Still, for constructivism to have a meaningful influence on instructional design, we must build a bridge to practice*" (1995:137).

Wilson, Jonassen and Cole (1993) indicate that the ID community continues to examine the foundations of its discipline. "Methodological advances such as rapid prototyping have reshaped traditional thinking about systems-based project management. Sophisticated computer-based tools are helping to automate the ID process. On a different front, critiques from cognitive psychology have called into question many of the recipe-like behavioural prescriptions found in traditional ID theories. As a result of these changes, ID is clearly moving toward a greater flexibility and power in it recommended processes and in it specifications or instructional products" (1993:2).

It is precisely the aim of this study to put forward a model which will embrace both cognitive psychology and the constructivist learning theories, incorporate modern computer technologies (namely GIS) and offer a framework for practical usage of the model.

If the research literature suggests a move towards constructivist instructional design and my theoretical position for this study is within the constructivist learning arena, we must explore briefly the nature of constructivist instructional design. The following extracts provide an idea of what writers consider the elements of constructivist instructional design to be.

Wilson, Teslow and Osman-Jouchoux (1995) offer a set of guidelines for revising instructional design practice and show how constructivist ideas can be incorporated into the instructional design process. Examples are shown in Table 4-2 below. Lebow (1995) takes the position that more explicit guidance is needed on how to apply constructivism to instructional design. He suggests that

"constructivist philosophy offers instructional designers an alternative set of values for addressing complex and ill-formulated design problems" (Lebow, 1995:176). Lebow (1995) points out that a review of constructivist literature advocates a set of inter-related values including *collaboration, autonomy, pluralism, authenticity, generativity, ownership, activity and reflectivity*. "When incorporated into a systematic approach to the design of instruction, these eight constructivist values expand the focus of design thinking to include enabling objectives and process goals traditionally overlooked by instructional designers" (Lebow, 1995:176).

Wilson, Teslow and Osman-Jouchoux's (1995) outline of constructivist instructional design incorporates two main ideas: firstly, who carries out the actual design, and secondly, ensuring that multiple perspectives are accommodated when designing instructional materials. Their first idea indicates that constructivist instructional design suggests that all major communities be represented in the design team including teachers and students. These end users – the 'consumers' of the instructional 'product' should contribute directly to the project's design and development. Greenbaum and Kyng (1991, cited in Wilson *et al*) refer to this as *participatory design*, and Clancey (1993, cited in Wilson *et al*) recommends that 'we must involve students, teachers, administrators, future employers and the community as participants in design […] working with the students and teachers in their setting" (1995:146). Wilson *et al* suggest that the traditional project team roles are unclear with constructivist design - roles are blurred; this can result in a "synergy or fusion of multiple perspectives that improves the design" (1995:147). This can lead to chaos and confusion if not properly managed.

Wilson *et al*'s (1995) second idea is based on the premise that more flexibility must be built into teaching as not all students share the same learning goals, students have different styles of learning and different background knowledge. "Rather than ignore these differences, instruction should acknowledge the evolving nature of knowledge and encourage students to engage in a continuing search for improved understanding" (1995:147).

Wilson *et al* (1995) offer what they call a 'laundry list of tips' for viewing instructional design from a constructivist perspective. The list encompasses general methodology, needs assessment, goal and task analysis, instructional strategy development, media selection and student assessment based on the statements they put forward. Due to space restrictions here, these will not be described in detail but rather a few examples are illustrated in a tabular format in Table 3-2 below.

Table 3-2 Guidelines for doing constructivist instructional design (Wilson, Teslow and Osman-Jouchoux, 1995:147-154)

Major guideline	Tips
General methodology	Apply a holistic/systemic design model that considers instructional factors (learner, task, setting etc.) in increasing detail throughout the development process Include end users (both teachers and students) as part of the design team
Needs assessment	Resist the temptation to be driven by easily measured and manipulated content Ask: who makes the rules about what constitutes a need? Are there other perspectives to consider? What and whose needs are being neglected?
Goal and task analysis	Don't expect to capture the content in your goal and task analysis Allow for instruction and learning goals to emerge during instruction Allow for multiple layers of objectives clustering around learning experiences Consider multiple stage of expertise Give priority to problem-solving, meaning-constructing learning goals
Instructional strategy development	Think of instruction as providing tools that teachers and students can use for learning; make these tools user-friendly Consider constructivist teaching models such as cognitive apprenticeship, intentional learning and case- or story-based instruction Allow for multiple goals for different learners Distinguish between instructional goals and learners goals; support learners in pursuing their own goals Appreciate the interdependency of content and method
Student assessment	Incorporate assessment into the teaching product where possible Evaluate processes as well as products Use informal assessments within classrooms and learning environments

What is most clear from the brief discussion on constructivist instructional design is three-fold: firstly, constructivist instructional design does not seem to follow a strict, procedural process. Rather, 'fuzzy' models, guidelines and principles are suggested for undertaking design. This indicates a tension between 'traditional' instructional design and the 'new' constructivist-based approaches which has yet to be resolved. Hence the concern of many authors that there needs to be less theoretical discussion and more reports of successful constructivist practice. Secondly, constructivist instructional design does not involve a single designer putting together the instruction. Rather, it is suggested that many parties, including the learner are involved in the design to make it more relevant. Thirdly, constructivist instructional design must produce flexible instruction.

As a conclusion to this section, the essence of C-ID can be encapsulated by the 'new educational paradigm' spoken about by Reigeluth (1997). The factors such as co-operative relationships, diversity, co-operative learning and advanced technologies as tools are themes that have and will continue to emerge in this study.

3.3. Framework for evaluating design models

Before continuing, the concept of evaluation should be explored. In education, evaluation has a very particular meaning. Scriven describes evaluation as undertaking "the systematic, objective determination of the extent to which any three properties are attributable to the entity being evaluated: merit, worth or significance" (cited in Perry, 2001:574). According to Walberg and Haertel, "evaluation is a careful, rigorous examination of an educational curriculum, program, institution, organisational variable or policy, where the focus is on understanding and improving the thing evaluated" (cited in Wilde and Sockey, 1995). The results of evaluation normally indicate the value or worth of the thing being evaluated. It is extremely important to note that in this study, the terms *evaluation* and *evaluation framework* are used to signify a process of selection or survey. The intended outcome is not to determine the value or worth of the items being evaluated or to place judgement upon them. Rather, the purpose of the evaluation in this study is to undertake a careful and rigorous examination of instructional design models in order to further understand them and to determine the significance of those items for this study. In the educational literature (Shaw, 1999; Weiss, 1998; Winberg, 1997; and Worthen and Sanders, 1987) strict guidelines are given for designing an evaluation. This evaluation will loosely follow those guidelines as follows:

1. An instrument or tool will be designed to facilitate the selection process and data collection for the evaluation. The tool will include criteria and scoring mechanisms. This tool will be based on ideas found in the educational literature (Andrews and Goodson, 1980; Reeves, 1997) as well as those from business literature (Meredith and Mantel, 2003). However, these ideas form the starting point for the tool; my contribution will to extensively fine-tune the model to work for this study and evaluation, and to perhaps make it relevant to other practitioners. The tool and its utility is described in this chapter.
2. Selection of audience, in this case the instructional design models that will be evaluated. This will be the focus of the beginning of Chapter 4.
3. Implementation of the evaluation i.e. reviewing and evaluating the selected instructional design models. This will appear in the second section of Chapter 4.
4. Presentation and discussion of evaluation results. This will be the penultimate section of Chapter 4.

Having explored instructional design and more particularly constructivist instructional design, this section develops the framework that will be used to examine design models which will be used as the basis for the new or enhanced model in this research.

An extensive literature review has been carried out in order to establish the kind of evaluation criteria there are available. Criteria or checklists have been reviewed which are used to evaluate web sites, computer-aided instruction (CAI), computer-based education (CBE) as well as

instructional design (ID); for the purposes of this chapter I will call these different types of evaluations 'educational technology evaluations[8]'. The checklists provided by the authors in these areas of expertise are often more applicable to a finished application or piece of instruction rather than for use as criteria for selecting instructional design models for review. As there is little literature to select from in connection with instructional design however, these criteria will need to form the basis for this study. As one would expect, one of the issues that has arisen as part of this literature review is that it appears that there are no criteria specific enough for this study, specifically with reference to evaluating instructional design models per se or for the GIS or South African context. A major part of this section will therefore focus on pinpointing those gaps and subsequently justifying the evaluation criteria that have been specifically devised for this study.

From this review, four high-level categories have been formed around which to base the discussion. These are: *theoretical, pedagogical, ethical, and technical adequacy*. Each of these will be described and discussed in turn in the context used by authors in the field. The discussion will also explicitly draw out where these criteria inform my own evaluation.

3.3.1. Literature Review of Evaluation Criteria

Theoretical

This category covers a broad spectrum of ideas but the main themes that can be extracted are that any evaluation of educational technology must include some kind of understanding of the epistemology (understanding of what knowledge is; the nature of knowledge) and learning theories that underlie that technology.

Let's explore the **epistemological** thread first. As with concerns expressed by Richey; Duffy and Jonassen; and Bednar *et al* on page 26 about instructional design being based on a particular learning theory, similarly I believe that instructional design should also **explicitly** reflect the *epistemological* beliefs of the designers and developers.

In his evaluation paper entitled '*Evaluating what really matters in computer-based education*', Reeves (1997) explicitly includes a dimension called 'epistemology'. He believes that users of educational technology should understand how the *designers* of that technology view knowledge as this will have influenced many of the decisions the designers would have made. He presents a continuum for this dimension which extends from 'objectivism' to 'constructivism' and illustrates how different points along this continuum influence design. However, other authors do not explicitly use the term 'epistemology' as a criterion. With other authors this is not as easily accessible or visible as a means of evaluating educational technology. This makes my task of trying

[8] Here I am referring in a **narrow** sense to the technology such as computers and the Internet that supports teaching in an educational context. I am not using the broader reference to 'educational technology' that is spoken about at length in educational literature.

to find models that satisfy my epistemological requirements more difficult as not only do the designers and developers not make this clear but also it is not an overtly stated evaluation criterion either. I intend to make it so in this study.

In their article on evaluating websites for learning purposes, Mioduser, Nachmias, Lahav and Oren (2000:58), include a 'knowledge dimension' which they describe as relating to "qualitative and structural issues concerning the site's knowledge [sic] and support for knowledge navigation". They do not specifically indicate that one needs to know what epistemology the site is based upon but rather what *type* of knowledge is displayed: "declarative, procedural, dynamic/systemic models of phenomena or systems, and continuously updated" (Mioduser *et al*, 2000:58) and by what *means* that knowledge is displayed: "text, still image, dynamic image, interactive image, and sound" (Mioduser *et al*, 2000:58). Under their 'pedagogical dimension' however, they indicate that some variables are concerned with the "developers' stance regarding the type of instruction elicited by their site" (Mioduser *et al*, 2000:58). For me, their variable 'instructional model' leans towards evaluating views of knowledge as they describe this as whether the website is directed and hierarchically organised, inquiry oriented or open-ended.

Interestingly enough not many authors define a criteria concerning ontology (the understanding of what is real) in their evaluations. This could be because many seem to conflate the ideas of ontology and epistemology. This is called the 'epistemic fallacy', which according to Margetson (2000) is the "fallacy of reducing being to our knowledge of being". Reeves seems to do just this as he describes his 'epistemology' dimension as a dimension "important to users of these systems is the theory of **knowledge or reality** held by the designers" [emphasis added] (1997:2).

The other thread that emerges from a survey of the literature which I have grouped under this category is that of **learning**: theories of learning (educational and psychological) such as those discussed in Chapter 2.

In this regard, many authors have clear criteria for evaluating these aspects of educational technology, some of which are broader than others. For example, Reeves (1997) has two dimensions that he calls 'pedagogical philosophy' and 'underlying psychology'. My interpretation of these dimensions of Reeves' are that 'pedagogical philosophy' is concerned with the *approach* taken to teaching whilst the 'underlying psychology' refers to the basic psychology underlying the learning. On the other hand Mioduser *et al* (2000) include these aspects as variables under their 'pedagogical dimension': *cognitive process, interaction type* are examples. Jackson (2000) mentions learning more in connection with **teaching** strategies rather than learning theories. His guidelines are whether the educational technology (website in his case) makes use of learning strategies such as lecturing, drill and practice, tutoring, games and so on and how well the content is

structured to facilitate learning. Jackson (2000) also mentions whether the student is encouraged to think. For me, these strategies are more to do with teaching than learning and as such are better placed under the heading of pedagogy.

Again, as we saw on page 48, I believe that it is important that any newly created educational technology or instructional design model should explicitly state its stance on how knowledge is learnt as well as the kind of strategies is uses for learning. In my study, I will be looking for a particular type of learning to take place, namely the development of higher-order cognitive skills as discussed in Chapter 2. Therefore, criteria for this study will need to be more specific with regard to learning.

One variable that comes out from a variety of authors is the concept of *motivation* and how the educational technology appeals to this aspect in the learners (Jackson, 2000; Kuittinen, 1998). The continuum provided by Reeves (1997) for his 'origin of motivation' dimension ranges from extrinsic motivation (outside the learning environment) to intrinsic motivation where it is integral to the learning environment. One of the tenets of constructivism is that learning should be intrinsically motivated by providing the learners with authentic tasks on which to learn and by involving them in the design process.

Finally in this category I would like to mention a schema used by Andrews and Goodson in 1980 that specifically aided in listing and describing models that are used for **designing instruction** rather than evaluating a finished product. These criteria or dimensions do not fall under the epistemology or learning theory theme, but from my point of view still provide a theoretical means of evaluating instructional design models. Although their dimensions will not aid me directly in evaluating instructional design models, their study is nonetheless important for my own research as the dimensions indicate the kinds of theoretical foundations that could make up the description of an instructional design model. For me this information has two purposes: 1) when reviewing models myself, these dimensions will assist understanding, and 2) in creating my own new model or enhancing an existing model, it is important that these dimensions be described as fully as possible in order that other educators may use my model with understanding.

Their study proposed a categorical schema for describing and categorising instructional design models. By undertaking an extensive literature review, they created a set of dimensions, which they could then use to describe the sample models. The dimensions they used are shown in Table 3-3 below and are briefly described. It is important to note that Andrews and Goodson allocated models to the various dimensions using the documentation and descriptions attached to the various models they reviewed.

Andrews and Goodson believe that knowing where a particular design model *originated* can help an educator use the model more appropriately. They indicate that there are two origin sources evident: theoretical and empirical. For them, *theoretical* models have their origins in a particular theory-based rationale (some examples include general systems theory or Gagne's conditions of learning) and that the description of the model should contain specific references to the theory it is based on. Their *empirical* element indicates that the description of the model will include reports of experience or research into using the model.

Their *theoretical underpinnings* dimension has to do with whether the model emphasises learning or instructional theory or whether the model focuses on different functions of general system theory such as control functions (ensuring that all portions of the instructional system behave in a prescribed manner) and analysis functions (users have confidence that the analysis of a task will proceed in a logical, orderly manner).

Andrews and Goodson used a '*purposes and uses'* dimension to determine what kind of instruction the original model was intended to be used for. Again, they have been subdivided into three categories: to teach the instructional design process, to produce viable instructional product(s) or activity(ies) or to reduce costs of training/education. In the second category, they have further subdivided into four sub-categories.

Finally, the *documentation* dimension is concerned with the quality of documentation about a particular model. The focus here is particularly on whether the model has been tried or used in an *actual* instructional setting and whether the instruction was effective or not.

Table 3-3 Dimensions used by Andrews and Goodson (1980)

Code	Dimension
1.0	***Origin***
1.1	Theoretical
1.1a	Total model (includes general systems theory or other total approach)
1.1b	One or some of the components (includes adult learning theory and other learning theories)
1.2	Empirical (includes reports of experience or research of viable processes)
2.0	***Theoretical underpinnings***
2.1	Emphasis on learning or instructional theory (includes constructs about adult learning requirements)
2.2	Emphasis on control/management/monitoring functions of systems theory
2.3	Emphasis on analysis function (includes content, task, and learning analysis of systems theory)
3.0	***Purposes and uses***
3.1	To teach the instructional design process
3.2	To produce viable instructional product(s) or activity(ies)
3.2a	Non-formal (included military, industrial, governmental, vocational, non-formal adult education)
3.2b	Formal (includes public, higher and professional education)
3.2c	Small-scale lesson/course/module development
3.2d	Large-scale curriculum/system/program development

Code	Dimension
3.3	To reduce costs of training/education
4.0	***Documentation***
4.1	Documentation, application or validation data relating to the use of the total model
4.2	Documentation, application or validation data relating to part of the model (the mere outline and description of a model being insufficient to qualify as documentation)

Pedagogical

This category is very well covered in literature. I have chosen to include all aspects of teaching (pedagogy) that can manifest themselves in educational technology. For example: aims/goals/objectives, assessment and evaluation of teaching, accommodation of learner differences, feedback to learners, interaction (learner-learner, learner-teacher), teaching strategies (drill and practice, problem solving, games, lecturing) etc. The discussion below will highlight some of these that may indirectly inform this study.

Aims, goals and objectives are another key theme in the literature. For evaluating CBE, Kuittinen (1998) suggests checking that the educational technology states the learning aims, as does Jackson (2000) and Roblyer and Edwards (2000). Roblyer and Edwards extend this to indicate if the stated skills and objectives are 'educationally significant' and align with the curriculum. Reeves (1997) takes this idea of simply checking that they are stated and employs a 'goal orientation' dimension along a continuum from sharply-focused to unfocused in order to establish where the educational program lies.

One aspect that seems to be lacking is that of *assessment* or evaluation as it tends to be referred to in the US. Of the authors reviewed, only Mioduser *et al* explicitly document a criterion for assessment / evaluation simply called 'evaluation' which they describe as "standardised tests to alternative evaluation" (2000:58). None of the authors mentioned have a criterion that determines how the educational technology deals with or incorporates assessment of the learners although some of them mention 'feedback' for the learners in different forms (Kuittinen, 1998; Roblyer and Edwards, 2000). In my opinion, this gap should be filled. In their guidelines for undertaking constructivist instructional design, Wilson, Teslow and Osman-Jouchoux (1995) support this view and indicate that assessment should be incorporated into the teaching product where possible and grounded using authentic contexts. Specifically, the form and content of assessment should be changed to represent important thinking and problem solving skills; in other words assessing the learner's understanding and active use of knowledge rather than behavioural performances (Shepard, 2000). Examples derived from Shepard (2000) would include: more challenging tasks to elicit higher order thinking, addressing learning processes as well as learning outcomes, and actively engaging learners in evaluating their own work.

Ethical

This small category includes those criteria which take into account social and ethical issues. For example, many authors include one or more criteria for evaluating whether the educational technology deals with controversial issues in a sensitive manner, depicts minorities in a respectful manner and is free from stereotyping and offensive material (Kuittinen, 1998; Roblyer and Edwards, 2000; Jackson, 2000 and Reeves, 1997).

Technical adequacy

Here I have included evaluation aspects such as availability of documentation and help functions (Andrews and Goodson, 1980; Kuittinen, 1998; Roblyer and Edwards, 2000 and Jackson, 2000); the flexibility or changeability of the educational technology (Jackson, 2000 and Reeves, 1997) and whether the educational technology is computer based and requires particular hardware and software (Kuittinen, 1998; Roblyer and Edwards, 2000 and Jackson, 2000).

This concludes the review of the evaluation criteria used to evaluate different kinds of educational technology, be they instructional design models or some kind of computer-based software or website.

So how do these facets allow me to decide which instructional design models to work with? Directly they don't. However, in my view the aspects of pedagogy, context etc. are very reliant on the theoretical dimensions. It is almost as if the results of the theoretical criteria must be established first before one can then apply pedagogical or other criteria. For example, if one is to evaluate an instructional design model in order to create a new piece of instruction or educational technology, one would first filter out those models that align with your own views on epistemology and learning. Then one would look for stages, steps or procedures in the model that would reinforce those basic principles. For example, if one was looking to design a piece of software to reinforce the learning of multiplication tables for primary school learners, one may look first for instructional design models that emphasise behaviourist learning and hence drill and practice strategies with precisely stated aims and objectives and assessment procedures.

3.3.2. Evaluation criteria devised for this study

Not having literature to provide specific criteria for this study, I have taken the concepts used by the above researchers and devised my own set of criteria. These are described in the following paragraphs. In an **ideal** world I would be able to find models that would satisfy all of the criteria listed and which could be applied directly the design of GIS materials for this study. As instructional design is used commercially as well as in the educational context, there is almost certainly countless undocumented models being used in the commercial world. However, from the academic literature review this is not evident and it is clear that it will not be the case that I will find

a model I can apply directly. To quote Wilson *et al* (1995:140) "there are no simple answers to design … so quit asking for the end-all, be-all model..."

Descriptive elements

The descriptive dimension (shown in Table 3-4 below) will allow me to document basic information about the model under examination such as the model name, who the authors of the model are, it's date of inception and where documentation is to be found on the model. If possible it will be valuable to determine where the model originated from and what it was originally used for. These last two aspects have been drawn from the study undertaken by Andrews and Goodson (1980) and will serve to provide background information on the model under review.

Table 3-4 Summary of descriptive elements

Model Name / Guidelines for	**Author(s) and Institution**	**Date**	**Source of Documentation**	**Possible Model Origin and Purpose**
Name given to the model or guidelines by the authors	Authors names and institution they publish under	Date of publication	Documentation reference e.g. journal article, web article, book chapter etc	- Has the model emerged from a theoretical or empirical background? Using the criteria given by Andrews and Goodson (1980): - Why was the model originally created? • For a practical or academic purpose? • To teach instructional design • To produce viable instructional / learning product(s) or activity(ies)

Evaluative elements

The *theoretical framework* is the core of the evaluation as can be seen from the discussion in Chapter 2 and in section 3.3.1 above. This subset includes foci on how the model under review regards the nature of knowledge (epistemology), how learning takes place as a result of designing using the model (learning theories) and fundamental beliefs in how these are reflected in classroom practice (pedagogy). The *ontological* focus has been placed slightly outside the framework. This is because this study aligns itself with a 'cognitive constructive science' approach and because I am not looking directly to evaluate instructional design models on how they view reality. The *implementation* subset concerns itself primarily with determining if the model under review is a computer-based model. There is overlap here with the theoretical framework in terms of interactivity which is a key driver for computer-based learning. Finally the *context* subset looks at those elements that will determine if models are suited to a South African context and will work in an OBE, high school context. This is the area where a lack of formal literature will make it impossible to apply these elements as primary criteria but represent instead the 'ideal' world. *Context* intersects with both the *implementation* and *theoretical framework*. As has been shown, OBE has a particular view of what knowledge is, how it is learnt and how this can be applied in classroom practice; hence the concepts of problem-solving, development of higher-order thinking skills and collaboration have been highlighted here. Figure 3-1 below is a diagrammatic

representation of the evaluative elements. The rationale for each evaluation element in the 'bubbles' is given in the paragraphs below and the final evaluation matrix is shown in Table 3-5 on page 60. The question numbers referred to in the subsequent paragraphs are those in Table 3-5

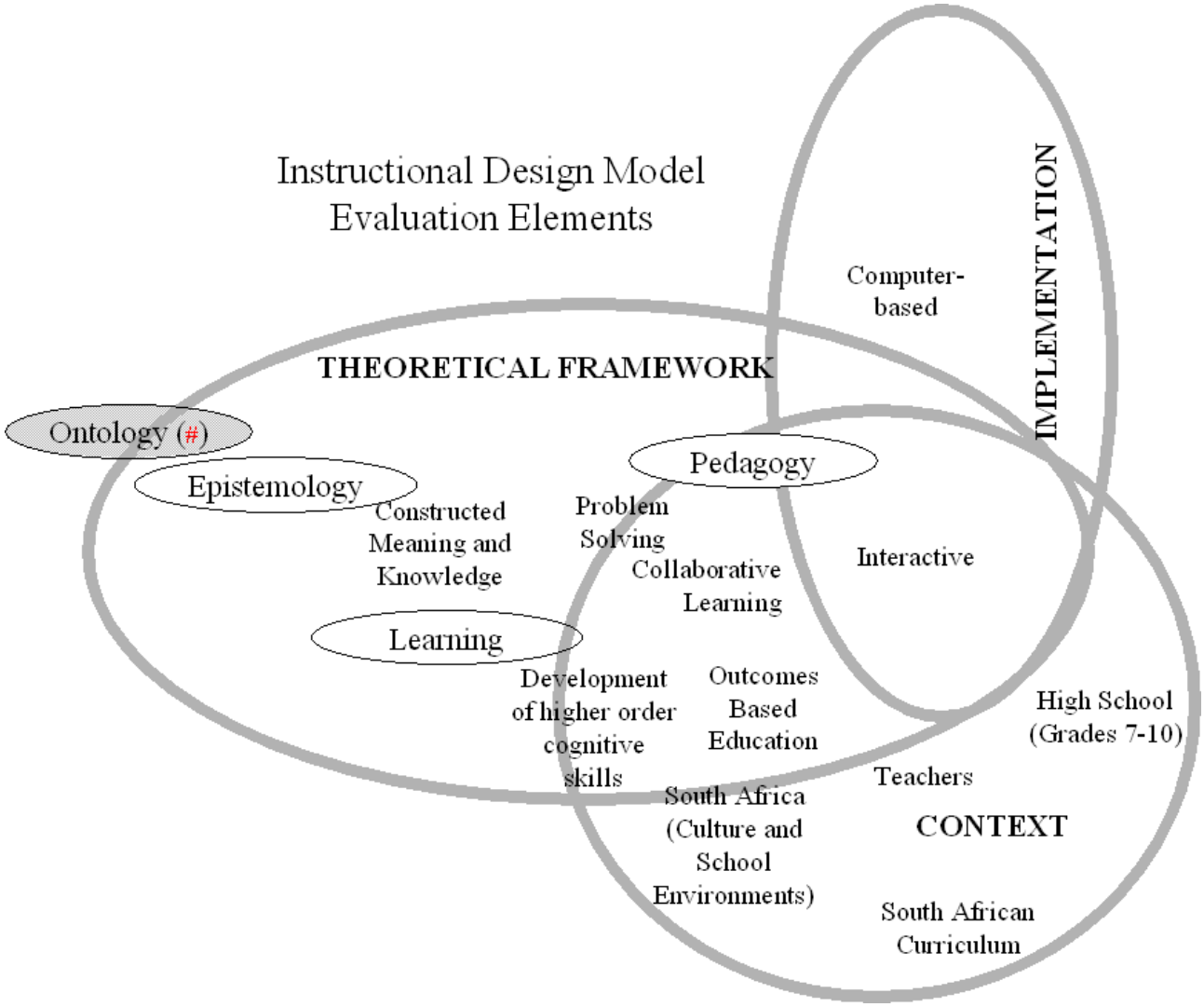


Figure 3-1 Diagrammatic representation of evaluative elements

Theoretical framework criteria

This grouping has been divided into three sub-sections: *knowledge* (*epistemology), learning* and *pedagogy*. Overall, the guiding questions for this section attempt to locate the model in the kind of cognitive-constructivist domain described in the section on learning theories in Chapter 2[9]. Specifically, the guiding question for *knowledge* has been derived from the work of Reeves (1997) but focuses on the kind of cognitive-constructivist instructional design model I am working with. For *learning*, the criteria are focussed on locating instructional design models that lean towards cognitive learning approaches and strategies. Again, these have been drawn from the dimensions employed by Reeves (1997), Mioduser *et al* (2000) and Jackson (2000). The specifics in questions 3

[9] In addition, the criteria have been derived from the theoretical category discussion in section 3.3.1.

to 6 have been refined based on guidelines for this kind of instructional design put forward by authors such as Jonassen, 1992; Bednar *et al*, 1992; Scardamalia, Bereiter, Mclean, Swallow and Woodruff, 1989 and Wilson *et al*, 1995[10]. The final subset is entitled *pedagogy* (questions 7-9). These focus on locating instructional design models which emphasise assessment as an integral part of the design process and use authentic tasks as part of learning experience. As I indicated earlier in this chapter, assessment is not well represented in evaluation criteria for educational technology. I have therefore attempted to put forward a number of questions that will focus on finding instructional design models that 1) include assessment as part of the design process and 2) focus on the kind of assessment that aligns with the cognitive-constructivist domain. Criteria 8 and 9 have been derived from Jonassen, 1992; Bednar *et al*, 1992; Wilson *et al*, 1995 and Reeves, 1997. Many of the criteria described in section 3.3.1 regarding pedagogy relate to aims / objectives / goals, motivation and so on have not been included as criteria in this section as I wish to focus more on the aspects I have already mentioned.

Questions 3, 4, 5, 7, 8 and 9 have been differentiated with an asterix (*) as a means of highlighting criteria which are conceptually more significant for this study than others[11]. As GIS technologies are the core technology for this study, it is necessary to link these questions with the GIS context if possible. Problem solving and higher-order thinking have been discussed at length in the study so far, but is there a connection with GIS technologies? The authors of the ESRI White Paper (1998) as well as Bednarz (1995) and Buss *et al* (2002) all believe that GIS technologies could be used to extend learning to include problem solving and to encourage acquisition of higher-order thinking skills. Specifically, Buss *et al*, point out that "investigations examining the claims that novices can use GIS technologies as problem solving tools and that these tools can enhance student understanding are informing instructional practices" (2000:1). These opinions relate to question 3.

Question 4 is concerned with engaging learners in the process of creating, organising, elaborating, interpreting and representing knowledge. Sarah Bednarz gives us some insight into empirical evidence that GIS technologies can support this aspect: a GIS based class project allowed learners to manage a complex case so they could see relationships and helped them develop "hypotheses to make tentative interpretations of experiences and go on to elaborate and test those interpretations" (1995:3). She goes on to point out that teaching *with* GIS may provide the ideal environment to construct understandings about complex relationships but that teaching *about* GIS will not (Bednarz, 1995).

[10] See section 0 for details of these guidelines.

[11] See page 62 for further discussion of these significant criteria.

The authors of the ESRI White Paper believe that because learning interventions or explorations with GIS technologies are based largely on real world authentic contexts (question 7), attention can be given to collaboration (question 5) between learners, educators and the community which provides "long-term benefit for all" (ESRI 1998:10). Furthermore, Broda and Baxter state that GIS technologies can help learners "explore, experience and analyse their surroundings in a direct and engaging format" rather than removing learners from the real world (2002:51).

There is little evidence in the GIS literature of GIS technologies being used for assessment purposes or for learning materials where assessment (question 8) is integral to the learning tasks, although due to it's nature, GIS does allow one to focus on real-world problems, which could then be designed to include authentic assessment (question 9). For me this is an opportunity to ensure once again that assessment is included in the model resulting from this study.

Implementation criteria

Questions 10 - 13 in the *implementation* grouping, concentrate on four specific aspects. Firstly, is the model under review used for designing computer-based learning? GIS is a computer-based product and the alignment suggested to cognitive tools in Chapter 2 means that instructional design models should have this as a central design factor if at all possible. I have found it necessary to include this criteria as instructional design models can be used to design **non** computer-based learning materials such as games, textbooks, audio-visual presentations and so on. Secondly, as an extension of the first, does the model account for interactivity between learners and computers? Kuittinen (1998) and Mioduser *et al* (2000) include variables or criteria for interaction or interactivity, which are concerned with *how* the learner interacts with the educational technology and not how the educational technology can be extended to ensure interaction between learners and groups. Thirdly, as we saw from the discussion in section 3.2, constructivist instructional design tends to be a very recursive, non-linear process. It will be interesting to see with the models reviewed if this is indeed the case. It is for this reason, that this question has not been marked with an asterix (*). The final question seeks to determine if the model has actually been used in educational situations and if there is any indication as to it's effectiveness. This was one of the key findings of the Andrews and Goodson study back in 1980. Many of the models reviewed then did not have data concerning their effectiveness so that other educators would know if it would work in their setting (Andrews and Goodson, 1980:176). I have included it here to see whether the situation has improved over the last 23 years.

Context criteria

This final grouping represents the 'ideal world' hence none of them are considered key criteria (*). Questions 14 - 16 are driven by the local context: South African education follows an Outcomes Based Education (OBE) approach which is highly influenced by globalisation and acquisition of the

required workplaces skills. These aspects are discussed in the section on OBE in Chapter 2. Question 16 has been derived from the writings of those authors reviewed in section 3.3.1 such as Kuittinen, (1998); Roblyer and Edwards, (2000); Jackson, (2000) and Reeves, (1997), all of whom include some aspect of cultural sensitivity or ethics in their evaluations. Ideally, I am looking for instructional design model documentation to include some kind of reference to this aspect, as these issues are very critical in the South African context.

Table 3-5 below is a summary of the evaluative elements. The next section presents how these elements will be incorporated into a scoring instrument / tool for the evaluation process.

Table 3-5 Summary of evaluative elements

		Guiding Questions (Criteria for selection)
Theoretical framework	*Knowledge (Epistemology)*	
		1. Within the broader 'constructivst' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology* whereby learners actively engage in building knowledge structures?
	Learning - Does the model:	
		2. Align itself with *cognitve learning theories*?
	*	3. Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning?
	*	4. Account for engaging learners in the process of creating, organising, elaborating or representing knowledge?
	*	5. Take into account learning as a result of *collaboration* between learners and others?
		6. Focus on the *process* of knowledge acquisition rather than the products of knowledge acquisition?
	Pedagogy - Does the model*:*	
	*	7. Focus on basing the learning around *authentic tasks* that have real-world relevance and value
	*	8. Give attention to assessment which is integrated into the task?
	*	9. Allow design of assessment that focusses on *authentic, real-world assessment criteria*?
Implementation	*Does the:*	
	*	10. Model take into account/design for *computer-based learning*?
		11. Model take into account/design for *interactivity* between computer and individual learner as well as computer and groups of learners (via computer networks, email etc)?
		12. Design process suggested by the model follow a *recursive* and non-linear process and / or a set of guidelines?
		13. Model have any evidence to indicate its *effectiveness* in practice?
Context	*Does / could the model:*	
		14. Operate in or developed in a South African context?
		15. Support an OBE approach to education?
		16. Include any aspects of *cultural sensitivity* (explicit or implicit)? Examples include: lack of stereotyping, gender sensitivity, controversial issues treated in a balanced manner, sensitive treatment of moral and social issues

3.3.3. Evaluation tool and scoring

As indicated in previous sections regarding availability of evaluation criteria, so too there is a dearth of literature describing ways to actually evaluate and 'quantify' instructional design models. In 1980, Andrews and Goodson devised their own tool or schema in order to list and describe a representative sample of instructional design models. Their purpose was to aid educators in determining which models could be used for designing instruction in their own contexts. In this study, the purpose is to find models that support the theoretical foundations of the study as well as

supporting the usage of GIS technologies. The schema used by Andrews and Goodson (1980) placed reviewed models under a particular element heading from which they then drew graphical and textual conclusions. In this study, it is important that there is some way of quantifying a model's position in relation to a guiding question or criterion. For these reasons, I have therefore found it necessary to design a framework to do this.

The framework is represented as a weighted scoring matrix. Weighted scoring matrices are used extensively in commercial environments, such as project management, as a means of evaluating items that cannot be scientifically measured and which are reliant on fairly subjective opinions. A weighted scoring matrix is a tool that provides a systematic process for selecting **projects** based on many criteria (Schwalbe, 2002; Meredith and Mantel, 2003) although the method can be used for selecting other items. The process of creating a simple weighted scoring matrix can be summarised as follows. First criteria important to the selection process must be identified. Subsequently weightings or percentages are assigned to each criterion based on their importance, so they add up to 100%. In a simple matrix, scores are then assigned to each criterion for each item under review. Finally the scores are multiplied by the weights and totalled to arrive at the final weighted scores. In the final analysis, the higher the weighted score, the better.

The matrix in this study has been extended to include a number of different components and each of these components is described in the subsections that follow[12]. The **components** are:

1. Individual guiding questions (criteria)
2. Individual criterion weighting (proportion)
3. Criteria alignment scale
4. Individual criterion 'critical' scores
5. Overall critical score indicator
6. Model scores

[12] An electronic copy of this matrix / tool is included with the CD-ROM that accompanies this study called *Model Evaluation - Weighted Decision Matrix.xls*. To aid understanding of this section, it may be helpful to open this file and navigate to the first sheet called **Blank Model.**

Component 1. Individual Guiding Questions

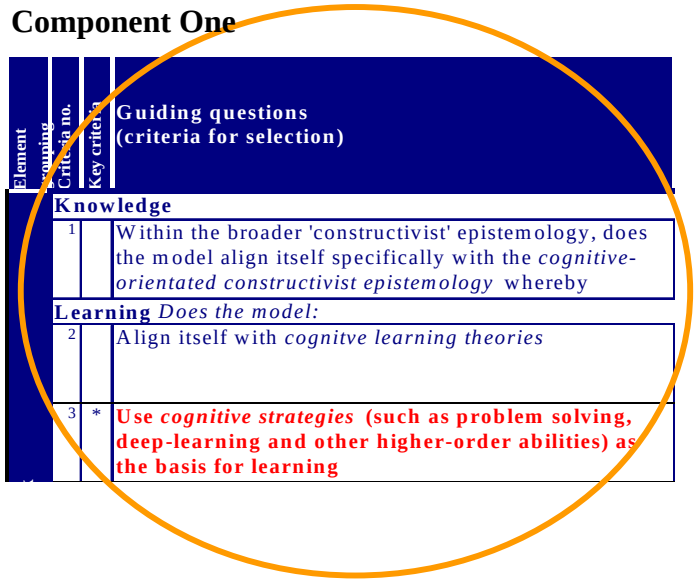


Figure 3-2 Evaluation Matrix - Component One

These guiding questions Figure 3-2 have already been detailed and discussed in the previous section. It was stated that key criteria were marked with an asterix (*); these are also represented in the matrix.[13].

2. Individual Criterion Importance and Weighting

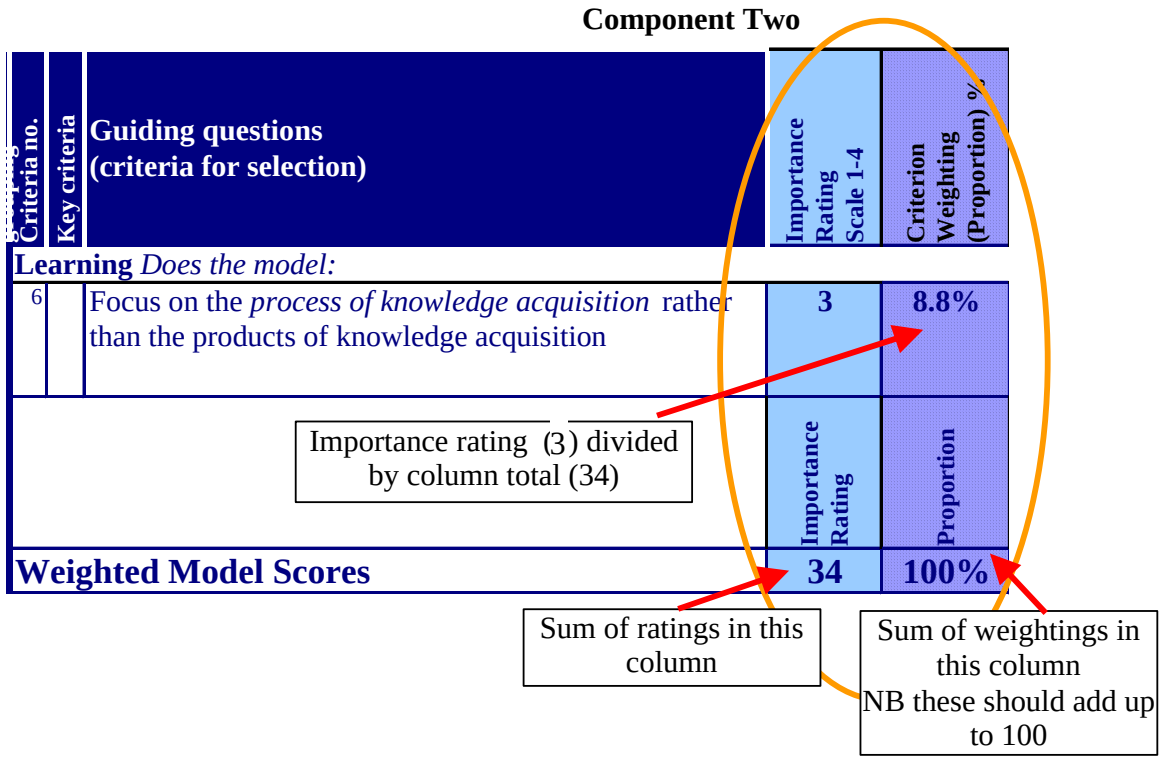


Figure 3-3 Evaluation Matrix - Component Two

In their explanation of how weighted scoring matrices work, Meredith and Mantel (2003) suggest that weightings should be allocated to the criteria to represent their **relative importance**; therefore,

[13] See Figure 3-5 on page 74 which shows the final instrument ready for use.

each of the criteria for this study have been allocated a weighting using the four-point scale shown in Figure 3-4 below

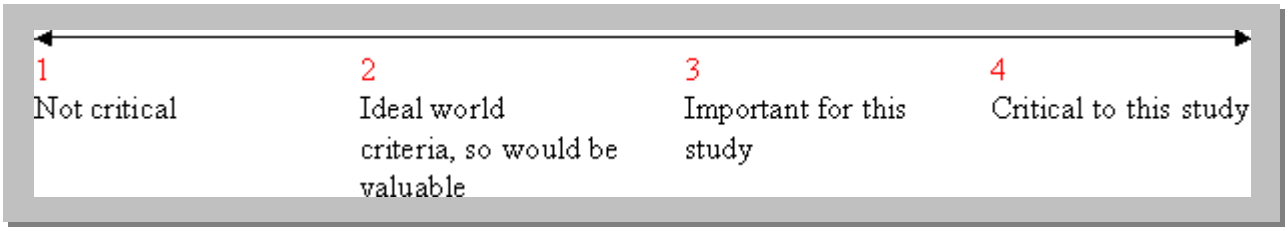


Figure 3-4 Four point scale for criteria importance

Meredith and Mantel indicate that "by their nature, criteria weightings are subjective as they are an expression of what the decision maker thinks is important" (2003:58); in this case, I am the decision maker. I hope, however, that the reasons for assigning the weights are clear from this and previous discussion of the criteria. For example, key criterion three has been allocated a score of 4, which indicates that it is critical to the study. For the reasons given in section 3.3.2, key criteria numbered 3, 4, 7 and 8 have been allocated a score of 4. Key criterion number 5 has been allocated a 3 indicating that it is an important criteria for the study but not critical. Although collaborative learning is a key tenet of constructivist learning its inclusion in instructional design models is not as important as other criteria. Similarly, key criterion number 9, has also been allocated a three; criterion 8 ensures that the idea of integrated assessment is evaluated in models, whilst this criterion represents more specific detail concerning assessment. Key criterion number 10 has been allocated a score of two. Whilst the core technology for this study is computer-based GIS technologies, many good instructional design models are not specifically for computers and I do not wish to exclude them based on this criteria.

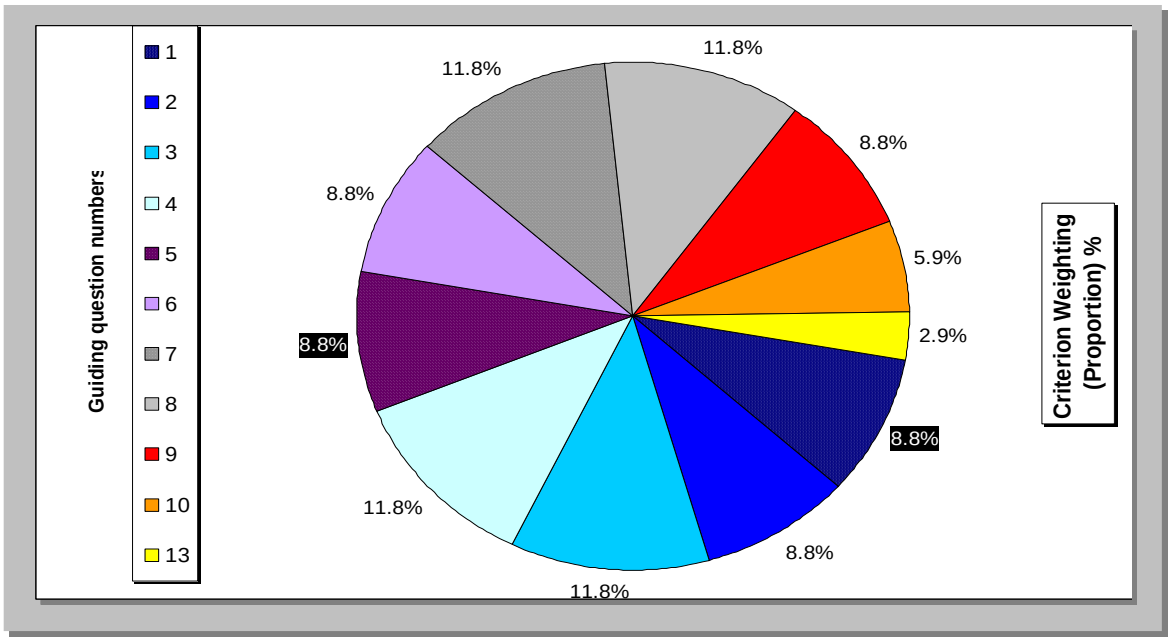


Figure 3-5 Pie chart representing the proportions for the criteria in this study

The pie graph in Figure 3-5 above shows the proportions of the weightings assigned for this evaluation. Obviously, if this evaluation matrix were to be used for a different evaluation, then the weightings, and proportions would be different.

Finally, there is the matter of the 'ideal world' criteria which have been included in the matrix. Meredith and Mantel (2003) caution against including a large number of criteria especially those that they call 'marginally relevant criteria' (2003:57). They point out that "after the important factors have been weighted, there is usually little residual weight to be distributed amongst the remaining elements" (2003:57) with the result that the evaluation is insensitive to major differences in the scores of the minor criteria. They recommend discarding elements from the matrix with weights less than 0.02 or 0.03. During the setting up of this matrix, this was exactly the problem encountered with the 'ideal world' criteria. For this reason, those criteria numbered 11, 12, 14, 15 and 16 have remained unweighted to allow a greater range for the key criteria. These elements will still be reviewed and scored during the model evaluation but they will have little bearing on the final score.

Component 3. Criteria Alignment Scales

Next, let's consider the *criteria alignment scale* used by this framework. This scale has two levels to it: the first is a *generic* alignment scale and the second is a detailed scale for *each* criterion.

The *generic* alignment scale gives the user of the framework a way of 'answering' the guiding question based on how well a particular model aligns with the question. For example, question 5 asks if the model takes into account learning as a result of collaboration between learners and others. If the documentation yields an explicit, positive response to this question, then a score of 5 can be allocated to the guiding question for that model. This scale has been derived from the basis of a Likert scale used in many fields of research but was primarily motivated by Reeves' concluding remarks in his *"Evaluating what really matters in computer-based education"* article. Here he mentions that quantitative scales should be integrated into each of the dimensions he proposes for them to have added merit and utility (1997:12). During my own review of his paper, I found it difficult to ascertain where to place myself on any given continua and decided to incorporate a quantitative scale into this study. The generic alignment scale is shown in

Figure 3-6 below.

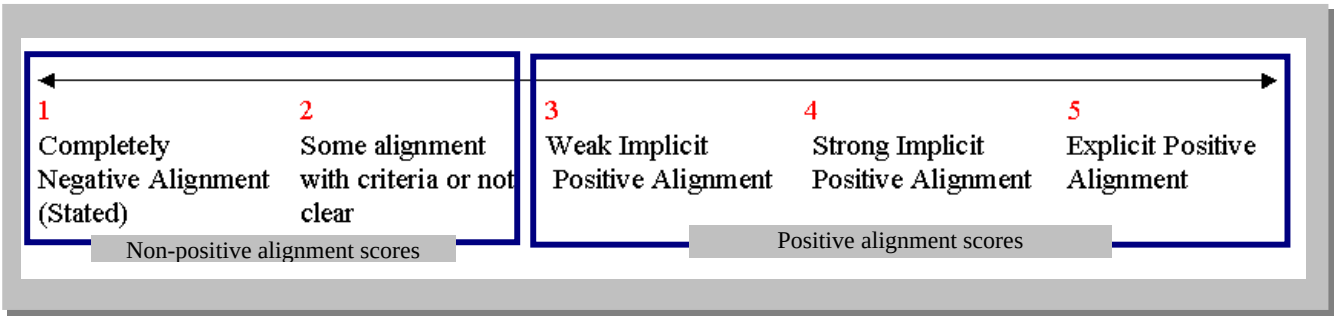


Figure 3-6 Generic criteria alignment scale

This concept has then been developed into a more detailed scale for each criterion, this time based on the suggestion given by Meredith and Mantel (2003) concerning a means of measuring the degree to which each criteria is satisfied. The detailed scales for each criterion are shown in Figure 3-7. You will notice, that textual descriptions have been provided only for the extremes of the scale i.e. scores 1 and 5. Combining the generic alignment scale shown at the top of the columns and the extreme descriptions can derive the in-between scores.

				Stated negative alignment	Some alignement with criteria or not clear	Weak implicit positive alignment	Strong implicit positive alignment	Stated explicit positive alignment
Element Grouping Criteria	no.	Key criteria	Guiding questions (criteria for selection)	1	2	3	4	5
Theoretical Framework	1		Within the broader 'constructivist' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology* whereby learners actively engage in building knowledge structures	Falls within objectivist epistemology				Model authors explicitly state their alignment with the cognitive-orientated constructivist epistemology
	2		Align itself with *cognitve learning theories*	Concerned with behaviour reinforcement such as drill and practice that can be directly observed				Emphasis placed on internal mental state of the learner
	3	*	**Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning**	Importance of content driven goals and objectives, content sharply defined /prescribed				Goals and objectives that focus on developing cognitive skills are explicitly stated in the model
	4	*	**Account for engaging learners in the process of creating, organising, elaborating or representing knowledge**	Learner seen as passive recipient of instruction				Learners are activley engaged in creating and representing knowledge
	5	*	**Take into account learning as a result of *collaboration* between learners and others**	Collaboration doesn't support learning				Collaboration stated explicitly and integral to model
	6		Focus on the *process of knowledge acquisition* rather than the products of knowledge acquisition	Products of knowledge acquisition are the results of learning				The processes of knowledge acquisition are critical to the learning process
	7	*	**Focus on basing the learning around *authentic tasks* that have real-world relevance and value**	Learning takes place in objective manner through the senses				Learning environment is a rich as possible
	8	*	**Give attention to assessment which is integrated into the task**	Assessment is summative and separate to the learning tasks				Assessment is ongoing and part of the learning tasks
	9	*	**Allow design of assessment that focusses on *authentic, real-world assessment criteria***	Assessment is norm-referenced or assessment critieria not transparent				Assessment criteria are based on real world examples, assessment is transparent and rubric based
Implementation	10	*	**Does the model take into account/design for *computer-based learning***	Not for computer-based instruction / learning				Model explicitly designed for computer-based learning
	11		Does the model take into account/design for *interactivity*	Interactivity not considered important in the model				Interactivity intrinsic to the model
	12		Does the design process suggested by the model follow a *recursive* and non-linear process and / or a set of guidelines	Structured, linear process				Explicitly stated that it is a set of guidelines or is recursive in nature
	13		Does the model have any evidence to indicate it's *effectiveness* in practice	No evidence				Evidence is discussed of the model's effectiveness
Context	14		Does the model operate in or developed in a South African context	No				Yes, definatley
	15		Does the model support an OBE approach to education	No				Yes, definatley
	16		Does the model include any aspects of *cultural sensitivity*	Cultural sensitivity is unimportant to learning				Cultural sensitivity is integral to the model

Figure 3-7 Detailed criterion scales

Component 4. Individual criteria critical score

Component Four

Criteria no.	Key criteria	Guiding questions (criteria for selection)	Criterion Weighting (Proportion) %	Criterion Critical Score (Scale 1 to 5)
Knowledge				
1		Within the broader 'constructivist' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology* whereby	**8.8%**	**3**
Learning *Does the model:*				
2		Align itself with *cognitve learning theories*	**8.8%**	**3**
3	*	**Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning**	**11.8%**	**5**
4	*	**Account for engaging learners in the process of creating, organising, elaborating or representing knowledge**	**11.8%**	**5**
5	*	**Take into account learning as a result of *collaboration* between learners and others**	**8.8%**	**4**
6		Focus on the *process of knowledge acquisition* rather than the products of knowledge acquisition	**8.8%**	**4**

Figure 3-8 Evaluation Matrix - Component Four

The fourth component of the scoring matrix is the *critical score*. The models[14] that are reviewed will be very similar and will more than likely already align either explicitly or implicitly with many of the key criteria. It is therefore necessary finally to determine a critical score such as that documented by Meredith and Mantel (2003).

To facilitate this, each criterion has an ideal/critical score allocated to it in the range one to five using the generic alignment scale shown in

Figure 3-6 above. It is important to note that each critical score is allocated to essentially arrive at the **overall critical score** (see below), which is the decisive filter. The reasons for allocating these scores are argued in Table 3-6 on page 69 below and should be reviewed in conjunction with the discussion concerning weightings for each criterion on page 62. The column headed *% of models with critical score equal or above* following directly after the critical score will be used after the evaluation has taken place to analyse what percentage of the examined models align with this critical score.

[14] The process of selecting models for review is discussed at the beginning of the subsequent chapter.

Component 5. Overall critical score indicator

Criteria no.	Key criteria	Guiding questions (criteria for selection)	Criterion Weighting (Proportion) %	Criterion Critical Score (Scale 1 to 5)
Knowledge				
1		Within the broader 'constructivist' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology* whereby	**8.8%**	**3**
Learning *Does the model:*				
2		Align itself with *cognitve learning theories*	**8.8%**	**3**
3	*	**Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning**	**11.8%**	**5**
4	*	**Account for engaging learners in the process of creating, organising, elaborating or representing knowledge**	**11.8%**	**5**
5	*	**Take into account learning as a result of *collaboration* between learners and others**	**8.8%**	**4**
6		Focus on the *process of knowledge acquisition* rather than the products of knowledge acquisition	**8.8%**	**4**
		Component Five	**Proportion**	**Critical Score Indicator**
Weighted Model Scores			**100%**	**4.09**

Sum of (weighting * criterion critical score) for all criteria (rows)

i.e. (8.8%*3) + (8.8%*3) + (11.8%*5)+ (11.8%*5)+(8.8%*4)+(8.8%*4)+ (11.8%*5)+ (11.8%*5)+(8.8%*3)+(5.9%*3)+(2.9%*2)

(0.264)+(0.264)+(0.59)+(0.59)+(0.352)+(0.352)+(0.59)+(0.59)+ (0.264)+(0.177)+(0.058) = 4.09

Figure 3-9 Evaluation Matrix - Component Five

Each 'critical' score is multiplied by the associated weighting percentage and added up to give arrive at the overall 'critical' score: in this case this equals **4.09**. It is important to note that if any of the values for the previous components are altered, then this score will adjust accordingly.

When the various models are evaluated using the matrix, it will not be essential that the model yields the exact score for each individual question, rather that its totalled score **exceeds** the critical score of 4.09. This will ensure that only those models that have a totalled score **exceeding** this critical score will be selected as discussion models.

Table 3-6 Justification for criterion critical score allocations[15]

Overall Critical Score Indicator			**4.09[16]**	
Guiding questions (criteria)			**Criterion Critical Score (Using generic alignment scale)**	**Reason**
Knowledge				
1		Within the broader 'constructivist' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology* whereby learners actively engage in building knowledge structures	3 - Weak Implicit Positive Alignment	Although this study seeks instructional design models with this orientation as a whole, instructional design models that align with the individual elements of this epistemology are more important than the whole.
Learning *Does the model:*				
2		Align itself with *cognitive learning theories*	3 - Weak Implicit Positive Alignment	Although this study seeks instructional design models with this orientation as a whole, instructional design models that align with the individual elements of this approach to learning are more significant than the whole.
3	*	Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning	5 - Explicit Positive Alignment	As this study is attempting to create tools to develop the critical skills needed for South Africa and to build on the theoretical foundations of this study, ideally all instructional design models examined would have '5' as a score here.
4	*	Account for engaging learners in the process of creating, organising, elaborating or representing knowledge	5 - Explicit Positive Alignment	As with question 3, the instructional design model's alignment here indicates a connection with the use of technology as a cognitive tool. Again, ideally every model examined would score a '5' here.

[15] Review these in conjunction with the allocated weightings on page 62.

[16] In addition note that each *criterion critical score* is allocated to essentially arrive at the *overall critical score indicator*, which is the decisive filter. When the various models are evaluated using the matrix, it will not be essential that the model yields the exact score for each individual question, rather that its totalled score **exceeds** the overall critical score of 4.09

Overall Critical Score Indicator			**4.09**[16]	
Guiding questions (criteria)			**Criterion Critical Score (Using generic alignment scale)**	**Reason**
5	*	Take into account learning as a result of *collaboration* between learners and others	4 - Strong Implicit Positive Alignment	Collaboration is one of the critical outcomes determined by OBE in South Africa as well as being a central theme in constructivist learning. It is important that the models examined make some reference to the significance of this in the design process – whether it is to do with collaboration in the actual design or collaboration between learners and others during the learning process.
6		Focus on the *process of knowledge acquisition* rather than the products of knowledge acquisition	4 - Strong Implicit Positive Alignment	The emphasis here is on the process rather than the end product. I am looking for instructional design models to have indications that the process of knowledge acquisition is of consequence, although it does not necessarily need to be explicitly stated.
Pedagogy *Does the model:*				
7	*	Focus on basing the learning around *authentic tasks* that have real-world relevance and value	5 - Explicit Positive Alignment	Authentic, integrated assessment is a key factor in OBE and in constructivist learning, and one which is the most difficult to design for and around. Hence the higher score.
8	*	Give attention to assessment which is integrated into the task	5 - Explicit Positive Alignment	
9	*	Allow design of assessment that focuses on *authentic, real-world assessment criteria*	3 - Weak Implicit Positive Alignment	As a sub-element of questions 7 and 8, this is a part of the study but takes on lesser relative importance than the other two questions, hence the score of '3'.
10	*	Does the model take into account/design for *computer-based learning*	3 - Weak Implicit Positive Alignment	Although GIS is a computer-based technology, this criterion is not as key as those of 3,4,7 and 8. As mentioned previously, many good instructional design models can be adapted for computer-based design if the other elements are present.
11		Does the model take into account/design for *interactivity*	0 - Not expecting alignment at all	Interactivity is closely related to collaboration although it takes place between the computer and learners.

Overall Critical Score Indicator		**4.09**[16]	
Guiding questions (criteria)		**Criterion Critical Score** **(Using generic alignment scale)**	**Reason**
12	Does the design process suggested by the model follow a *recursive* and non-linear process and / or a set of guidelines	0 - Not vital	This criterion is not vital in directing the study; however it is included for various reasons. How authors communicate the design process to other users and readers is often determined by the presentation and clarity of the design process. A recursive, non-linear model indicates an alignment with constructivist learning values.
13	Does the model have any evidence to indicate its *effectiveness* in practice	2 - Some alignment with criteria or not clear	It would be advantageous if the models examined indicated their effectiveness. However the presence or lack of this information is not essential to moving this study forward.
14	Does the model operate in or developed in a South African context	0 - Not expecting alignment at all	As indicated in many ways during the course of this study, there is a lack of formal research in instructional design in South Africa for OBE. Of the models examined, I would not expect any of them to originate in South Africa and to score highly.
15	Does the model support an OBE approach to education	0 - Not expecting alignment at all	
16	Does the model include any aspects of *cultural sensitivity*	2 - Some alignment with criteria or not clear	It would be convenient if the models examined included an aspect of cultural sensitivity. However the presence or lack of this information is not essential to moving this study forward. By the mere fact that it is here, alerts users to the fact that it should be taken into account.

Component 6. Model Scores

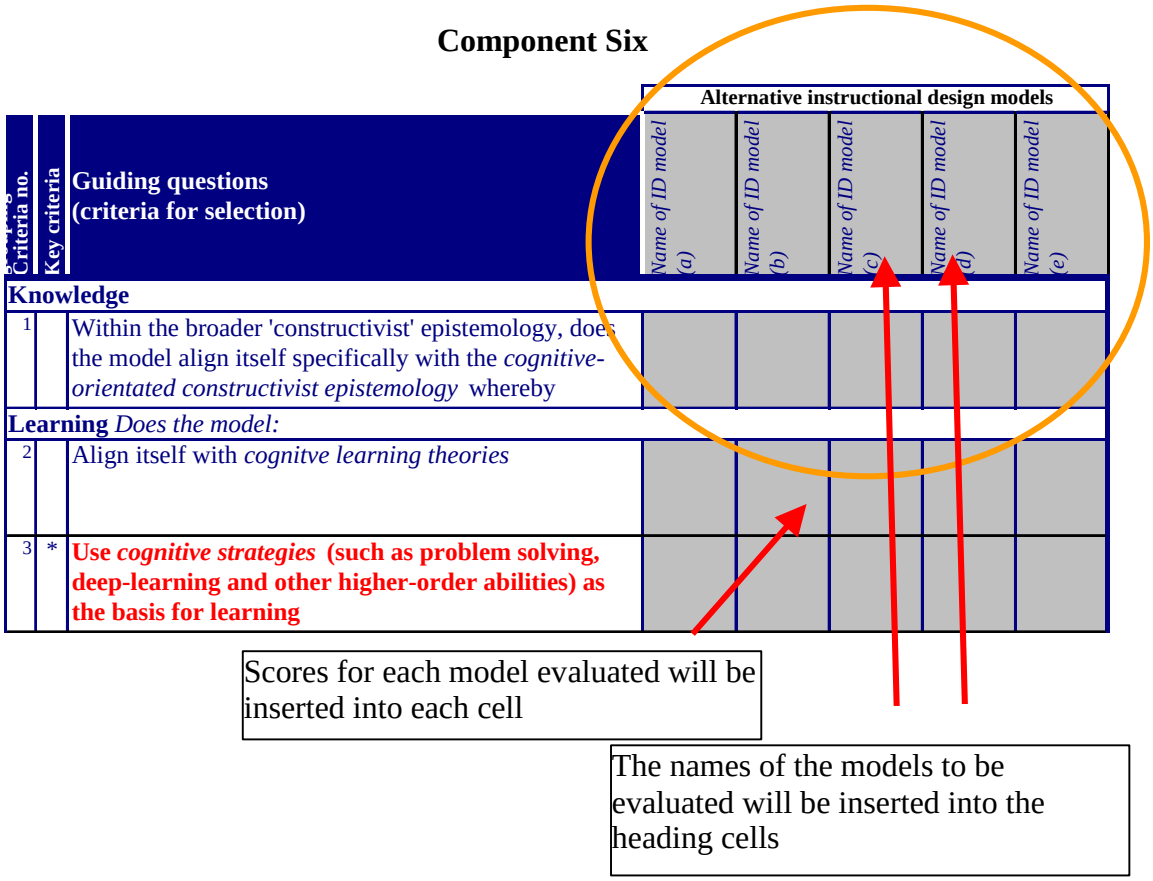


Figure 3-10 Evaluation Matrix - Component Six

The model is now ready to be used for an evaluation. The diagram above shows where the model names and scores will be inserted when the evaluation is carried out (see Chapter 4).

Summary

This completes the discussion of the weighted scoring matrix framework devised for this study. The prepared scoring matrix is shown in Figure 3-11 on page 74 below indicating the various components that have been discussed above.

It is necessary however, to raise a few issues about the framework as a whole. The creation of an evaluation framework is a difficult and complex task and one that should not be undertaken lightly especially when there is little support in the literature. Therefore, a large degree of subjectivity has taken place in the creation of the various elements of this framework although justification has been made for each of these. The author extends an invitation to other educators to apply this framework to their own situations and needs in order to provide valuable feedback on its utility.

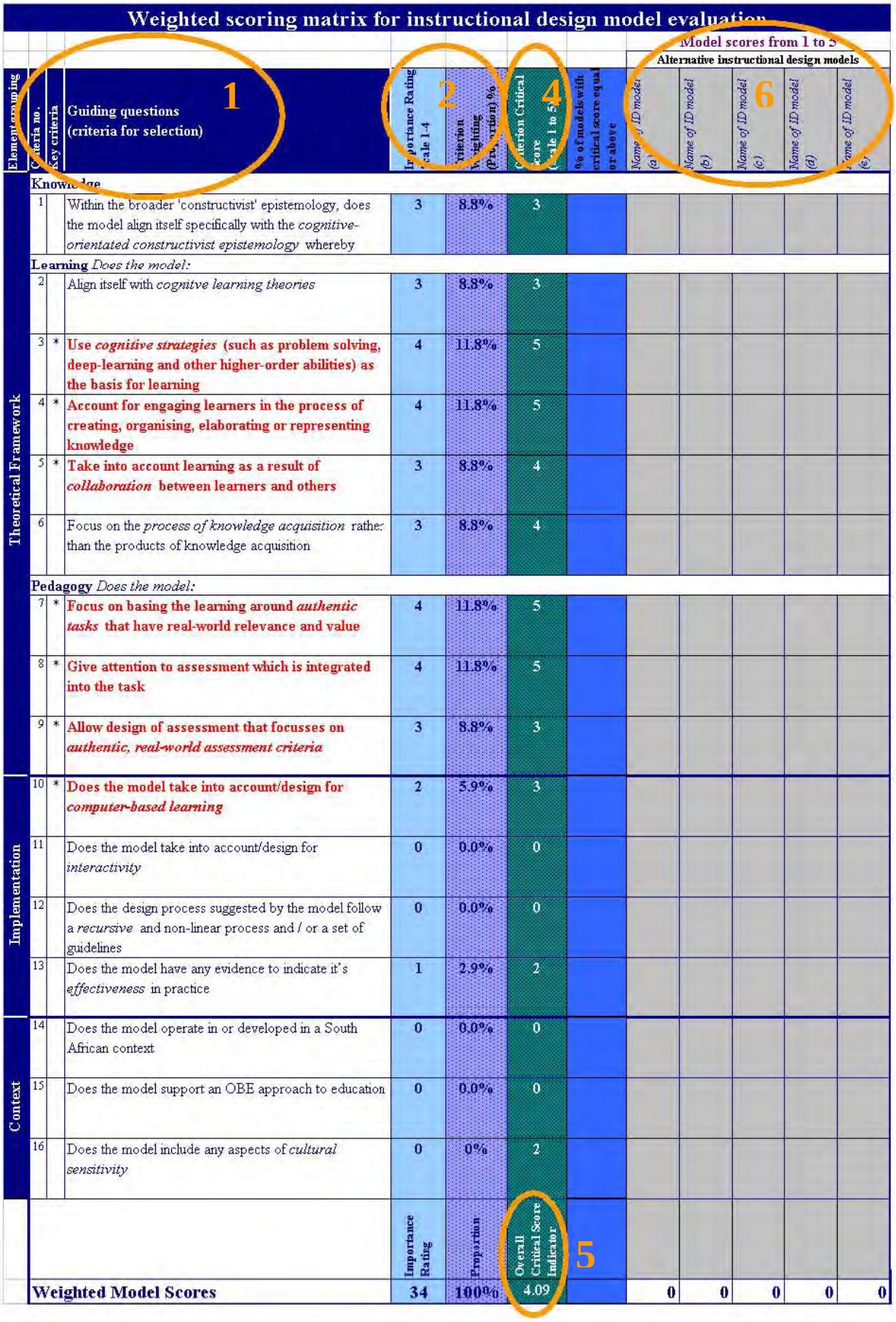
Meredith and Mantel (2003:61) cite a number of advantages and disadvantages of using a weighted scoring model. The advantages that made it attractive to use these scoring matrices in this study include that they:

- Allow multiple criteria to be used for evaluation and decision making
- Are structurally simple and therefore easy to understand and use
- Are a direct reflection of the issues that the evaluators feel are important
- Allow for the fact that some criteria are more important than others

The disadvantages that need to be considered are that:

- The output is a relative measure. The scores do not represent the value or utility associated with the items under evaluation.
- The ease of use of these models is conducive to the inclusion of a large number of criteria, most of which have such small weights that they have little impact on the total project score.

Finally I would like to point out that everything in this model is flexible and changeable – from the questions through to the overall critical score; the person or people who will be undertaking the evaluation decide all the values. This is what makes it a potentially powerful framework for other users.



Weighted scoring matrix for instructional design model evaluation

Element grouping	Criteria no.	Key criteria	Guiding questions (criteria for selection)	Importance Rating (scale 1-4	Criterion Weighting (Proportion) %	Criterion Critical Score (scale 1 to 5	% of models with critical score equal or above	Model scores from 1 to 5 — Alternative instructional design models: Name of ID model (a)	Name of ID model (b)	Name of ID model (c)	Name of ID model (d)	Name of ID model (e)
			Knowledge									
Theoretical Framework	1		Within the broader 'constructivist' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology* whereby	3	8.8%	3						
			Learning *Does the model:*									
	2		Align itself with *cognitive learning theories*	3	8.8%	3						
	3	*	**Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning**	4	11.8%	5						
	4	*	**Account for engaging learners in the process of creating, organising, elaborating or representing knowledge**	4	11.8%	5						
	5	*	**Take into account learning as a result of *collaboration* between learners and others**	3	8.8%	4						
	6		Focus on the *process of knowledge acquisition* rather than the products of knowledge acquisition	3	8.8%	4						
			Pedagogy *Does the model:*									
	7	*	**Focus on basing the learning around *authentic tasks* that have real-world relevance and value**	4	11.8%	5						
	8	*	**Give attention to assessment which is integrated into the task**	4	11.8%	5						
	9	*	**Allow design of assessment that focusses on *authentic, real-world assessment criteria***	3	8.8%	3						
Implementation	10	*	**Does the model take into account/design for *computer-based learning***	2	5.9%	3						
	11		Does the model take into account/design for *interactivity*	0	0.0%	0						
	12		Does the design process suggested by the model follow a *recursive* and non-linear process and / or a set of guidelines	0	0.0%	0						
	13		Does the model have any evidence to indicate it's *effectiveness* in practice	1	2.9%	2						
Context	14		Does the model operate in or developed in a South African context	0	0.0%	0						
	15		Does the model support an OBE approach to education	0	0.0%	0						
	16		Does the model include any aspects of *cultural sensitivity*	0	0%	2						
				Importance Rating	Proportion	Overall Critical Score Indicator						
			Weighted Model Scores	34	100%	4.09		0	0	0	0	0

Figure 3-11 Blank weighted scoring matrix showing key components

3.4. Conclusion

To draw this chapter to a close, it remains to summarise where we have been and where we are going. Figure 3-12 below shows a diagrammatic representation of how the chapter logic flows.

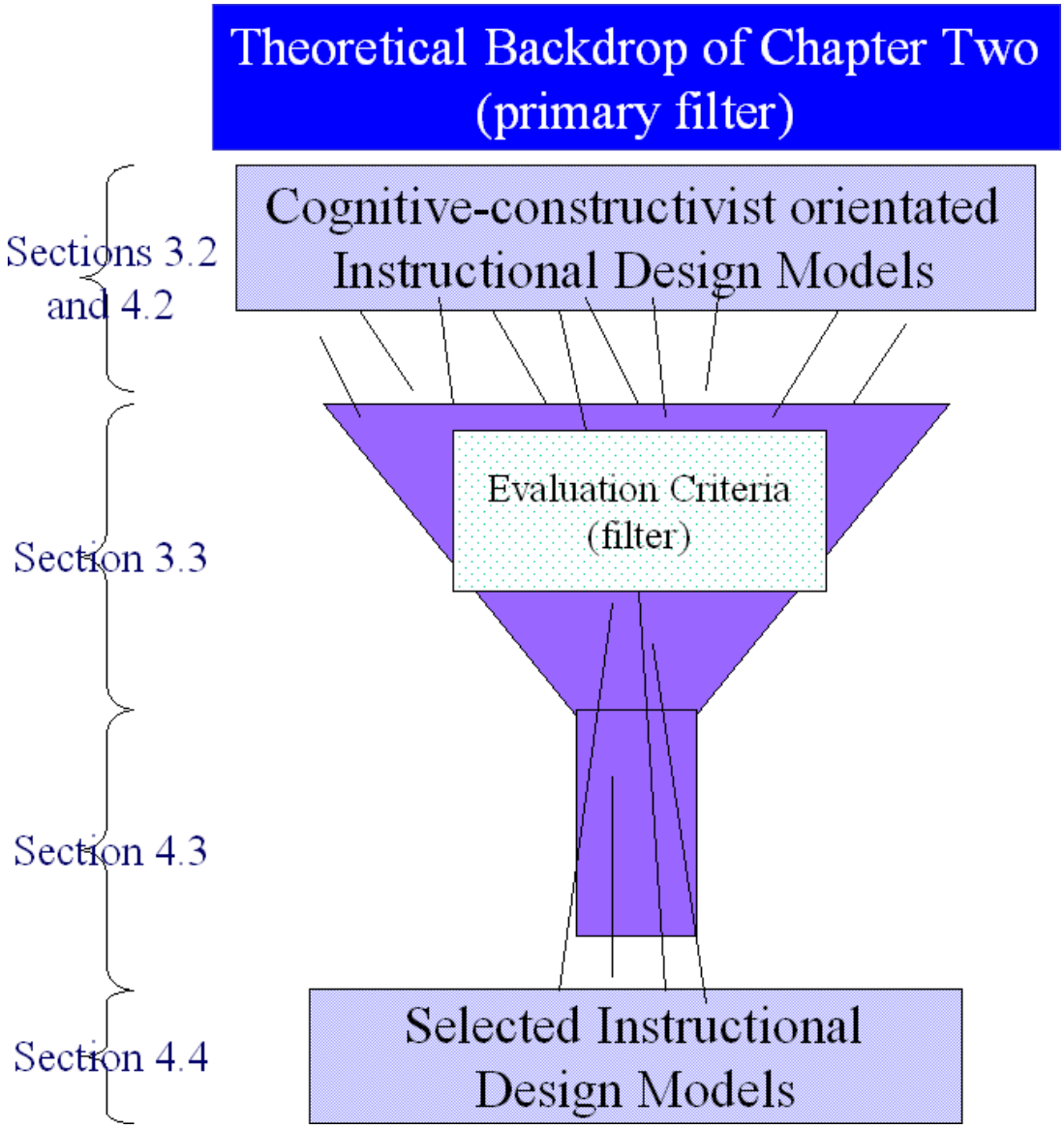


Figure 3-12 Diagrammatic representation of chapter logic

The purpose of this chapter has been twofold. 1) To give the reader an overview of instructional design and particularly constructivist instructional design in order to contextualise the evaluation framework and subsequent chapters. What was evident from the discussion, is that although there is a great need to undertake research into constructivist instructional design, this creates a conflict between the key tenets of constructivism, the people who practice instructional design and the practice of instructional design. 2) To review the kind of evaluation criteria available in the educational literature that are used to evaluate instructional design models, educational web sites and computer-based education. From this review, a framework has been developed that can be used

to filter instructional design models that are relevant to this study in particular. The criteria have either been supported by those already in use in literature or from gaps that have been identified. In Chapter 4 these criteria will be applied to a selection of cognitive-constructivist orientated models and evaluated as described in this chapter. Those that qualify will then be further analysed in Chapter 4. From this further analysis, I am hoping that it will be possible to extend one or more of the models to support the primary research question in this study:

> *"How does one design a model or framework for developing computer-based learning materials based on GIS technologies for secondary education in South Africa?"*

Chapter 4 Evaluation of instructional design models

4.1. Introduction

The purpose of this chapter is twofold: firstly to examine a selection of cognitive-constructivist orientated models using the evaluation framework described in the previous chapter; secondly to describe and discuss those that qualify to form the basis of a new or enhanced model. As with Chapter Three, this forms a facet of data collection for developmental research whereby the evaluation process is documented by reviewing the characteristics of effective instructional products, programs or delivery systems.

4.2. Selection of models to be evaluated (sample audience)

Many papers and articles have been reviewed for this section and what has become clear, not unexpectedly, is that there are not many constructivist instructional design (C-ID) 'models' available for review. Rather there is a proliferation of guidelines, frameworks or design goals and considerations consistent with the constructivist viewpoint (Jonassen, 1991 and 1992; Honebein, 1996; Willis, 2000; Wilson *et al*, 1995; Wilson, Jonassen and Cole, 1993).

When planning how to choose the sample for this evaluation, several factors were important. Initially I wished to evaluate models that have been used / developed for and in nonformal (i.e. commercial uses) as well as formal settings (academic and educational uses). I was also keen to find models that were used for both module or course development as well as for large-scale curriculum or program development. However, it soon became clear that with the proliferation of constructivist guidelines and frameworks and the limited requirements of this study that I would have to sample in a different way.

As a result, the following methods of sampling were used. The major category of sampling used was *purposeful* sampling whereby the sample is chosen based on "judgement regarding the characteristics of the target population and the need of the study. Some members of the target population may have a greater chance of being chosen, whereas others do not" (Suvedi, undated, online). Suvedi indicates that under *purposeful* sampling can consist of accidental, reputational, convenience and snowball sampling. Ultimately, this study used firstly convenience (a group that is readily available for data collection) and then snowball (whereby previously identified members of the population identify new members of the population) sampling. *Convenience* sampling was appropriate in the first instance due to access to available journal articles, book chapters and so on from my local academic library and the Internet. Having perused the models available in this literature, some of the articles mentioned other models which I then managed to track down from supplied reference lists, giving rise to the *snowball* sampling technique. An example of this was the Willis article in *Educational Technology* (2000) entitled '*The maturing of constructivist*

instructional design: Some basic principles that can guide practice'. This mentioned the A-Maze model authored by Bing and associates (1997).

4.3. Implementation of the evaluation

4.3.1. Descriptive elements matrix

As described in Chapter 3 (page 61), the first four columns of the matrix shown in Table 4-1 below provide for the documentation of background information about the models under examination. In addition, if the information about the model origin and original purpose of the model is available, it is included. This last column provides the background for the possible model origin and purpose: has the model emerged from a theoretical background to teach instructional design or from an empirical background to produce viable instructional / learning product(s) or activity(ies).

Table 4-1 Descriptive elements matrix

	Model Name / Guidelines for …	**Author(s) and Institution**	**Date**	**Source of Documentation**	**Possible Model Origin and Purpose**
1	CSILE (Computer-Supported Intentional Learning Environments)	SCARDAMALIA, M; BEREITER, C.; MCLEAN, R.; SWALLOW, J. and WOODRUFF, E. Centre for Applied Cognitive Science, Ontario Institute for Studies in Education	1989	Journal article. *Journal of Educational Computing Research* 5 (1) 51-68 article	For academic purpose and to produce instructional / learning activities.
2	New Reflective, Recursive Design and Development (R2D2) Model	WILLIS, J. and WRIGHT, K.E. WILLIS, J. College of Education, Iowa State University	2000	Journal article. *Educational Technology* 40(2) 5-18	Academic
3	A-Maze	BING, J.; FLANNELLY, S.; HUTTON, M. AND KOCKLANY, S.	1997	Web Article available at: http://www.nova.edu/~huttonm/Amaze.html	Academic purpose to produce instructional / learning activities.
4	e-ducation	NULDEN, U. Viktoria Institute and Department of Informatics, Goteborg University, Sweden	2001	Journal article. *Journal of Computer Assisted Learning* 17, 363-375	Academic purpose. Used to design a university course.
5	Engaging learners in complex, authentic contexts: instructional design for the web	HERRINGTON, J.; OLIVER, R. AND STONEY, S. School of Management Information Systems, Edith Cowan University, Australia	2000	Conference paper. *Engaging Learners in Complex, Authentic Contexts: Instructional Design for the Web*.	For academic purposes and to produce instructional / learning activities.
6	7 Pedagogical Goals	HONEBEIN, P.C. Instructional systems consultant, Reno, Nevada	1996	Book chapter. In B. Wilson (Ed.) *Constructivist learning environments*. Englewood Cliffs, NJ	For academic purpose and to produce instructional / learning activities.
7	Rich environments for active learning (REALs)	DUNLAP, J.C. and GRABINGER, R.S University of Colorado, Denver	1996	Book chapter. In B. Wilson (Ed.) *Constructivist learning environments*. Englewood Cliffs, NJ	
8	Guidelines for doing constructivist instructional design	WILSON, B., TESLOW, J. and OSMAN-JOUCHOUX, R.	1995	Book chapter. In Seels, B.B. (1995) (Ed.) *Instructional Design Fundamentals: A Reconsideration* New Jersey: Educational Technology Publications	

4.3.2. Evaluative elements matrix

A weighted scoring matrix has been used as a method of capturing scores from the evaluation of various instructional design models. Each of these numbered questions shown in Table 3-5 in Chapter 3 will be applied to the particular model under review and scored according to the procedure described in 3.3.3.

The completed matrix is shown in Figure 4-1 below. The models that qualify for the evaluation are shown in both the matrix (Figure 4-1) and the graph (Figure 4-2), namely CSILE, A-Maze and Wilson *et al*'s guidelines. These then are the models that will be described in detail in the following section.

The actual scores allocated to each question for each model are shown in the intersecting cells (grey). The final weighted score for each model is shown at the bottom of each column. Underneath each score, is a red Yes/No flag. This indicates if the score for the model exceeds that of the critical score indicator (4.09). Models that are below the critical score have been highlighted in red circles and will be discussed below.

Weighted scoring matrix for instructional design model evaluation

Element grouping	Criteria no.	Key criteria	Guiding questions (criteria for selection)	Importance Rating Scale 1-4	Criterion Weighting (Proportion) %	Criterion Critical Score (Scale 1 to 5)	Model scores from 1 to 5 — Instructional design models: CSILE	R2D2	A-Maze	e-ducation	HERRINGTON et al	HONEBEIN	REAL-s	WILSON et al	%of models with critical score equal or above
Theoretical Framework			**Knowledge**												
	1		Within the broader 'constructivist' epistemology, does the model align itself specifically with the *cognitive-orientated constructivist epistemology*	3	8.8%	3	2	2	2	5	2	2	2	4	25.0%
			Learning *Does the model:*												
	2		Align itself with *cognitve learning theories*	3	8.8%	3	5	2	3	2	1	2	3	3	50.0%
	3	*	**Use *cognitive strategies* (such as problem solving, deep-learning and other higher-order abilities) as the basis for learning**	4	11.8%	5	5	5	5	5	3	3	5	5	75.0%
	4	*	**Account for engaging learners in the process of creating, organising, elaborating or representing knowledge**	4	11.8%	5	5	3	5	3	5	5	5	5	75.0%
	5	*	**Take into account learning as a result of *collaboration* between learners and others**	3	8.8%	4	5	4	5	5	5	5	5	3	87.5%
	6		Focus on the *process of knowledge acquisition* rather than the products of knowledge acquisition	3	8.8%	4	5	3	3	4	5	5	5	3	62.5%
			Pedagogy *Does the model:*												
	7	*	**Focus on basing the learning around *authentic tasks* that have real-world relevance and value**	4	11.8%	5	5	5	5	5	5	5	5	5	100.0%
	8	*	**Give attention to assessment which is integrated into the task**	4	11.8%	5	5	2	5	3	5	2	2	5	50.0%
	9	*	**Allow design of assessment that focusses on *authentic, real-world assessment criteria***	3	8.8%	3	3	2	5	3	4	2	2	5	62.5%
Implementation	10	*	**Does the model take into account/design for *computer-based learning***	2	5.9%	3	5	5	3	5	5	3	2	3	87.5%
	11		Does the model take into account/design for *interactivity*	0	0.0%	0	3	5	5	3	3	3	2	2	
	12		Does the design process suggested by the model follow a *recursive* and non-linear process and / or a set of guidelines	0	0.0%	0	5	5	5	4	5	5	5	5	
	13		Does the model have any evidence to indicate its *effectiveness* in practice	1	2.9%	2	5	2	1	3	2	4	2	2	50.0%
Context	14		Does the model operate in or developed in a South African context	0	0.0%	0	0	0	0	0	0	0	0	0	
	15		Does the model support an OBE approach to education	0	0.0%	0	2	2	2	1	2	2	3	3	
	16		Does the model include any aspects of *cultural sensitivity*	0	0.0%	2	0	2	5	0	0	0	0	0	25.0%
				Importance Rating	Proportion	Overall Critical Score Indicator	CSILE	R2D2	A-Maze	e-ducation	HERRINGTON et al	HONEBEIN	REAL-s	WILSON et al	
			Weighted Model Scores	34	100.0%	4.09	**4.56**	**3.26**	**4.15**	**3.94**	**3.97**	**3.47**	**3.68**	**4.18**	
			Model passes filter scores?				Yes	No	Yes	No	No	No	No	Yes	

Figure 4-1 Model evaluation results

The graph in Figure 4-2 shows the differences between the final weighted scores for the models evaluated. The critical score indicator has been included as part of the graph and is shown as the red bar at the base of the graph. The models which exceed this score of 4.09 have been highlighted to differentiate them from the others. The grid or data table at the bottom of the graph gives the actual scores for each model.

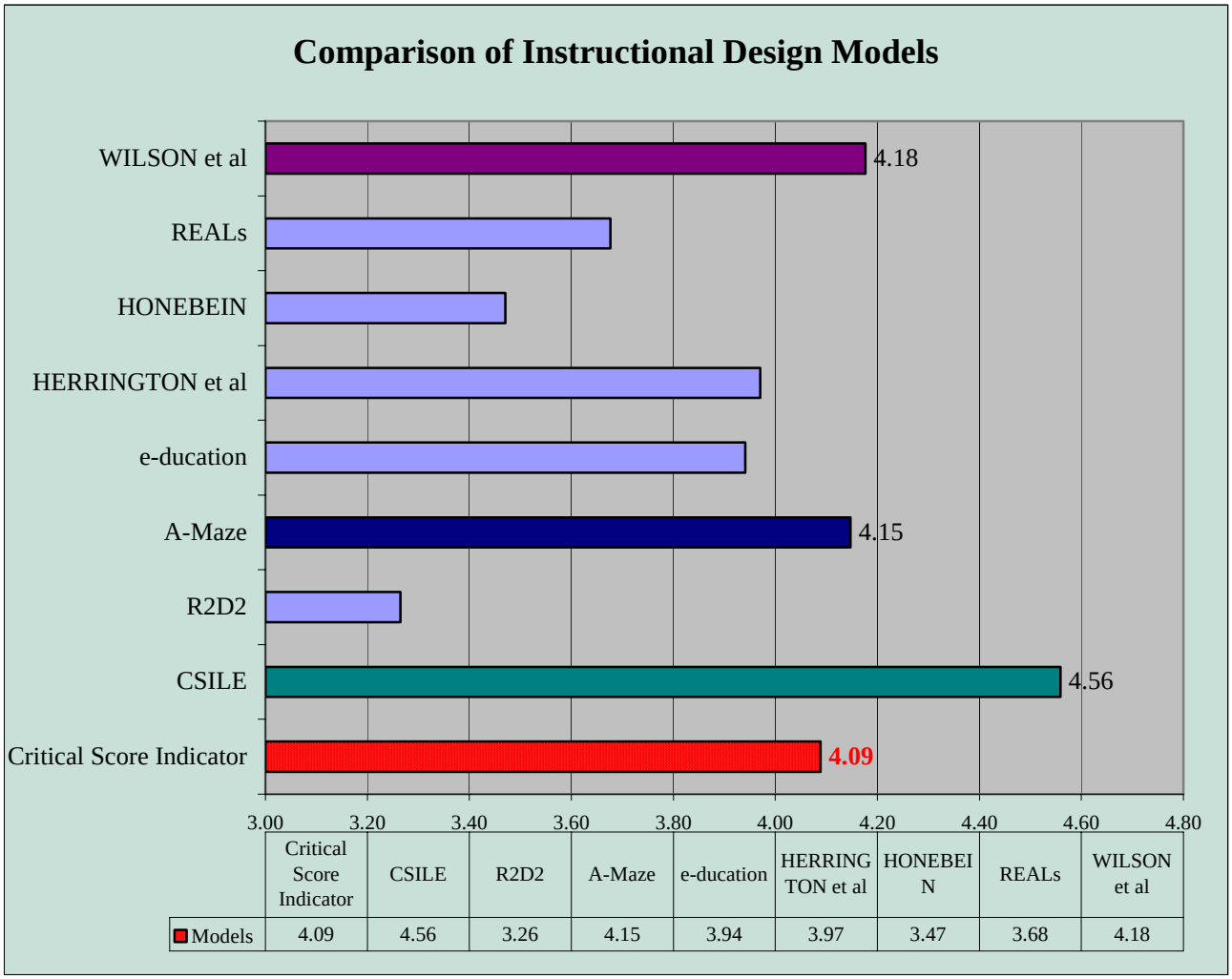


Figure 4-2 Graphical representation of model evaluation

Discussion of evaluation results

Let's consider initially at whether each model has scores equal or above the critical score for the key criteria[17] in conjunction with Figure 4-1 above. Scores that are below the critical score have been highlighted with a red circle.

Under the **theoretical** framework in the *learning* sub-section, the following is observed. For key criteria number **3**, all models except Herrington *et al* and Honebein have a score equal to that of the critical score; 6 out of the 8 models evaluated (75%) show an alignment with the notion of using *cognitive strategies*. For criteria number **4** (*engaging learners in the process of creating and representing knowledge*), 75% of the models (6 out of the 8 evaluated), have a score of 5, which is equal to the critical score. R2D2 and e-ducation are the exceptions with scores of 3. For criteria number **5** where the critical criterion score is a 4, all models except Wilson *et al* (who has a score of 3) score 4's or 5's and therefore display an 87.5% alignment with the critical score and the concept of *collaboration*. It is interesting that although Wilson *et al* score a three for this criterion, they are still one of the qualifying models: an acceptable motivation for using the final critical score indicator as suggested by Meredith and Mantel (2003).

Still under the **theoretical** framework, in the *pedagogy* sub-section, criteria number **7** that of learning around *authentic tasks*, has 100% positive alignment, highlighting this as a central element of constructivist instructional design models. *Integrated assessment* (key criterion **8**) has been an area of concern for this study due to its lack of inclusion in evaluation criteria; 50% of the models examined do not seem to include a notion of integrated assessment, namely R2D2, e-ducation, Honebein and REALs. The next criterion based on *assessment criteria*, number **9**, yields a slightly more promising 62.5% (5 out of the 8) alignment with the critical score of 3.

Finally, in the *implementation* section, criterion **10** was set at a critical score of 3 in order to not exclude any models from evaluation. Interestingly, 7 out of the 8 models (87.5%) of the models have scores of 3 or more, showing positive alignment with the criterion.

The **non-key criteria** show a mix of positive alignment with the critical score as well as negative alignment. For example, only e-ducation and Wilson *et al* give an indication of their alignment with the *cognitive-orientated constructivist epistemology* (criterion **1**). One could suggest various reasons for this but as this evaluation is not to pass judgement on a particular model, this will not be done. The explicit alignment with *cognitive learning theories* (criterion **2**) is 50% of the models: only CSILE, A-Maze, REALs and Wilson *et al* seem to place importance on this aspect. On the other

[17] Those numbered 3,4,5,7,8,9 and 10 are the criteria typed in red

hand, the process of *knowledge acquisition* (criterion **6**) indicates that 5 models (62.5%) emphasise this concept.

Using

Figure 4-3 below let's explore where the scores fall on the generic alignment scale[18]. There were a total of 16 questions in the evalaution and given that the scores will fall into either the positive or non-positive extremes of the scale, a certain amount of analysis can take place.

CSILE, A-Maze, e-ducation and Wilson *et al* have 75% of scores in the positive alignment scale. CSILE has the highest number of '5' scores with A-Maze having the second highest amount. Interestingly enough, very few of the models yielded a high number of '4' scores. Even though e-ducation has 75% of scores in the positive alignment scale, most of these are '3' scores which means that the model fails to exceed most the of individual critical criterion scores (which are mostly 4's and 5's) and the overall critical score of 4.09.

	CSILE	R2D2	A-Maze	e-ducation	HERRINGTON et al	HONEBEIN	REALs	WILSON et al
Explicit or implicit positive alignment scores								
No of '5' scores	10	5	9	5	7	5	6	6
No of '4' scores	0	1	0	2	1	1	0	1
No of '3' scores	2	2	3	5	2	3	2	5
Number of positive alignmnet scores for each model	12	8	12	12	10	9	8	12
Percentage positive alignment scores	**75%**	**50%**	**75%**	**75%**	**63%**	**56%**	**50%**	**75%**
Non-positive alignment scores								
No of '2' scores	2	7	2	1	3	5	6	2
No of '1' scores	0	0	1	1	1	0	0	0
No of '0' scores	2	1	1	2	2	2	2	2
Number of nen-positive alignmnet scores for each model	4	8	4	4	6	7	8	4
Percentage non-positive alignment scores	**25%**	**50%**	**25%**	**25%**	**38%**	**44%**	**50%**	**25%**
Total nunber of guiding questions (criteria)	16	16	16	16	16	16	16	16

Figure 4-3 Analysis of scores

What does this say about the models evaluated? It seems that many of the models do fall within the cognitive-constructivist area of focus; this was as I expected due to the selection of these models as the 'audience' of the evaluation. Many of them also have a high percentage of explicit or implicit positive alignment scores. It would have been almost impossible to select models for further discussion without the use of the scoring matrix as a way of comparing model alignment with specific criteria.

[18] Review the scores in conjunction with the generic alignment scale (page 65) and detailed criterion scales (page 66).

4.4. Qualifying model discussion

Finally this section turns to describing and discussing those models or sets of guidelines that have been filtered from the previous section (4.3.2). For each model the following will be detailed:

- Overview of the model. This will give details of who the authors are, the context in which the authors operate, information on practical usage of the model and it's effectiveness and so on.
- Theoretical basis for the model. Where possible, this section will describe the theoretical foundations used by the authors for their work. It may include references to other authors as well as arguments for the way they have approached the topic.
- Design process. This section will detail how the model or guidelines actually work for the design of instruction or learning experience.
- Discussion. Finally, this section will draw out the aspects of the models that fit most closely to this study and explain why as well as providing argument for those aspects which do not seem relevant.

At the end of this section it will become clear which aspects of these models I could incorporate into my own work. It may be that I choose to use one of the models as a basis and extend it for my own purposes or it may be the case that I will need to create an entirely new model of my own.

4.4.1. Computer-supported intentional learning environments (CSILE)

Overview of the model

This model has been developed by Scardamalia, Bereiter, Mclean, Swallow and Woodruff at the Centre for Applied Cognitive Science, Ontario Institute for Studies in Education. CSILE stands for Computer-Supported Intentional Learning Environment and is "designed to support students in more purposeful and mature, or intentional, processing of information" (Scardamalia *et al*, 1989:51). The acronym *CSILE* refers specifically to the computer-supported environment that they developed, whilst the term *computer-supported intentional learning environments* refers generically to the types of environments that promote the ability of students to exert control over their learning.

They present a model based on eleven principles as a suggested means of designing computer environments that support intentional learning. In their article, each of the eleven principles is described for use in designing *computer-supported intentional learning environments* and then related to how this was implemented in the design of their own CSILE product.

Their CSILE product was initially developed for university and graduate level students, although, at the time of writing they hoped to develop into use for all grade levels and for all school subjects.

This particular article describes the trials undertaken with grades five and six who used the CSILE product for eight months.

Theoretical basis of the model

Their work is firmly rooted in cognitively orientated research and they believe that cognitive research has made substantial progress over the last decade or so to provide a basis for designing computer-based instruction that supports students in learning how to learn and specifically in how to set cognitive goals and to develop "problem-solving and other higher-order abilities that are important objectives of education" (Scardamalia *et al*, 1989:53). Further, they believe that if computers are to provide the most support for the development of these higher-order abilities, then they will need to "encourage active rather than passive learning strategies and give students help in sustaining the more active approaches to learning" (Scardamalia *et al*, 1989:53).

Their work is based on the idea of '*procedural facilitation*'. This is a theory that provides learners with temporary supports while they are trying to adopt more complex strategies. They indicate that procedural facilitation has the "distinct advantage of being applicable to computer-mediated learning" (1989:54) and that the computer can provide the facilitating structure and tools that enable the learners to make the maximum use of their own intelligence and knowledge. In my view, theirs is a similar view to that discussed in Chapter 2 regarding cognitive tools. For this reason, their work aligns very satisfactorily with the goals of this study.

Design process

Each of the eleven principles are discussed in turn and examples given of how this was achieved during the development of their CSILE application. The guidelines are laid out on pages 55-65 of their article, which are summarised in Table 4-2 below.

Table 4-2 CSILE (Scardamalia et al, 1989:55-56)

Principle	Description
1. Make knowledge-construction activities overt	Where possible make goal-setting, identifying and solving problems on understanding, connecting old and new knowledge activities overt and identifiable, so that learners become aware of them and are better able to carry them out deliberately. Suggestions are given in how to achieve this.
2. Maintain attention to cognitive goals	Learners should be called on to state what they will learn and what they will do en route to attaining their goal. Where possible, these goals should be cognitive goals (learning, finding out etc) and not task goals (scoring points, finding treasure etc)
3. Treat knowledge lacks in a positive way	Knowing what one does not know is a vital kind of meta-knowledge. Where possible, provide ways for learners to identify what they do not know or need to find out.
4. Provide process-relevant feedback	Design partner or team activities in which one member has the job of monitoring processes and is provided with computer support for doing so.

Principle	Description
5. Encourage learning strategies other than rehearsal	Emphasis comprehension strategies. Examples are given of these.
6. Encourage multiple passes through information	Ways should be sought to make it worthwhile for learners to call back information they have dealt with previously and to reconsider it or to use it in a different context.
7. Support varied ways for students to organise knowledge	Provide varied means for learners to organise / structure their knowledge: timelines, graphs, maps, narrative sequences, story grammar structures, concept nets and causal chains. They suggest that whenever designers are about to involve students in working with a hierarchical list they stop and consider the possibility of using some other way of organising information.
8. Encourage maximum use and examination of existing knowledge	Rather than limiting the learners to using the 'knowledge' encapsulated in the software, draw on other forms of knowledge: large databases, internet, audio-visual sources, own knowledge etc
9. Provide opportunities for reflectivity and individual learning styles	The educational software must provide the learners with time, opportunity and peace in which to think about what they are doing and why. This means that the software must not be so busy 'motivating' the learner that it keeps up a bombardment of stimulation and it should not be so structured that it is always controlling what the learner thinks about.
10. Facilitate transfer of knowledge across contexts	Educational software has an opportunity to cut across curricular lines.
11. Give students more responsibility for contributing to each other's learning	The emphasis here is on co-operative learning not co-operative task completion / performance. It takes dedicated planning to achieve the former. For co-operative learning to occur, learners must recognise what they are trying to learn, value it and wish to share that value. Educational software should help learners recognise what it is they are learning and provide aggregate data that will allow them to monitor the learning process of the class as a whole and not just their own progress.

Discussion

Their approach to design follows the expected constructivist model whereby a set of principles are adhered to rather than a strict process. Scardamalia *et al* do mention that they wish to develop 'specifications' that can be used in a variety of educational software design environments. Interestingly enough they state that specifications are needed as there is a "potential conflict between the principles that inform most software development and those that ought to guide development of educational software. In most software design it is presumed desirable to make the software as intelligent as possible and to demand as little intelligence as possible from the user. Educational applications, on the other hand, should be aimed at developing the intelligence of the user. Educationally irrelevant burdens should be minimised, but not in ways that deprive students of occasions to develop the planning, monitoring, goal-setting, problem-solving and higher-order abilities that are important objectives of education" (1989:52-53).

It is useful that an example has been provided to support the textual descriptions of the principles, especially as the example is of software that exists and has been used in practice. In some cases the advice given is extremely useful. Having said this, I find a few of their principles a bit vague and these are not well supported in the example either; for example, encourage learning strategies other than rehearsal, provide process-relevant feedback and facilitate transfer of knowledge across contexts.

The principles that will most likely inform this study are: maintain attention to cognitive goals, treat knowledge lacks in a positive way, encourage multiple passes through information, support varied ways for students to organise knowledge, provide opportunities for reflectivity and individual learning styles and facilitate transfer of knowledge across contexts. These are embedded in sound cognitive theory and as such directly support both the theoretical basis of this study as well as the evaluation criteria used to filter instructional design models.

4.4.2. A-maze – An instructional design model

Overview of the model

The authors of this model are Bing, Flannelly, Hutton, and Kocklany (1997). Joann Bing and her colleagues present an instructional design model which is compared to more traditional instructional design models as it is described. A comprehensive discussion provided at the end of the paper gives support for the likely uses of the A-Maze model in different contexts. At the time of writing their paper, it does not seem that the model has been used in practice.

Theoretical basis of the model

The A-Maze model is firmly rooted in constructivist learning theory as stated by the authors in their abstract. The authors believe that by working with their model, the instructional designer "shifts emphasis from instruction to learning" (Bing et al, 1997, 5) and becomes a learning designer rather than an instructional designer. This paradigm shift that they point out is congruent with many authors and the shift from behaviourist / objectivist based design.

Design process

Before looking at the model structure, it is worth noting that for Bing and colleagues, the common element throughout their **entire** process is the learner. They believe that the learner should take an active role in the design process as well as in the learning process. The learner forms part of team of stakeholders made up of at least the instructor and the instructional designer (learning designer).

Why

Bing *et al* begin their journey into design with the single question: *why*? For them, this question encompasses the "reasons for learning, anchors the entire ID process, and shifts the design orientation from prescriptive to descriptive" (1997:1). For them, this equates to the 'needs assessment' phases / steps advocated by the more traditional

instructional design models. They point out that even though this step is well defined in traditional models, the general public remains dissatisfied with the results of the instruction given using those models. In their view, there is an inconsistency between what the problem is and how that problem should be solved. Without input from the learner, the "needs assessment fails to take into account socioeconomic issues, complete background" (1997:3). Ownership of the learning is also made stronger by inclusion of the learner.

What

Here the A-Maze model turns its attention to both the content of instruction and the knowledge the learner will acquire from exploration and interaction with the content. They base this phase of their model on the work of Duchastel (1993-1994 cited in Bing *et al*, 1997):

1. Scope of content (knowledge) – determining the extents of the content to be explored
2. Establishing the content structure – determining how the elements of knowledge fit together whilst taking into account what each individual learner will bring to the learning environment and making adjustments accordingly.
3. Creation of content information – based on the content scope, provision and creation of an collection of tools with which the learner can engage such as books, CD-ROMs, computer software programs, access to the internet and email, lists of websites and so on.
4. Creation of a content map – where information / tools can be found
5. Validation of content – using outside experts and educators as subject matter experts.

How

This phase of the A-Maze model determines 'how' the learning environment is to be designed. Bing *et al* believe that "congruence between learning context and performance context is maintained by providing authentic learning opportunities, and solving real world problems" which are within the ability level of the learner (1997:13). They suggest a modification of Savery and Duffy's (1996 cited in Bing *et al*, 1997) steps:

1. Discuss and negotiate with the learners to develop an authentic problem or task to which all learning activities are anchored and for which the learners can take ownership
2. Design the task and learning environment to reflect the complexity of the real world environment
3. Give the learners ownership of the process used to develop a solution to the problem

4. Tailor the learning environment to support and challenge the learners thinking
5. Encourage testing ideas against alternative views and contexts
6. Provide and support reflection on content learned and the learning process. Through this process of reflection, opportunities for formative evaluation will occur as well as authentic assessment using real-world standards and criteria.

How well

This aspect has a dual purpose: to determine if transfer of learning (*assessment* of learners) has taken place and to *evaluate* the effectiveness of the learning experience whilst the learning experience is taking place. They have based the assessment on the constructivist theory for authentic assessment whereby alternatives are provided for "fact memorisation and out-of-context learning" (1997:17) by using real, problem-solving situations. They emphasise that both learners and instructors develop scoring rubrics to evaluate performances, and that performance assessment is not determined by "traditional standardised test scores" (1997:18).

Discussion

The central premise of this model is that the learner is cast in a dual role: designer and learner. This idea is not unique in the field and is advocated by other authors such as Jonassen (1994), Steyn (2001), Reeves (1998) and Vincini (2001) and is derived from the constructivist premise of collaboration in both the learning and design process. It is worth emphasising at this point that this study will not be taking this approach to its fullest extent. There are several reasons for this: firstly, at the time of writing, GIS technologies are still relatively new in the South African educational context and there are few teachers or schools who have the infrastructure or the skills to design *learning material*s themselves – this will no doubt change in time; secondly in South Africa, there are great extremes between the teaching in schools and the needs of the learners in those schools. Private schools (non government schools) have been teaching in more progressive ways for many years and are relatively comfortable about teaching in the manner required by the OBE approach. These schools would no doubt welcome the chance to involve their learners in the design of new learning materials and environments. At the other extreme, there are those schools (typically in rural locations) where there are large student numbers and where the students are struggling to gain an education. For these teachers, primary concerns are to have materials that they can use and apply without having to design them themselves. More on this aspect will be discussed in Chapter 5 on page 104.

The A-Maze model seems to have been well thought out and is grounded in theory but there is unfortunately no evidence of effectiveness in practice. It would be interesting to find out if other researchers or designers have used the model to design learning experiences and to get their feedback.

As with other constructivist models, the lack of a linear process makes it difficult to explain to readers how the model actually 'works' without reliance on a worked example. This may be part of the problem many designers are experiencing in the field at present. Interestingly enough, Willis and Wright (2000) use a figure to conceptualise their R2D2 model but this is little more than a circle with fuzzy interior! Again the problem raises its head of having general principles and not detailed steps.

One useful element of this model is the fact that assessment is dealt with in detail in the 'How well' phase and the manner in which it is dealt with. Another facet that stands out is the collaborative nature of development in learning environments. This will be useful in my own work.

In particular, the 5 steps documented in the 'What' phase and the 6 in the 'How' phase will influence my study greatly. They are logical and incorporate various of the ideas put forward by Scardamalia *et al* such as providing reflection on learning, tailoring learning to challenge thinking and so on.

4.4.3. Guidelines for doing constructivist instructional design

Overview of the guidelines

These guidelines appear in a chapter of the book *Instructional Design Fundamentals: A Reconsideration* edited by Barbara Seels and are put forward by Wilson, Teslow and Osman-Jouchoux. What Wilson and his colleagues are attempting to do is show how constructivist ideas can be incorporated into the instructional design process without "totally disrupting the management and quality-control functions of traditional" instructional design models (Wilson *et al*, 1995, 137). They are also trying to address some of the practical concerns designers have about constructivist theories for their work.

Theoretical basis for the guidelines

Obviously, the theoretical basis here is constructivism, but with a decidedly post-modern slant. Interestingly, they have chosen to present their guidelines using the phase / steps from the more traditional instructional design models (needs analysis, goal/task analysis etc).

Table 4-3 Guidelines for doing constructivist instructional design (Wilson, Teslow and Osman-Jouchoux, 1995:147-154)

Major guideline	**Tips**
General methodology	Apply a holistic/systemic design model that considers instructional factors (learner, task, setting etc.) in increasing detail throughout the development process Use fast-track or layers-of-need models Include end users (both teachers and students) as part of the design team Use rapid prototyping techniques to model products at early stages

Major guideline	Tips
Needs assessment	Consider solutions that are closer to the performance context Make use of consensus- and market-oriented needs assessment strategies, in addition to gap-oriented strategies Resist the temptation to be driven by easily measured and manipulated content Ask: who makes the rules about what constitutes a need? Are there other perspectives to consider? What and whose needs are being neglected?
Goal and task analysis	Distinguish between educational and training situations and goals Use objectives as heuristics to design Allow for multiple layers of objectives clustering around learning experiences Don't expect to capture the content in your goal and task analysis Allow for instruction and learning goals to emerge during instruction Consider multiple stages of expertise *Give priority to problem-solving, meaning-constructing learning goals* *Look for authentic, information-rich methods for representing content and assessing performance (e.g. audio, video)* *Define content in multiple ways. Use cases, stories and patterns in addition to rules, principles and procedures* Appreciate the value-ladenness of all analysis Ask: who makes the rules about what constitutes a legitimate learning goal? What learning goals are not being analysed? What is the hidden agenda?
Instructional strategy development	Distinguish between instructional goals and learners' goals; support learners in pursuing their own goals Allow for multiple goals for different learners Appreciate the interdependency of content and method Resist the temptation to 'cover' material at shallow levels Look for opportunities to give guided control to the learner, encouraging development of metacognitive knowledge Allow for the 'teaching moment' Consider constructivist teaching models such as cognitive apprenticeship, intentional learning and case- or story-based instruction Think in terms of designing learning environments rather than 'selecting' instructional strategies *Think of instruction as providing tools that teachers and students can use for learning; make these tools user-friendly* Consider strategies the provide multiple perspectives and that encourage the learner to exercise responsibility Appreciate the value-ladenness of instructional strategies
Media selection	Consider media factors early in the design cycle Include media literacy and biases as a consideration in media decisions
Student assessment	*Incorporate assessment into the teaching product where possible* Critique and discuss products grounded in authentic contexts, including portfolios, projects, compositions and performances Evaluate processes as well as products Use informal assessments within classrooms and learning environments

Design process

Wilson *et al* (1995) offer what they call a "laundry list of tips" for viewing instructional design from a constructivist perspective. The list is organised according to generic instructional design phases and covers *general methodology, needs assessment, goal and task analysis, instructional strategy development, media selection and student assessment*. It seems worthwhile to list the headings for all of their 'tips' as they are very revealing in themselves (shown in Table 4-3). However, due to space restrictions, the tips will not be fully described. Rather, in the discussion section below, I will make examples of those that reflect the evaluation criteria that I have already applied; these are highlighted in *italics*.

Discussion

Wilson *et al* advocate using a *holistic* design model whereby key factors such as task setting are continuously revisited during the project design cycle. This reflects what many other authors say about constructivist instructional design in that it does not follow a strict, procedural process and that the design process should be an iterative one. Indeed the two models described above follow exactly such a 'process'.

Under their 'needs assessment' guideline they mention resisting the temptation to be driven by easily measured and manipulated content and they go on to say "many important outcomes cannot be easily measured" (1995:148). This is especially true if one is designing instruction or learning environments that aim to develop higher-order thinking skills, as is the case with this study. It is extremely difficult to firstly determine the outcomes in any amount of detail and secondly to measure those outcomes once defined. They do suggest prioritising problem-solving and meaning-constructing learning goals rather than simple rule-following ones, so that learners are asked to make sense out of learning material and to demonstrate their understanding of it. They do not however, offer more concrete ways of doing this; therefore creativity of all the stakeholders must surely come into play at this stage.

Some of the main criteria used in this study have been concerned with assessment and the use of authentic tasks in the learning environment. These are both mentioned by Wilson *et al* as practical ways of representing content in the learning environment. As well as suggesting that assessment is incorporated into the teaching product, they also propose using authentic, information-rich methods for representing content as well as for assessment purposes. Audio and video presentations can be used as tools by the learners to represent and demonstrate what they know in assessment scenarios. Content can be defined in many different ways: using rich case studies and stories as alternatives for finding and representing content as well as for presenting problems to the learners. The idea using these as *cognitive tools* is recalled again. Indeed, they go on to say that instruction should be seen as providing tools that teachers and learners can use for learning by making creative and intelligent use

of these resources. Many more of their guidelines have undoubtedly informed the specifics of my own model.

4.4.4. Comments on other models not evaluated using the evaluation process

A number of models have been examined in the course of undertaking this survey and have not been described in detail. I would like at this stage to mention some aspects from two other models that may be useful in my own work.

The R2D2 model documented by Willis and Wright (2000) in the *Educational Technology* journal revolves around three focal points: Define, Design and Development, and Dissemination. Willis and Wright indicate that these focal points are "a convenient way of organizing our thoughts about the work" (2000:5) which needs to be undertaken as part of the instructional design process. As an observation, the first two of these focal points are very similar to the phases/stages used in software development and often appear in linear software development models. As these points of focus are already familiar to me from a software development context, they may well be important to my own model as phases/stages are an important way of logically structuring and describing an instructional design process.

The R2D2 model (Willis and Wright, 2000) has three other features that are worth mentioning. In their 'Define focus' focal point, they indicate that a *supporting* participatory team should be created and that a *contextual* understanding should be developed. Firstly, the team: they indicate that creating a team is not a difficult task, but a supporting, encouraging and participating team can be. They suggest ways of doing this and indicate that it requires thought, preparation co-operation. Coming as I do from a commercial software development background, I cannot imagine creating any kind of product without co-operation from users and other stakeholders, so for me this is an important element. Secondly, they state that there is much that is "unique in each design context" (2000:8) and therefore designers and developers must have / develop a "sophisticated understanding of the particular context in which design work will take place" (2000:8). For me, this is crucial to the successful implantation of any software product but particularly in an educational context where it must be certain that the product is right for the needs of the learners, school and community at large.

Finally, still with Willis and Wright (2000), their final focus point is that of 'dissemination'. For them this includes: final packaging, diffusion and adoption. In diffusion and adoption, the focus in on ensuring that learners and teachers are able to adapt the materials to their local context rather than for training them to use the material the 'right' way. For me, this gives closure to the process and encapsulates the constructivist view about the importance of context and multiple perspectives.

One other model that has influenced my thinking remarkably is not related to instructional design at all, in fact it is drawn from my own experience in software development. For many years, software development has been entrenched in using linear (waterfall) development models, showing parallels with instructional design. However, due to many issues with finished products many new models have been developed that follow a recursive, non-linear approach. One of these is known as Boehm's Spiral Model (Boehm, 1988). This can been described as using evolutionary development. The traditional waterfall model is used for each step although these are not defined in detail at the first pass – rather just those features that are the highest priority features. Once those have been defined and implemented, feedback can be obtained from users/customers and with that feedback, other features can then be defined and implemented in smaller segments (Boehm, 1988). The model is intended to help manage risks and the feedback phase distinguishes 'evolutionary' from 'incremental' development. An example of the Spiral Model is shown in Figure 4-4 below. With this model, the starting point is in the centre with the review and requirements plan and successive iterations of work move outwards towards the final prototype and ultimately service.

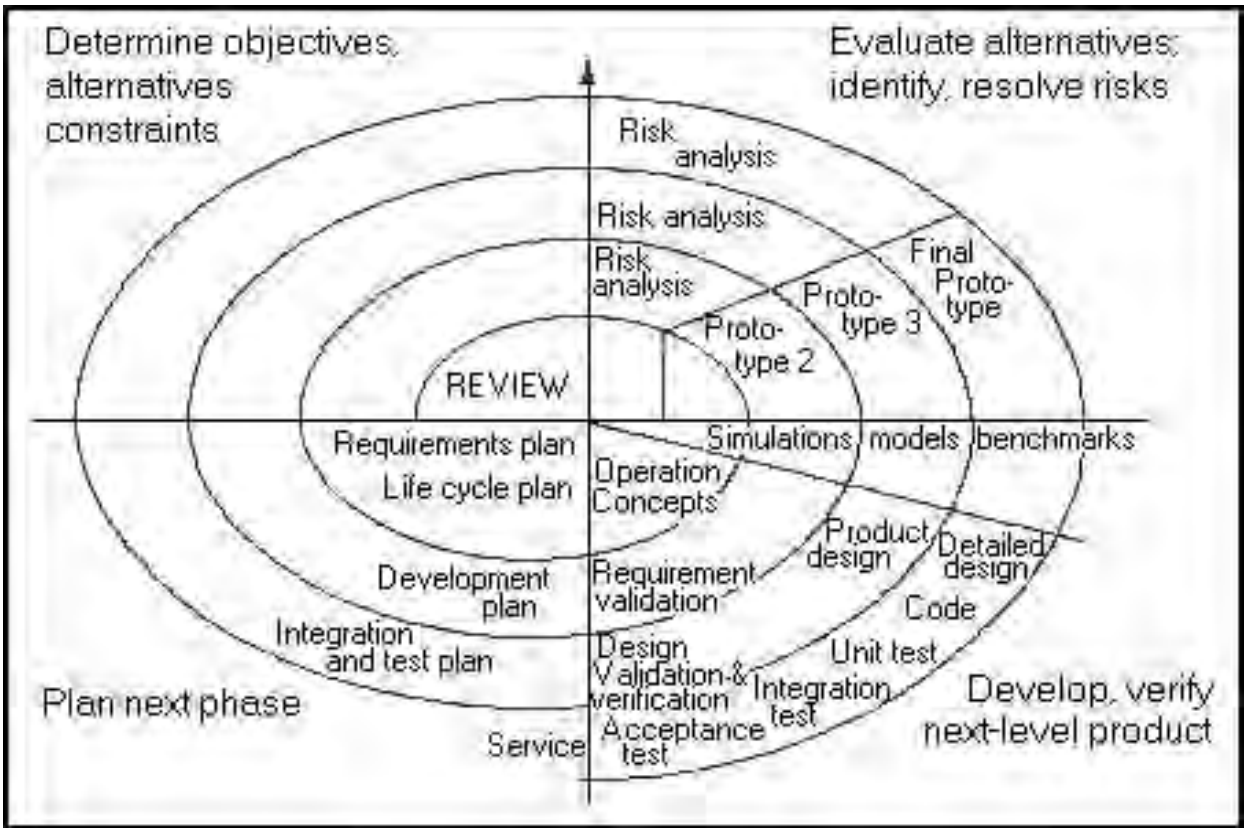


Figure 4-4 Boehm's Spiral Model of Software Development and Enhancement (1988)

For me, this model aligns well with the recursive, non-linear constructivist instructional design models as discussed in this research. As such, it may be that elements will be derived from Boehm's model for my own work.

4.5. Conclusion

This is perhaps one of the most practical chapters in this study as it applies the framework devised in Chapter 3 to a real situation and allows evaluation and analysis of a number of instructional design models. As mentioned previously, the results shown and the associated analysis are by no means a passing of judgement on any particular model, rather it is a means of making sense of the myriad of models in the instructional design field and a means of deciding which ones will be helpful for this study. As this chapter and the previous one have explained and then subsequently used the evaluation framework, it is hoped that other researchers will be able to see the usefulness of the framework and will be able apply and use it for their own purposes in different situations. Finally, of course, the models that exceed the evaluation's critical score are discussed.

It is important to note that any researcher wishing to apply the framework to their own context will need to undertake a similar exercise as that undertaken in Chapter 3.

Chapter 5 GIS^{3}D design model for GIS Technologies

5.1. Introduction

Having come to the point in the study where I present an instructional design model, it is important to identify key considerations that must be taken into account when using this model.

It is essential to show where this study is guided by the research methodology. One fundamental purpose of type 2 developmental research is the production of knowledge "in the form of a new (or enhanced) design or development model" (Richey and Nelson, 1225) and that developmental research endeavours to "produce the models and principles that guide the design, development and evaluation processes" (Richey and Nelson, 1216). This is the primary focus of this chapter and the culmination of the study.

GIS technologies are the base technologies on which the learning materials / environments will be based. A feature of this study is that we are learning ***with*** GIS technologies not learning ***about*** them. In the process that follows, we will not be 'teaching' learners how to use the technologies, but they will be interacting with them and perhaps learning how to become GIS experts as a hidden outcome. GIS technologies use information about places (spatial data) as their core data sets. This spatial data can be made up of satellite images, photographs and so on. In order to work with the technologies, the data must be created or acquired from a recognised source. This forms an important part of the design / development process.

This model is initially intended for use in South African secondary schools and so must operate within the current OBE approach. As mentioned in Chapter 4, infrastructure and teaching practices in schools across South Africa vary enormously. This must be taken into account in the development of any learning materials for use in the South African educational context.

Chapter 2 discussed the theoretical possibility of using GIS technologies as cognitive tools or mindtools in the same way that Jonassen and others have used other computer based applications. The author is cognisant of that fact and the model put forward here has a strong bias in this regard: the development of cognitive skills in the learner is paramount. As claimed in earlier chapters, the model is aligned with the learning theory that Bednar *et al* (1992) call 'constructivist cognitive science'.

In developing this model, which I have labelled GIS^{3}D, I have tried to develop a holistic/systemic design model that considers instructional factors (learner, task, setting etc.) in increasing detail throughout the development process as suggested by Wilson et al (1995). Learning material developed as a result of using this model should provide teachers and learners with user-friendly tools they can use for learning. I would like to believe that in time, as computer and GIS skills in

South African schools enhance, that the model will allow for the design of learning environments. The GIS3D model is shown in Figure 5-1 below.

The model is represented as a spiral. The process starts where indicated from the 'fuzzy', undefined, outer loop[19] and proceeds into inner loops as definition becomes clearer, until finally, after many iterations, the process is completed by reaching the central red dot in the centre. Four iterations are shown on the diagram; however, these can be as many as required. Each iteration in the model will go through three phases, namely: *definition*, *design and development*, *dissemination*. The phase names have been inspired by those used by Willis and Wright (2000:5) although they also closely resemble the software development phases that I am familiar with. The phases are shown as sectors on the GIS^{3}D model spiral and are shown in more detail in Figure 5-1 below. Tam (2000) describes constructivist inspired instructional design models as organic, reflective, collaborative and developmental. I would like to think that this model reflects those descriptions.

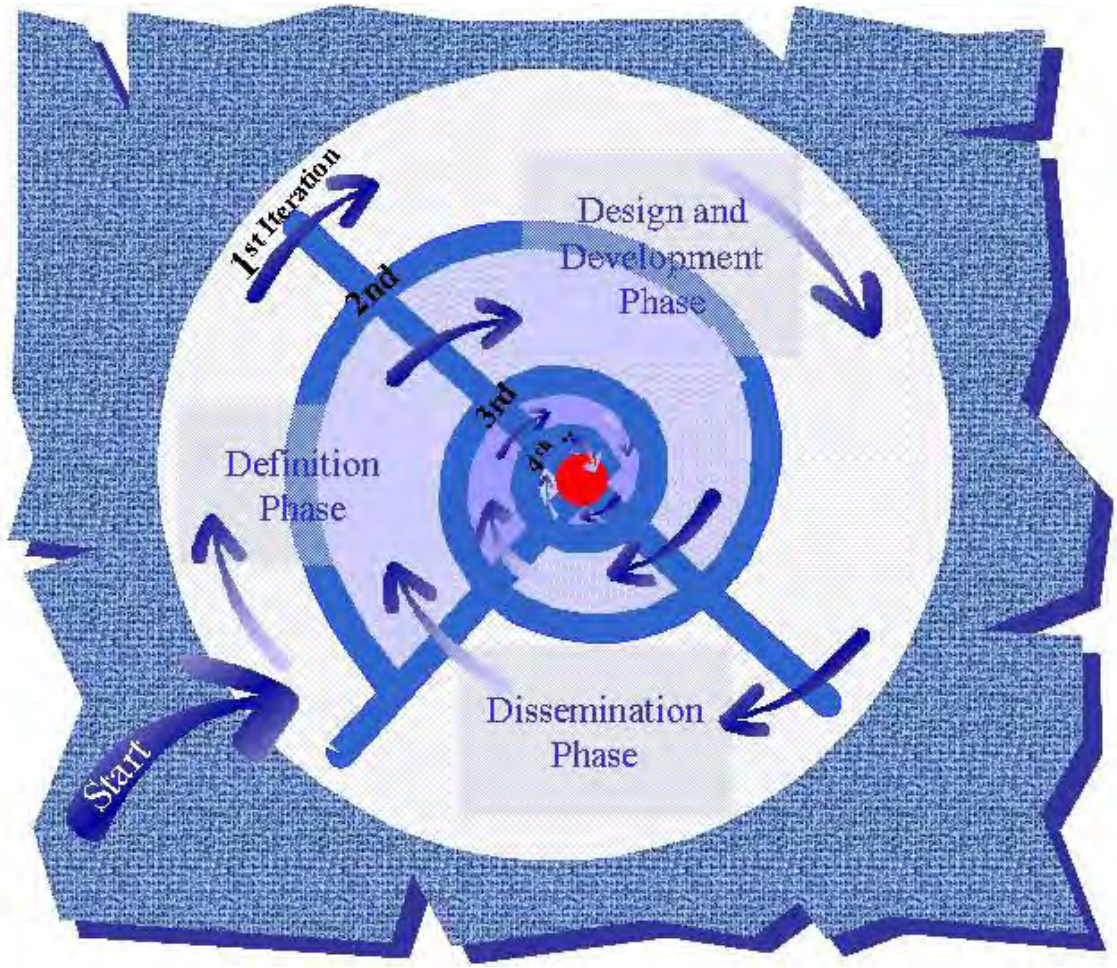


Figure 5-1 Visual representation of the GIS^{3}D Instructional Design Model

Figure 5-2 below illustrates how each of the phases from Figure 5-1 is broken down into steps. Tam (2000) indicates the constructivist inspired models will be recursive and sometimes seem chaotic.

[19] This is opposite to Boehm's spiral model of software development described on page 95.

The steps do not need to be followed in strict order but it is simpler to represent and describe it thus and will hopefully avoid the idea of chaos. Each of the phases is discussed in turn in section 5.2 below.

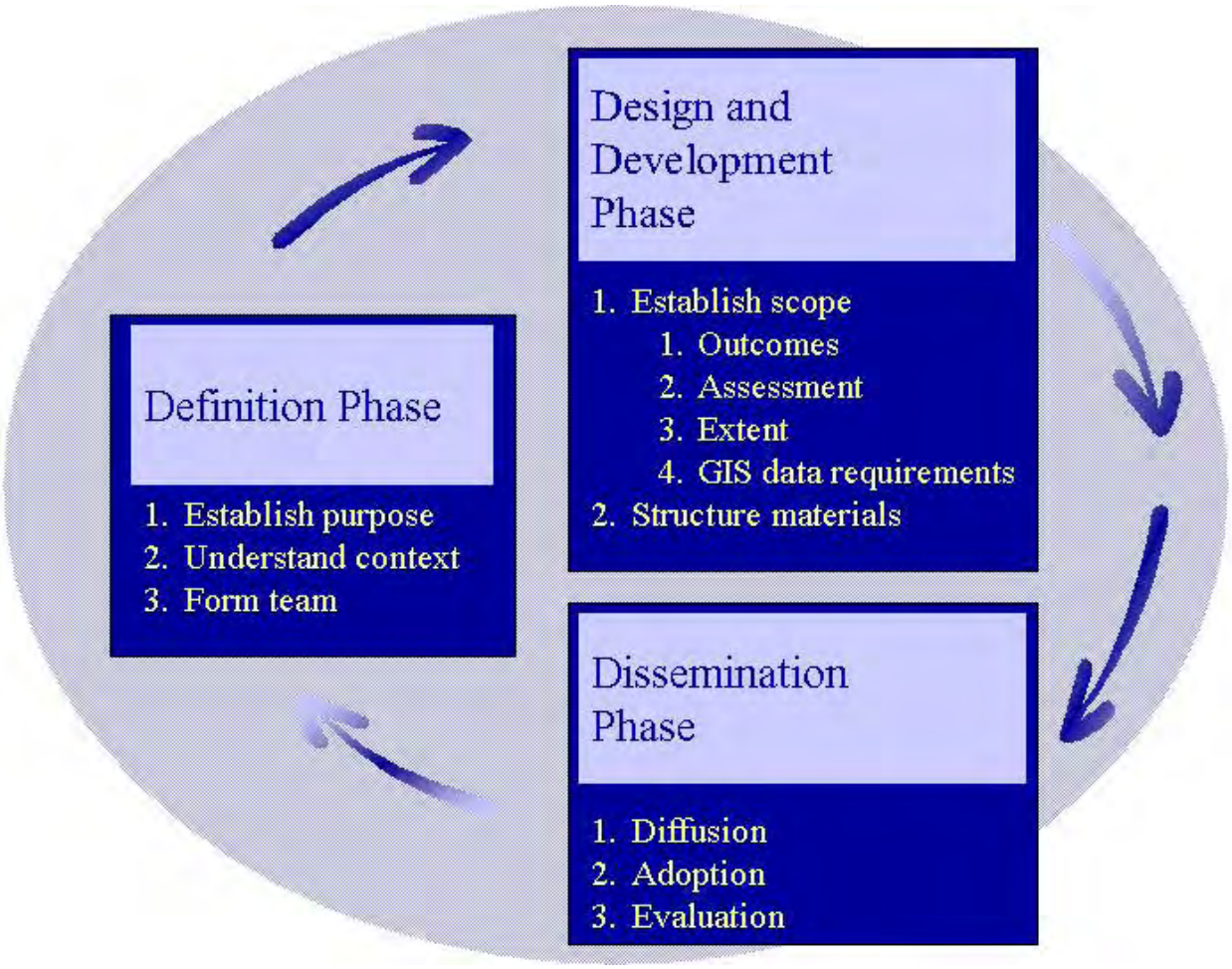


Figure 5-2 Detail of the steps in each phase

5.2. How it works

Each phase is described and the accompanying steps detailed. To ensure clarity, where possible, the GIS^{3}D model will be related to *learning materials* that are in the process of being developed at the time of writing. Examples of these are included in Appendix C.

5.2.1. Definition Phase

The starting point for the model is roughly congruent with a '*needs assessment*' step in traditional instructional design. The primary concern for this phase is to determine the reason why the learning materials are needed. Secondary concerns are to form a participatory team and to establish contextual understanding for the module and team members as recommended by Willis and Wright (2000).

There are various methods of determining the purpose for the learning materials. If the task or learning environment comes into being as the result of a real world problem or phenomena, then it can be designed to reflect the complexity of the real world environment and include authentic tasks to which all learning activities are anchored and for which the learners can take ownership as suggested by Bing *et al* (1997). Learners and teachers can be surveyed at this point to furnish these types of problems / tasks based perhaps on current news stories, motion pictures and so on. If the learners are involved in determining the 'topic' for the learning materials, then it will contribute to their sense of purpose and ownership of the learning (Bing *et al*, 1997). Need can of course be driven by the curriculum but this does not then encourage this ownership. In the early iterations of the process, it may not be possible to 'package' the problem distinctly, but this is to be expected: as Wilson *et al* point out, we should "resist the temptation to be driven by easily measured and manipulated content" (1995:148). At this point it is possible to consider other perspectives and to determine if other needs will be neglected if a particular path is taken.

Hand in hand with the 'generation of a problem' or need, should be the idea of developing a contextual understanding of the entire project. This can be thought of as a 'project information gathering process'. Obviously in the early iterations, the information gathered will be more substantial than in the later ones. If the learning is to be based on authentic tasks and include authentic assessment elements, then first and foremost this must comprise a genuine understanding of the problem area and how this is represented in the real world. The team must also endeavour to understand the multiple stages of expertise that they may be designing for, the backgrounds from which the learners come, the infrastructure and resources available to the teachers and learners. At this stage it is also possible to consider controversial issues of stereotyping, gender sensitivity and to gather enough information to ensure these are treated in a balanced manner for the given context. Much of this information can be ascertained by undertaking classroom visits, having interviews with teachers and learners as well as consultations with subject specialists.

During the first iteration of this phase it is important to establish a team who will be with the project until completion in order to give continuity and consistency to it as recommended by Willis and Wright (2000) and from my own experience of working on design projects. The core of this team should consist of end users (both teachers and learners), designers, GIS application experts as well as subject experts if possible. Other stakeholders may be added to the team as necessary. Examples may include parents, community members and other public figures.

5.2.2. Design and Development Phase

Our focus now turns to what we are creating (*design*) and how (*development*) that will be done. Here we consider both the content of the learning materials and the knowledge and cognitive skills the learner will acquire from exploration and interaction with that content; always mindful that the

underlying technology is GIS. We will also consider and decide how the learners will be assessed in an authentic way and what form the assessment will take. The major contribution in terms of assessment comes from the constructivist instructional design guidelines suggested by Wilson *et al* (1995).

Design

This phase has two steps that have been derived from the A-maze model (Bing *et al*, 1997) and then extended accordingly. Again, in the early iterations, it may be difficult to pin these things down. Collaboration with the team and other stakeholders will assist in clarifying things as will moving forward with the development, as this generally reveals what the gaps are in understanding.

The first is to establish the 'scope' of content (knowledge) and cognitive skills that will be developed by using the materials (Bing *et al*, 1997).

At this point in traditional instructional design, designers would attempt to write performance objectives or specify learning goals. I would like to refer to this consideration as establishing learning outcomes. By structuring the learning materials around rich learning experiences, a whole cluster of meaningful learning outcomes may emerge - problem-solving, meaning-constructing learning outcomes. Wilson *et al* indicate the "instruction need not be objectives-driven" (1995:149). Many learning outcomes may emerge during the learning experience (initiated by the learners and the teacher) and the design of the learning materials should allow this to take place. An observant teacher will be alert for these and will make the most of these when they arise and if possible use the learning materials as tools to allow for the 'teaching moment' as recommended by Wilson *et al* (1995). Further, it is important not to capture the **content** when setting the outcomes, as the focus is then on content and not learning. Finally, when setting the outcomes, it is important to remember that this model focuses on cognitive skills and as such should encompass skills such as 'finding out', 'learning about', 'obtaining information', 'predicting', 'summarising', 'finding sequences', 'planning' and so on. The list of skills provided in the table concerning critical, creative and complex thinking in GIS technologies on page 40 is a good source for the kinds of skills that can be developed using *learning material*s of this type.

- Hand in hand with the idea of determining skills and outcomes goes the concept of assessment. Shepard (2000) and others (Wilson et al, 1995 and Bing et al, 1997), suggest that assessment is tied to the learning process of steps and not left until the end-point of instruction. Shepard (2000) offers concrete examples for achieving this using open-ended performance tasks to solve problems and to apply knowledge in a real world context. She suggests expanding traditional assessment methods to include a broader range of assessment tools where learners produce their own work to capture the important learning process such as learner observations, interviews, reflective journals, projects, demonstrations, collections

and self-evaluation. If the cognitive and other skills have been outlined and criterion-referenced assessment is to carried out, then this is the perfect time to set out the explicit assessment criteria that will go with the assessment tasks.

Establishing the content is the second part of this step. Largely, this will be determined by real world problem at the core of the material as indicated by Bing *et al* (1997). Essentially, the design team will determine the **extent** to which the problem will be studied. In terms of GIS technologies, it is important at this stage to define what data and / or images will be required for the materials. Decisions need to be made if data will be local or global as this influences the sourcing of data and images.

Again as indicated by Bing *et al* (1997), the second design step is to establish the structure of the learning materials and to establish how the elements of knowledge fit together. The materials may consist at this stage of a list of content, assessment ideas and data sets. How will these be combined to facilitate navigation through the materials, to support learning and so on? At this stage, there are a number of areas to consider. These have been listed below and are derived from the models reviewed in Chapter 4.

a. Treat knowledge lacks in a positive way. Where possible, provide ways for learners to identify what they do not know or need to find out as knowing what one does not know is a vital kind of meta-knowledge (Scardamalia *et al*, 1989).
b. Encourage multiple passes through information. Ways should be sought to make it worthwhile for learners to call back information they have dealt with previously and to reconsider it or to use it in a different context (Scardamalia *et al*, 1989).
c. Support varied ways for students to organise knowledge. Provide varied means for learners to organise / structure their knowledge: timelines, graphs, maps, narrative sequences, story grammar structures, concept nets and causal chains. When, as designers, one is to involve students in working with a hierarchical list, stop and consider the possibility of using some other way of organising information (Scardamalia *et al*, 1989). Wilson *et al* (1995) also suggest presenting content in multiple ways using cases, stories and patterns in addition to rules, principles and procedures.
d. Provide opportunities for reflectivity and individual learning styles. Provide the learners with time, opportunity and peace in which to think about what they are doing and why. This means that the materials must not be so busy ‘motivating’ the learner that it keeps up a bombardment of stimulation and it should not be so structured that it is always controlling what the learner thinks about (Scardamalia *et al*, 1989).
e. Facilitate transfer of knowledge across contexts (Scardamalia *et al*, 1989). Where possible try to find links between the materials under design and other disciplines or subject areas

and incorporate these into the design process. Also look for ways to link old knowledge to new knowledge.

f. Consider strategies to provide multiple perspectives (Wilson *et al*, 1995) on the problem at hand and try not to pre-package the entire learning experience. Learners can be encouraged to generate their own questions and formulate hypotheses and assumptions.

g. At this point it is important to plan the collaboration that will take place between learners as well as the community, as this will give rise to opportunities for assessment as well as of making the learning useful and meaningful. "The emphasis here is on co-operative learning not co-operative task completion / performance. It takes dedicated planning to achieve the former. For co-operative learning to occur, learners must recognise what they are trying to learn, value it and wish to share that value" (Scardamalia *et al*, 1989:64-65).

Development

The actual development phase involves creating or developing the learning materials or environment based on the information established in the design phase. For GIS technologies, this means acquiring raw data and images and compiling that raw data into learning materials such as a GIS atlas or simulation so that the learners and teachers can interact with them in a meaningful way. Other resources such as textbooks, website addresses, audio-visual materials must also be gathered at this stage and incorporated into the learning materials. In early iterations of the process, resources and data may be scarce – these can be added to in later iterations.

5.2.3. Dissemination Phase

Willis and Wright (2000:15-16) use the term '*dissemination*' to describe a closing phase to the process. I have 'borrowed' or made use of their activities: *diffusion*, *adoption* and *evaluation* and will use them to describe the closing phase of the GIS3D model.

Diffusion

The word '*diffusion*' suggests the idea of circulation, dissemination or distribution. In this step, the learning materials must be packaged and circulated to those that will use them. As these are computer-based materials, they will require installation instructions so that the materials can be installed on computers. The materials will also need to be produced on media that schools and teachers can work with such as CD-ROM.

Adoption

If technology is to realise it's potential, it must address the attitudes of the teachers towards technology, their technology skills as well as their epistemological and pedagogical viewpoints. Niderhauser and Stoddart (2001) indicate that, in the United States, the assumption has been that by simply providing technology infrastructure, teachers' classroom practice will change. Based on their research, they conclude that this approach has done little to change the instructional approach

prevalent in schools. Indeed, Roblyer and Edwards point out that an educator's "definition of the appropriate role of technology depends on their perceptions of the goals of education itself and the appropriate instructional methods to help students attain these goals" (2000:49). This indicates that the teacher's own view of knowledge (epistemology) and pedagogy will influence how they view and use technology in their teaching. It is vitally important that extensive teacher education is undertaken to ensure that there is an 'infusion' of technology into the curriculum and classroom practices (Hadley, Eisenwine, Hakes, and Hines 2002; Snider 2003 and Larson 1995). The concept of 'infusion' suggests seamless cross-curriculum integration as well as a blending of the teacher's technological, pedagogic and content knowledge (Pierson, 2001).

This stage of '*adoption*' deals with these issues and will be crucial to the success of the learning materials. Teachers must be helped to use and adapt the material to their own context with confidence. This can be done by formal or informal training, coaching or in context mentoring. It will be vital that teachers are confident with the GIS aspects of the learning materials and how these fit into the learning materials as a whole.

Evaluation

All instructional design models, both traditional and constructivist, include an *evaluation* element to one degree or another whereby the learning materials are evaluated to determine their effectiveness, to provide data for inclusion in subsequent revisions and ultimately, to improve the product and future learning. Willis and Wright describe evaluation thus: "it is the story of what happens when the material is used in a particular context in a particular way with a particular group of learners" (2000:16) and recommend that during the evaluation 'rich, thick' data be collected to support other more quantitative data gathered.

In an environment where the design process is iterative, by necessity the evaluation must also be iterative, namely formative evaluation, which takes place *during* the learning process rather than at the end. There are many ways that this can be undertaken, but Bing *et al* (1997) suggest these techniques that they have derived from various sources.

a. One-to-one evaluation with learners as they use the materials. This assists the design team in finding problems with the materials from the point of view of design and development. Can the learners use the materials as anticipated, can they find and use the resources etc?

b. Small-group and large-group evaluations. The purpose here is to determine if the learners can use the learning materials without the teacher. Both performance and attitude data are collected.

Following collection of data from these sources, revisions will be made to the learning materials that directly affect the learning materials and their usage in the learning context.

This same process can then be used for each iteration in the design cycle with the aim of constantly refining the learning materials with each iteration.

Chapter 6 Conclusion

In concluding, I would firstly like to point out where key aspects of the research methodology have been applied. This study used 'developmental research' as the underlying methodology. To recap, by definition developmental research is "the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness" (Seels and Richey cited in Richey and Nelson, 1996:1213) and developmental research endeavours to "produce the models and principles that guide the design, development and evaluation processes" (p1216). This study has indeed been a systematic study of programs and processes and it has produced two practical products that will hopefully guide the processes used in future development of learning materials. Type 2 developmental research is the production of knowledge "in the form of a new (or enhanced) design or development model" (p1225). In this study I have enhanced the **design** component (analysis and planning for development, evaluation, use and maintenance) of an instructional design model. Due to the limited scope of a half thesis in a coursework masters, this study only covers the first stage in developmental research and does **not** include research into the actual process of development of the *learning material*s nor evaluation of the framework itself in a working situation. As mentioned, these are opportunities for further study. I would also like to draw attention to other key characteristics of this type of research that are important to note for this study. In developmental research of this kind, research questions rather than hypotheses guide the study as is the case here. This kind of research does not begin with the actual development of the product but rather has concentrated on previously developed instruction and / or models of instructional design which have formed the basis of the meta-analysis. Developmental research studies employ a great diversity of research methods and tools: this has been illustrated by the development and use of the weighted scoring matrix.

In the opening chapter of this study, a case was put forward for using GIS technologies to develop critical outcomes and skills in learners and the challenge arose on how to develop these kinds of learning materials for South Africa and the OBE context by taking into account the relationship between learning, educational practice and psychological research. The primary research question or goal for this study was presented as:

> *How does one design a model or framework for developing computer-based learning materials based on GIS technologies for secondary education in South Africa?*

As a means of accomplishing the primary goal of this study, a model called GIS^{3}D has been proposed for developing computer-based learning materials based on GIS technologies for secondary education in South Africa. GIS technologies are the foundational technologies on which

the learning materials / environments are based. A feature of this study is that the focus is on learning ***with*** GIS technologies not learning ***about*** them. In using the materials developed by this model, learners will not specifically be taught how to use the technologies, but rather they will use them and interact with them as cognitive tools. The model is mindful of this fact and so has a strong bias in this regard: the development of cognitive skills in the learner is paramount and as such the model aligns itself with the learning theory that Bednar *et al* (1992) call 'constructivist cognitive science'.

This model is initially intended for use in South African secondary schools and so must operate within the current OBE approach and must be taken into account in the development of any learning materials for use in the South African educational context.

The GIS^{3}D model is a holistic/systemic design model that considers instructional factors (learner, task, setting etc.) in increasing detail throughout the development process. Learning material developed as a result of using this model should provide teachers and learners with user-friendly tools they can use for learning. I would like to believe that in time, as computer and GIS skills in South African schools enhance, that the model would allow for the design of learning environments and not just learning materials.

The model has been designed by considering a number of elements, which were offered in the form of sub-goals for reaching the primary goal. The first sub-goal was concerned with *finding definitions in a review of the literature to form the theoretical basis for my study*. These definitions have been established. Concepts such as higher-order thinking skills and cognitive tools have been explored and defined. These definitions have been set against a theoretical backdrop by reviewing learning theories.

The second sub-goal was to *explore the characteristics of GIS technologies that could be enhanced to allow their use as cognitive tools in an educational setting.* These characteristics of GIS technologies have been explored and it has been shown in a **theoretical** way how these can be enhanced to allow their use as cognitive tools in an educational setting. This has been achieved by evaluating them against a set of criteria proposed by David Jonassen for evaluating computer applications as cognitive tools. It was necessary to do this in order to observe some kind of educational value in GIS technologies before continuing with the study and in particular for determining the kind of instruction that can be undertaken with these technologies.

Evaluation criteria selected from the literature would assist in forming the basis of an evaluation framework to determine suitable instructional design models was offered as the third sub-goal. In order to create the enhanced instructional design model it was essential to set down criteria for evaluating instructional design models reviewed by this study. These evaluation criteria were

selected from the literature to form the basis of an evaluation framework to determine suitable instructional design models.

For the fourth and final sub-goal, it was important to *investigate which principles and guidelines arose from the reviewed instructional design models could be synthesised to form the elements of a new or enhanced model*. The models found in the literature were then evaluated using these criteria and the process documented. Models that qualified for review were subsequently discussed in detail. From the detailed discussion it was possible to ascertain the principles and guidelines that could be used to form the elements of the enhanced model.

A number of unexpected features arose from this process. The weighted scoring matrix used to evaluate the instructional design models developed into a complex and valuable tool, without which I would not have been able to find a clear path for finding a smaller set of instructional design models to work with. I hope that the tool will prove as valuable to other evaluators in the future.

The theoretical evaluation of GIS technologies as cognitive tools was unplanned. As the chapter on cognitive tools developed I found that I had enough theoretical evidence in the literature to conclude the chapter with the evaluation and to open up opportunities for further study. For example, the basis features and functions of GIS Technologies could be introduced into classrooms with the specific intention of evaluating them as cognitive tools, in much the same way that David Jonassen has evaluated other computer technologies such as spreadsheets and databases. Interestingly enough, GIS is being introduced into South African Grade 10 to 12 learners as part of the Geography Curriculum in 2006. This would provide a perfect arena for an evaluation of this kind.

I would like to think that any learning materials developed using the GIS^{3}D model will attend to some of the issues raised in the opening paragraphs of this study, especially in regard to the South African context. In terms of opportunities for further studies, obviously the process of developing learning materials using the GIS^{3}D model would need to be carefully evaluated. This could then be followed by an in-depth appraisal of the usage of such materials in a representative sample of South African classrooms.

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Note: The 🖫 symbol in the first column indicates online articles that have been downloaded and saved to a CD-ROM for perusal by examiners. Page numbers cited in the text for these references will refer to the **downloaded** page number.

Appendix A - Integrated Thinking Model

A.1. Introduction

This appendix is intended to substantiate the detail of the Iowa Department of Education's *Integrated Thinking Model* discussed in Chapter 2**,** section 2.2.1. The section has been reproduced in it's entirety from Jonassen's '*Computers in the Classroom: Mindtools for Critical Thinking*' book (JONASSEN, D.H. (1996:19-20, 29-34) New Jersey: Merrill)

Section A.2. describes in the Integrated Thinking Model in detail whilst section A.3.expands upon Jonassen's criteria for evaluating a product as a 'Mindtool' or a cognitive tool.

A.2. Model of Complex Thinking

"All of these conceptions are useful in helping us to understand the kinds of thinking that Mindtools engage. However, in order to compare and contrast the effects of using Mindtools, it is easier to use a single conception of critical thinking. Therefore, I have selected as a model one of the most comprehensive and useful models of critical thinking, the Integrated Thinking Model (Iowa Department of Education, 1989). It defines complex thinking skills as an interactive system, not a collection of separate skills. It also describes the various processes that are referred to as "thinking," and their relationships to each other I will use this model to analyze and compare the effects of Mindtools discussed in this book.

This model has three basic components of complex thinking (see Figure 2-2): content/basic thinking, critical thinking, and creative thinking (the three circles surround the complex thinking core). Complex thinking includes the "goal-directed, multi-step, strategic processes, such as designing, decision making, and problem solving. This is the essential core of higher order thinking, the point at which thinking intersects with or impinges on action" (Iowa Department of Education, 1989, p. 7). It makes use of the other three types of thinking in order to produce some kind of outcomes design, a decision, or a solution. I will discuss these three types of thinking in turn.

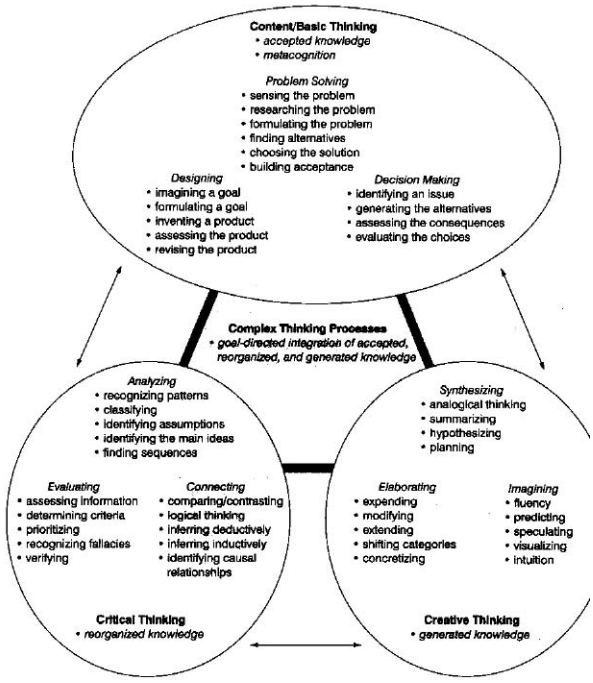


Figure 2.1
Integrated Thinking Model

A Content/Basic Thinking

Content/basic thinking represents "the skills, attitudes, and dispositions required to learn accepted information, basic academic content, general knowledge, `common sense,' and to recall this information after it has been learned" (Iowa Department of Education, 1989, p: 7). Content/basic thinking thus includes the dual processes of learning and of retrieving what has been learned. Content/basic thinking describes traditional learning, except that it is important to note that this content based knowledge is in constant interaction with critical, creative, and complex thinking because it is the knowledge base from which they operate. Since the hypothesis of this book is that Mindtools engage learners in critical thinking (which, in this model, consists of critical; creative, and complex thinking), I will focus exclusively on those thought processes in the analysis of each Mindtool.

B Critical Thinking

Critical thinking involves the dynamic reorganization of knowledge in meaningful and usable ways. It involves three general skills: evaluating, analyzing, and connecting.

Evaluating involves making judgments about something by measuring it against a standard. Evaluating is not expressing a personal attitude or feeling. It involves recognizing and using criteria in different instances. Recognizing criteria is important when criteria are unstated; otherwise, the learner is required to use a publicly available set of standards. It is also important that students be able to determine which criteria are appropriate. Evaluating information involves skills such as:

- Assessing information for its reliability and usefulness, and discriminating between relevant and irrelevant information (e.g., evaluating the meaningfulness of criticism of a film based on the ability of the critic; evaluating an historical account in terms of its accuracy)
- Determining criteria for judging the merits of ideas or products by identifying relevant criteria and determining how and when they will be applied (e.g., developing an evaluation sheet for critiquing research studies; establishing evaluation guidelines for judging an art show)
- Prioritizing a set of options according to their relevance or importance (e.g.; ranking a set of interventions for solving a child's behavioral problem; rating a set of bonds for long-term gain)
- Recognizing fallacies and errors in reasoning, such as vagueness, non sequiturs, and untruths (e.g., propaganda in political campaigns; sales pitches that promise more than they can deliver)
- Verifying arguments and hypotheses through reality testing (e.g., solving proofs in geometry; checking the accuracy of arguments in court actions)

Analyzing involves separating a whole entity into its meaningful parts and understanding the interrelationships amongst those parts. Manipulating part/whole relationships helps learners understand the underlying organization of ideas. Analyzing knowledge domains involves skills such as:

- Recognizing patterns of organization (e.g., meter and rhyme schemes in poetry; arithmetic series)
- Classifying objects into categories based on common attributes (e.g., sets in math, plant/animal classifications; economic, social, or political groups)
- Identifying assumptions, stated or unstated, including suppositions and beliefs, that underlie positions (e.g., postulates in geometry; meaning in advertising campaigns)
- Identifying the main or central ideas in text, data, or creations, and differentiating core ideas from supporting information (e.g., discovering the theme of a series of paintings; finding important arguments or themes in a passage or poem)
- Finding sequences or consecutive order in sequentially organized information (e.g., determining sequences for preparing dishes in a meal; determining the order of operations in solving math problems).

Connecting involves determining or imposing relationships between the wholes that are being analyzed. Connecting compares and contrasts things or ideas, looks for cause-effect relationships, and links the elements together Connecting builds on analyzing because it often compares wholes based on the parts that were analyzed. It involves skills such as:

- Comparing/contrasting similarities and differences between objects or events (e.g., comparing business plans; contrasting different phyla of animals in terms of locomotion)
- Logical thinking, required to analyze or develop an argument, conclusion, or inference or provide support for assertions (e.g., evaluating the logic used in a geometric proof or a position paper in economics; using a method for determining an unknown element in chemistry)
- Inferring deductively from generalizations or principles to instances (hypothetico-deductive or syllogistic reasoning) (e.g., proving theorems given a set of axioms; solving logic problems in philosophy)
- Inferring a theory or principle inductively from data (e.g., developing a theory of animal behavior from observing animals in the wild; drawing conclusions from collections of data such as tables or charts)
- Identifying causal relationships between events or objects and predicting possible effects (e.g., predicting the effects of a physics experiment; inferring the causes of social strife in a country)

C Creative Thinking

Creative thinking requires going beyond accepted knowledge to generate new knowledge. Many creative thinking skills are closely tied to critical thinking skills. Critical thinking makes sense out of information using more objective skills, such as analyzing and evaluating information using established, external criteria. Creative thinking, on the other hand, uses more personal and subjective skills in the creation of new knowledge, not the analysis of existing knowledge. That new knowledge may also be analyzed using critical skills, so the relationship between critical and creative thinking is dynamic. The major components of creative thinking are synthesizing, imagining, and elaborating.

Synthesizing involves skills such as:

- Thinking analogically, which involves creating and using metaphors and analogies to make information more understandable (e.g., creating characters to describe different chemicals or chemical groups; finding everyday occurrences to relate to fictional events in literature)
- Summarizing main ideas in one's own words (e.g., summarizing the meaning of a story in English or foreign language; stating a personal method for solving math problems)
- Hypothesizing about relationships between events and predicting out comes (e.g., sampling classmates' attitudes about new laws and projecting their parents' beliefs; predicting the reaction of chemicals in a laboratory simulation)

- Planning a process, including a step-by-step procedure for accomplishing activities (e.g., developing a new study sequence for improving course grades; developing a plan for completing a term paper)

Creative thinking also involves *imagining* processes, outcomes, and possibilities. It involves intuition and fluency of thinking, and often calls on students to visualize actions or objects. Visualization is a skill that some students will find difficult to develop because of individual differences in thinking abilities. Although imagining skills are not as concrete or easily taught as other skills, they are nonetheless important for generating new ideas.

Imagining includes skills such as:

- Expressing ideas fluently or generating as many ideas as one can (e.g., thinking of things that are red and round; generating an adjective checklist to describe individuals in history lessons)
- Predicting events or actions that are caused by a ,set of conditions (e.g., predicting the effects of new seat belt laws on traffic fatalities; predicting the effects of healthier diets and exercise on body weights and fat counts)
- Speculating and wondering about' interesting possibilities, and solving "what if" questions without logical evaluation (e.g., speculating about the effects of a major earthquake in California; what if historical figures had known each other)
- Visualizing, which involves creating mental images or mentally rehearsing actions (e.g., imagining yourself performing a double front flip in a diving class; imagining a battle between the immune system and an invading virus)
- Intuition or hunches about ideas are powerful strategies that are impossible to teach but worth accepting; at least as hypotheses that can be tested using other skills (e.g., guessing the worth of a painting in an art class; predicting who will win an election).

Creative thinking also involves *elaborating on information*, that is, adding personal meaning to information by relating it to personal experiences or building on an idea. Elaborating includes skills such as:

- Expanding on information by adding details, examples, or other information (e.g., generating as many examples as possible of a concept such as "value"; developing a story around solving a type of math problem)
- Modifying, refining; or changing ideas for different purposes (e.g., change a story line to have a sad ending rather than a happy one; modifying the form of a musical composition)

- Extending ideas by applying them in a different context (e.g., treating science problems like military battles. from history; translating experiences from one culture to another foreign culture)
- Shifting categories of thinking by assuming a different point of view (e.g., changing from the role of a Democrat in a debate to that of a Republican; classifying food groups and nutritional values of typical meals from different countries)
- Concretizing general ideas by giving examples and uses (e.g., writing a short poem in different meters; creating a voyage to the centre of different atoms)

D Complex Thinking Skills

Finally, at the centre of the Integrated Thinking Model are complex thinking skills. These thinking processes combine the content, critical, and creative thinking skills into larger, action-oriented processes. The three major, types of complex thinking skills involve problem solving, designing, and decision making. These processes, each with a number of steps, are used in deciding whether, when, and where to use Mindtools. The Iowa Department of Education (1989) has described the critical and creative skills that are involved in each of these steps.

Problem solving involves systematically pursuing a goal, which is usually the solution of a problem that a situation presents. Problem solving is perhaps the most common complex skill. It includes the following steps and their related skills:

- Sensing the problem (intuition, visualizing, fluency, identifying assumptions)
- Researching the problem (assessing information, shifting categories, classifying, recognizing fallacies)
- Formulating the problem (summarizing, inferring, hypothesizing, concretizing,. identifying main ideas)
- Finding alternatives (expanding, extending, modifying, predicting, fluency, speculating)
- Choosing the solution (assessing information, comparing/contrasting, determining criteria, prioritizing, verifying)
- Building acceptance (planning, fluency, shifting categories, infer ring, identifying causal relationships, predicting)

Designing involves inventing or producing new products or ideas in some form, whether artistic, scientific, mechanical, or other It involves analyzing a need and then planning and implementing a new product. Designing includes the following steps and their related skills:

- Imagining a goal (fluency, shifting categories, speculation, visualizing, intuition)
- Formulating a goal (visualizing, predicting~ identifying causal relationships, recognizing patterns, hypothesizing; planning, logical reasoning)

- Inventing a product (fluency, planning, expanding, concretizing, shifting categories, analogical thinking, visualizing)
- Assessing the product (determining criteria, assessing information, comparing/contrasting, recognizing fallacies, verifying)
- Revising the product (expanding, extending, modifying)

Decision-making involves selecting between alternatives in a rational, systematic way. Decision-making includes awareness and manipulation of objective and subjective criteria. It involves the following steps and their related skills:

- Identifying an issue (identifying the main idea, recognizing patterns, identifying assumptions, recognizing fallacies)
- Generating alternatives (fluency, extending, shifting categories, hypothesizing, speculating, visualizing)
- Assessing the consequences (classifying, comparing/contrasting, determining criteria, identifying causal relationships, predicting, thinking analogically)
- Making a choice (summarizing, logical thinking, inferring, concretizing, intuition)
- Evaluating the choices (assessing information, verifying, intuition)

The Integrated Thinking Model from the Iowa Department of Education, described above, is probably the most comprehensive and rational model available for describing critical, creative, and complex thinking. Throughout the remainder of the book, each Mindtool will be described and evaluated in terms of the critical, creative, and complex thinking skills it engages and supports."

A.3. Criteria for Evaluating Mindtools

"In this final section, I will provide some criteria for assessing whether or not an application you encounter qualifies as a Mindtool. These are not absolute criteria, but rather indicators of "Mindtoolness." Each of the Mindtools described in this book will be evaluated using these criteria. The first three criteria are practical:

1. ***Computer-based***. Doubtless there are many non-computer applications that can function as Mindtools, but this book is about how to use computers more effectively as Mindtools.
2. ***Available applications***. The software applications that are used as Mindtools are readily available, general computer applications. Good Mindtools may also function in ways that support other computing needs. For example, databases have a range of applications other than serving as a Mindtool, such as record keeping, scheduling, information access, and producing the index for this book.
3. ***Affordable***. Additionally, Mindtools should be affordable. Most Mindtool applications are available in the public domain, as shareware, or from educational consortia, such as the

Minnesota Educational Computing Consortium, that distribute software inexpensively. If not, they should be available from vendors at a reasonable cost.

The next six criteria are pedagogical and relate to the learning outcomes supported by Mindtools:

4. ***Knowledge representation***. The application can be used to represent knowledge, what someone knows or how someone represents content or personal knowledge.

4. ***Generalizable.*** The application can be used to represent knowledge or content in different areas or subjects. Most Mindtools can be used in pure science (chemistry, physics, biology) or applied science (engineering) courses, math courses, literature courses, social science (psychology, sociology, political science) courses, philosophy courses, home economics and health, and even many physical education and recreation courses.
5. ***Critical thinking.*** Using Mindtools engages learners in critical thinking about their subject. That thinking is deeper, higher order, and/or more meaningful than memorizing and paraphrasing what someone else (the teacher or the textbook) said about the content.
6. ***Transferable learning.*** Using Mindtools results in the acquisition of generalizable, transferable skills that can facilitate thinking in various fields. This is different than number 5 above, which stated that Mindtools can be used in different subjects. This criterion suggests that critical thinking developed in the context of using Mindtools in science classes will transfer to (be applicable in) English classes.
7. ***Simple, powerful formalism.*** The formalism embedded in the Mindtool is a simple but powerful way of thinking. The thinking required to build knowledge bases or produce multimedia is deep. Expert systems require learners to think causally. If then, cause-effect connections are not always obvious, but they are not that difficult to find when one searches for them in the appropriate way.
8. ***Easily learnable.*** The mental effort required to learn how to use the software should not exceed the benefits of thinking that result from it. The software should be learnable in one to two hours or less. The syntax and method for using the software should not be so formal and so difficult that it masks the mental goal of the system. You may want students to think causally about information in a knowledge domain, but if the system requires weeks of agonizing effort to learn, the benefits of thinking that way will be outweighed by the effort to learn the system."

Appendix B Developmental Research Methodology

Richey and Nelson (1996:1230-1232) explain the actual methodology or *stages* in **developmental research**.

Define Research Problem

- Focus on a particular aspect of the design, development or evaluation process
- Establish the parameters and scope of the study
- Use research questions or objectives rather than hypotheses to guide the study
- Define the limitations or unique conditions that may be operating in the study as these limitations will affect the extent to which one may generalise the conclusions of the study.

Review of Related Literature

- Procedural models that might be appropriate for the task at hand
- Characteristics of effective instructional products, programs or delivery systems
- Factors that have impacted the use of the target development process in other situations
- Factors that have impacted the implementation and management of the target instructional product, program or delivery system in other situations
- The methodology of developmental research

Research procedures

- Population and sample. May be several populations or samples in developmental research projects, indeed the project itself may be the object of the study.
- Research design. Procedures should address both the development and traditional research facets. Firstly, the critical design and development processes should be explicated (i.e. how and when will the development take place, how and when will the instruction be implemented etc). Secondly, those procedures that draw on traditional research methodologies should be described such as case studies, surveys etc.
- Data collection and analysis procedures. Data collection in a developmental study takes a variety of forms depending on the focus of the research. Typical types of data collection in developmental research relate to factors such as:
    a. Documentation of the design, development and evaluation tasks
    b. Documentation of the conditions under which the development and implementation took place
    c. Conducting the need assessment and the formative and summative evaluations
    d. Profiling the target populations
    e. Profiling the design and /or implementation contexts

f. Measuring the impact of the instruction and the conditions that are associated with its impact

- Data analysis and synthesis are not unlike those of other research projects. There are likely to be descriptive data presentations, qualitative data analyses using data from documentation and observations and correlational and comparative analyses.

Results and conclusions.

The results of a developmental study are likely to be extensive, given the wide range of data typically collected. The format for presenting these results varies depending on the nature of the reporting medium (dissertations, reports, journals etc). The types of conclusions have been discussed before. Most often, all developmental research projects attempt to make additions to the field's knowledge of instructional design, development and evaluation. This may be done by constructing new procedural models, or formulating generalised principles, or by describing the 'lessons learned' in a particular project.

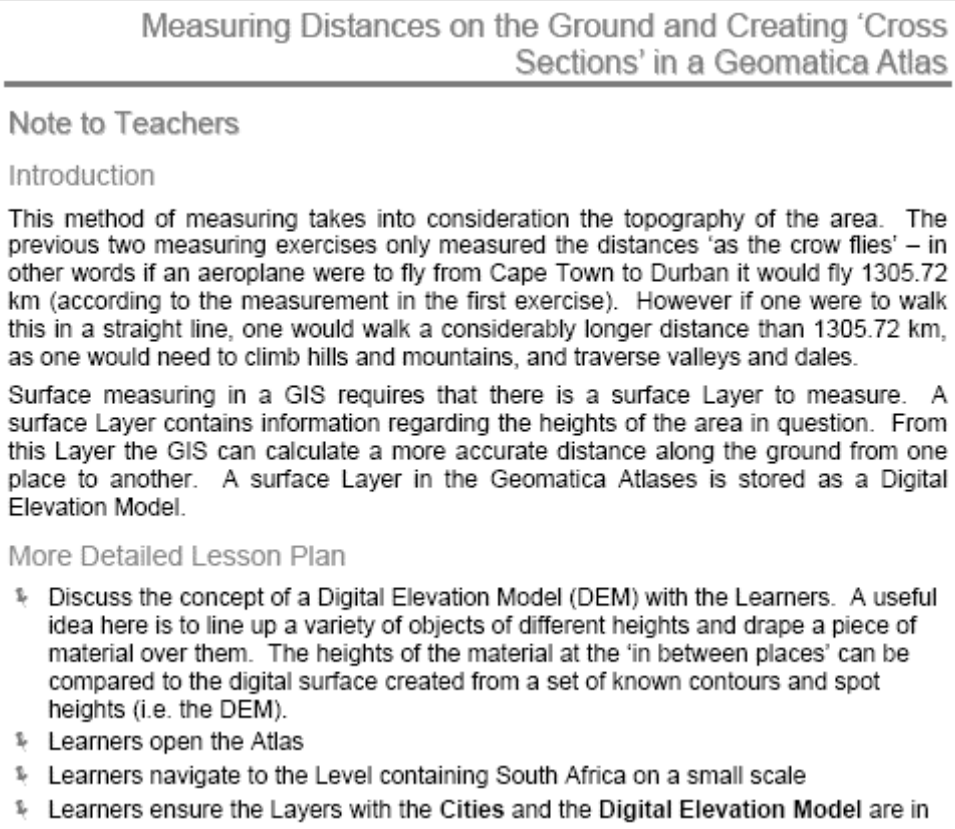
Appendix C Learning Material Examples

This appendix displays examples of the Teachers Materials and software screen shots from the current GIS product suite built on the concepts explored in this study. The product suite shown below is called Geomatica and is available from Napierian GIS Technologies[20]. This product is currently being used in schools in South Africa.

As yet, learning materials have not been developed that could be classified as 'cognitive tools'. Some of these GIS features are to be considered for the next release of the product suite.

Examples of learning about GIS rooted in real-world contexts

1



Measuring Distances on the Ground and Creating 'Cross Sections' in a Geomatica Atlas

Note to Teachers

Introduction

This method of measuring takes into consideration the topography of the area. The previous two measuring exercises only measured the distances 'as the crow flies' – in other words if an aeroplane were to fly from Cape Town to Durban it would fly 1305.72 km (according to the measurement in the first exercise). However if one were to walk this in a straight line, one would walk a considerably longer distance than 1305.72 km, as one would need to climb hills and mountains, and traverse valleys and dales.

Surface measuring in a GIS requires that there is a surface Layer to measure. A surface Layer contains information regarding the heights of the area in question. From this Layer the GIS can calculate a more accurate distance along the ground from one place to another. A surface Layer in the Geomatica Atlases is stored as a Digital Elevation Model.

More Detailed Lesson Plan

- Discuss the concept of a Digital Elevation Model (DEM) with the Learners. A useful idea here is to line up a variety of objects of different heights and drape a piece of material over them. The heights of the material at the 'in between places' can be compared to the digital surface created from a set of known contours and spot heights (i.e. the DEM).
- Learners open the Atlas
- Learners navigate to the Level containing South Africa on a small scale
- Learners ensure the Layers with the **Cities** and the **Digital Elevation Model** are in

[20] Contact Napierian GIS Technologies on +27 (46) 622 4314 or www.geomatica.co.za

2

Skills Suite A

Spin-off discussions from this lesson

- What does the DEM represent and why is it important for measuring surfaces and creating 'cross sections'?
- What do the colours of the DEM represent? How can one tell where the high points and low points of the country are?
- Trace the various rivers in South Africa using the DEM only – the Orange River is a striking example through the Northern Cape.
- Using the Profile View, examine the various features which are topography related in South Africa – such as the Drakensberg, the Lesotho Highlands, the Cape Fold Belt, the Karoo.
- Trace the circuitous routes of various rivers and view their profiles. It must be noted that the scale of the DEM and the river data will be reflected in the profile (the river will appear to flow uphill in some areas). However, the GIS can create a trend line for the profile – click on *Show, Trend line* in the Profile View Window.

Spin-off Geomatica exercises

- Use AppliCase 1 as a means of measuring surface distances and creating cross sections in a local environment using the toposheet data available. The DEM in the dataset for the local environment is not of a scale to be used with the aerial photography.
- Learners can calculate the difference in distance between flying and driving from one place to another.

3

Examples showing consideration of outcomes and assessment standards

4

Grade 8 Assessment Standards

This suite covers the following Assessment Standards for Curriculum 2005

Geography:

Code	Outcome
G1	Interpret maps and atlas information, graphical and statistical sources
G2	Measure distances on orthophotos maps and maps of local areas, and compare map distances with distances in reality
G3	Identify some physical and constructed features from aerial and orthophotos of local and other areas
G4	Report on the knowledge gained in the enquiry by constructing an argument based on sources of information in a variety of ways, use maps, diagrams and graphics, using computers in the presentation

Mathematics:

Code	Outcome
M1	Recognise, describe and represent numbers and their relationships
M2	Estimate, calculate and check
M3	Recognise, describe and represent patterns and relationships as well as solve problems using algebraic language and skills (scale)
M4	Describe and represent characteristics and relationships between two dimensional shapes and three dimensional objects in a variety of orientations and positions
M5	Use appropriate measuring units, instruments and formulae in a variety of contexts
M6	Collect, summarise, display and critically analyse data in order to draw conclusions and make predictions, and to interpret and determine chance variation

5

Overview

Exercise overview:

This exercise exposes the Learners to an aerial photograph of a familiar territory (the school grounds or a suitable local area nearby), thereby allowing them to view an environment they know from a different perspective. Learners will be required to estimate distances of this environment, measure these distances physically, and then use the GIS to measure the same distances. Learners should be encouraged to participate in discussions in order to consider the implications of the various activities they have undertaken, and to consolidate their experiences.

Activity Description	Assessment Standards that can be covered	Minimum Time Required	Level of Difficulty	Teaching Materials (Teacher)	Teaching Materials (Learners)	Prerequisites
Estimation of distance, physical measurement, Teacher input, Learner participation	G2 M1, M2, M5, M6	1 hour, 15 minutes	Introductory	Prepared lesson on measurement, and a list of features identified from Skills Suite A data	Measuring tools such as tape measure, click wheel, or the like	An understanding of measurement and distance
Identifying features on aerial photographs, Measuring in 2 dimensions using a GIS	G1, G2, G3, G4 M1, M2, M3, M4, M5, M6	1 hour, 5 minutes if well prepared	Challenging	Teacher preparation and familiarisation of Skills Suite A	Computer access with ApoliCase 1 available	Previous activity
Time for discussion, collation of information	G1, G2, G3, G4 M1, M2, M3, M4, M5, M6	45 minutes	Moderate	Area to collate information, such as the table on page	Information from previous activities	Previous 2 activities

Examples showing assessment of various types

6

Summative Assessment

Note to teachers

The following is a pool of questions ranked from elementary to advanced. The teacher can draw from this pool, create new questions, or adapt questions to suite the Learners' needs and abilities. Some questions should not be used simultaneously in a single assessment, as they answer each other.

The datasets for these assessment questions are located in the Assessment Atlas.

Elementary questions

Question	Answer	Value	Value allocation
Extract of Rhodes University Data			
What type of features dominates this photograph?	Sports Features	1	Right or wrong
Name two sports that are catered for according to this photograph.	Athletics, Cricket, Hockey and Golf (note the sand bunker around -3687473, -45419)	2	Right or wrong
What is the distance that would be run if an athlete completed one circuit on the track? Give your answer in meters.	Range between 400m to 450m	2	1 for correct distance 1 for correct units
How many athletes are catered for on this track?	8	1	Right or wrong
Identify the features labeled A to E on the Feature Identification Layer	a. Car b. House c. Pool d. Tree/Shrub e. Tennis court	5	Right or wrong
What is the area of the southern-most building?	Approximately 180m^2		

7

Advanced questions

Question
Extract of Rhodes University Data
What is the difference between the distance that athletes would run on the inside lane of the track as opposed to the outside lane of the track, assuming that the athletes started and ended along a straight line? Give your answer in m. If there were a full complement of athletes running in individual lanes, completing 1 circuit, at what interval would they be spaced at the starting line in order that they each ran an equal distance?
Name four sports that are catered for according to this photograph
If an athlete were to compete in a 100m race, starting on the straight length of the track, next to which feature would the race end?

The grounds person needs to order top dressing for the three cricket nets that are in poor condition. Top dressing is usually 2cm deep. Calculate how many cubic meters of topdressing needs to be ordered.

8

Assessment of AppliCase 1

Lesson 3: Discussion and Collation of Information		
Assessment Standards Covered: M1 – M6; G1 – G4; CO1, CO4, CO6, CO7		
Assessment Method: Self and/or Peer and/or Teacher		
Learner Activity	**Time**	**Proposed Evidence to Be Presented**
Comparison of the three sets of measurement – estimate, real, and GIS	15 mins	• A collated set of measurements • A report on the various measuring methods used and the differences between each • Participation in a discussion on the application of different measuring methods in different situations (linked to the effect of scale)
Discussion of the different methods used – accuracy and time elements of each	15 mins	
Discuss the affect that scale would have on the different methods of measurement	15 mins	
Assessment note: Self and Peer assessment: The Learners can compare their tabulated answers with fellow Learners. Where answers differ radically from each other, the Learners can be encouraged to revisit the GIS and measure again to determine which measurement is more correct. Teacher assessment: The Teacher can assess the Learner's ability to apply the knowledge and skills gained by supplying a number of measuring scenarios to which the Leaner should recommend a measuring method		

9

Appendix 6: Presentation Assessment Rubric (Session 5)

Student Name:			Date:		Assessor:		
Assessment Criteria	**1. Not competent (< 50%)** **0 to 4**	**2. Average (50 to 59%) 5**	**3. Competent (60 to 74%) 6 to 7**	**4. Highly competent (Over 75%) 8 to 10**	**Weight**	**Total**
Organisation of content	No attempt to organise the topic No definitions given Strayed from the topic	Structure is evident but not logical Some attempt at defining terminology	Topic is organised into a structure but doesn't take the building block approach Not all terms have been defined	Topic is exceptionally well organised into a structure that gives basics first and then builds on these Terms and jargon have been defined	X 1.5	
Depth of content	Explanations of concepts and / or theories are inaccurate and incomplete Too much material or irrelevant material presented for the context Difficult to ascertain the key issues No interpretation of material to match the context (simple regurgitation)	For the most part, explanations of concepts and theories are accurate and complete Key issues of the topics are not clearly identified Some material not relevant or too detailed for the topic and context Very little interpretation	For the most part, explanations of concepts and theories are accurate and complete Key issues of the topics are identified Majority of the information presented was relevant to the topic and context Most of the material presented was interpreted	Speakers provide an accurate and complete explanation of key concepts and theories, drawing upon relevant literature Key issues of the topics are clearly evident Listeners gain insights Only material relevant to the topic and context were presented and it was carefully interpreted	X 2	
Use of Language Grammar and word choice	Listeners can follow the presentation, but are distracted by grammatical errors and use of slang Some sentences are incomplete / halting and /or vocabulary is somewhat limited or inappropriate	No criteria for this level	For the most part, sentences are complete and grammatical and they flow together easily With a few exceptions, words are chosen for their precise meaning	Sentences are complete and grammatical, and they flow together easily Words are chosen for their precise meaning	X 1.5	
Handling of questions	Cannot answer questions at all Continually defer to the facilitator	The questions are answered but in a muddled, unconfident fashion	Answer given is generally well structured and explained	Presenters are able to listen to the question and answer it confidently and with sensitivity to issues that may surround it Answer given is well structured and explained	X 2	
Length	The presentation is too short or too long by ten minutes or more	The presentation is too short or too long by five minutes or more	The presentation is too short or too long by two minutes or more	The presentation is within assigned time limits		
Style	Presenter seem uncomfortable and can be heard only if the listener is very attentive Much of the information is read from notes Lack of confidence on presentation	Pacing is sometimes too fast or too slow The presenter seem slightly uncomfortable at times and the audience occasionally has trouble hearing him /her	There is some reading of notes Speaker is generally comfortable in front of the audience and can be heard by all Confident on the topic most of the time	It is not a reading of a paper The presenter is clearly comfortable in front of the audience and can be heard by all Speaks confidently on their topic Imagination and creativity is evident	X 2	
Total *Out of 100*						

Examples showing application of knowledge and higher-order cognitive skills

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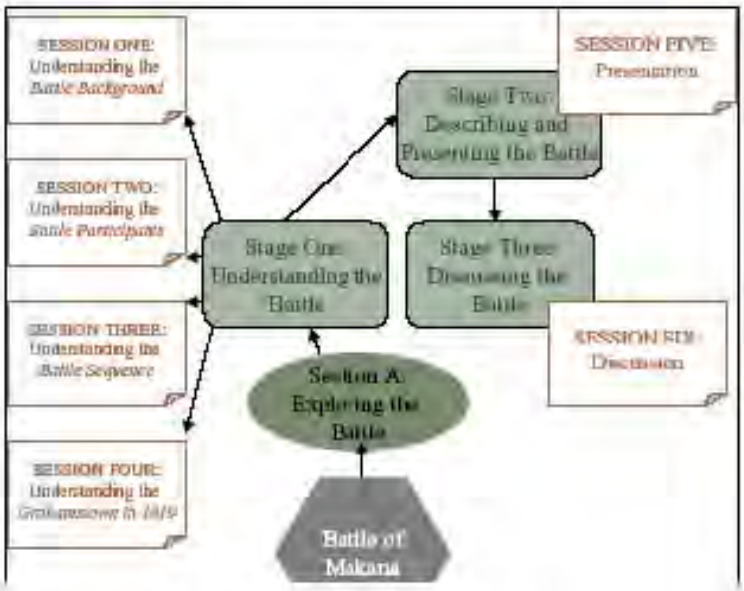
Introduction

Overview

This AppliCase uses a historical topic (the Battle of Grahamstown) as its main focal point but it is designed to be cross-curricular. Elements of Geography and Mathematics are incorporated in most of the sessions, and underpinning everything is Language, which is utilised to its fullest capacity in a variety of ways throughout. Key elements include the complete understanding of the Battle, spatial awareness and three-dimensional visualisation, utilisation of maths and geography in the interpretation of the history, and the use of language.

Structure of AppliCase2

The diagram below shows the structure of the AppliCase.



11 Communication

- There were thousands of Xhosa warriors. How could the leaders have communicated to the warriors, and with each other, before and during the battle?
- How would the British have communicated?
- Did the Xhosa and British communicate?

Military Strategy

- Why were the Xhosa army defeated, when they greatly outnumbered the British, and had the advantage of attack?
- If the Xhosa had not been seen by Colonel Willshire, would they have won the battle? How important is the element of surprise?
- If you were a British commander, how would you have defended Grahamstown?
- What was the traditional Xhosa battle attack formation?
- How would the British have defended Fort England (the building itself)? Does this relate to the design of the Fort itself?

Emotions

- How would you feel if you were one of the British? – one of the Xhosa? – a woman or child?
- How big a role did superstition play? Is it a factor in modern day warfare?
- How important is respect and leadership?

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Appendix 3: Worksheet 1 - Analysis of Battle Participants

Objective

This interpretation exercise aims to perform simple statistical analysis on the makeup of the battle participants, and to represent this graphically.

Task 1

Complete the following table by entering the numbers of participants associated with each group.

Task 2

Add up the total number of British allies and enter this value twice: once at the bottom of the table and once next to "British Allies".

Task 3

Add up the total number of all participants and enter this value next to TOTAL.

Task 4

Work out what percentage of all Battle Participants the Xhosa and the British (and their allies) were, and enter these values in the table.

Group	Numbers	Percentage
Xhosa		
All British Allies		
TOTAL		
Cape Corps		
Colonial Troops		
38th Light Company		
Royal Africa Corps		
Boezac's Buffalo Hunters		
Town Irregulars		
Total British Allies		

Task 5

What percentage of the British Allies were Boesac's men?

13 *Task 6*

Draw an appropriate style graph (e.g. pie chart or bar chart) showing the proportions of Xhosa versus British.

Discussion Questions

Based on these numbers, and your knowledge of the weaponry available, whom would you expect to win and why?

How can we find out how many people and whom were involved in the battle?

How accurate are these sources of information?

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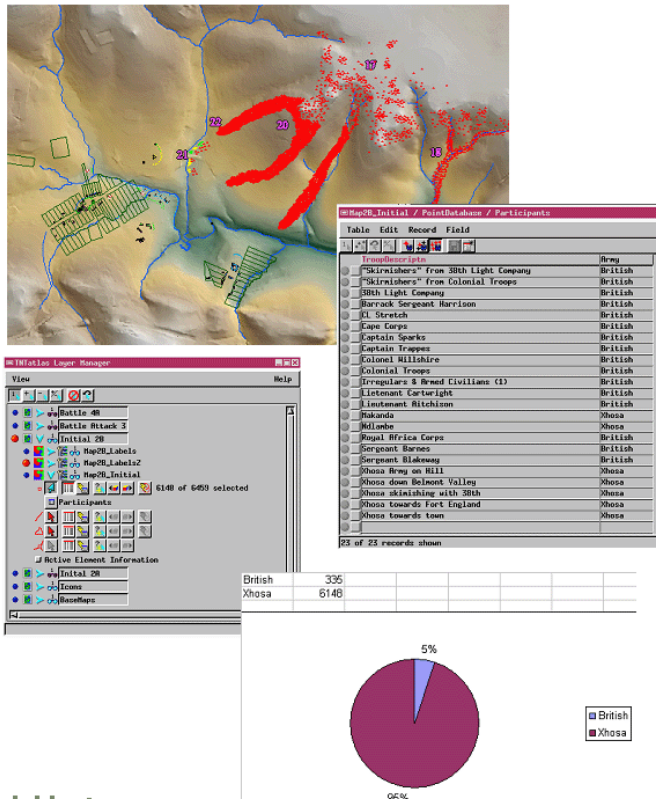

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Appendix 4: Worksheet 2 – Growth of Grahamstown

Objective

This interpretation exercise aims to measure the area of Grahamstown over time, to perform simple statistical analysis on these measurements, and to represent this graphically.

Note: Consider the discussion questions below before commencing the Worksheet.

Task 1

Use the polygon tool in the GeoToolbox to measure the area and perimeter of Grahamstown for each of the years in hectares. Complete the following table by entering the area and perimeter associated with each year.

Task 2

Work out what percentages the area of Grahamstown in 1814, 1819, 1820 and 1824 were compared to 1992, and enter these values in the table.

Year	Area (hectares)	Perimeter (kilometres)	Percentage Area of 1992
1814			
1819			
1820			
1824			
1992			

Task 3

Enter the above measurements into a spreadsheet and use the functionality of the software to calculate the percentages for you.

Task 4

Draw an appropriate style graph illustrating the growth in area of Grahamstown.

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Task 5

Use the spreadsheet software to generate the graph in Task 4. Experiment with alternative types of graphical representation.

Task 6

How does the change in Perimeter relate to the change in area? Does this relationship indicate the distribution (clustered or spread out) or shape of a settlement?

Discussion Questions

- How do you decide what the extent of a town is? Do you measure the centre of town only, or include outlying areas? Do you include the area in between?
- What units of measurement were used in the 1820's? What units of measurement do we use today? How do you convert between them?
- How is it most appropriate to represent this type of time series data graphically?
- How can perimeters and areas be used to analyse the shape or distribution pattern of a settlement?

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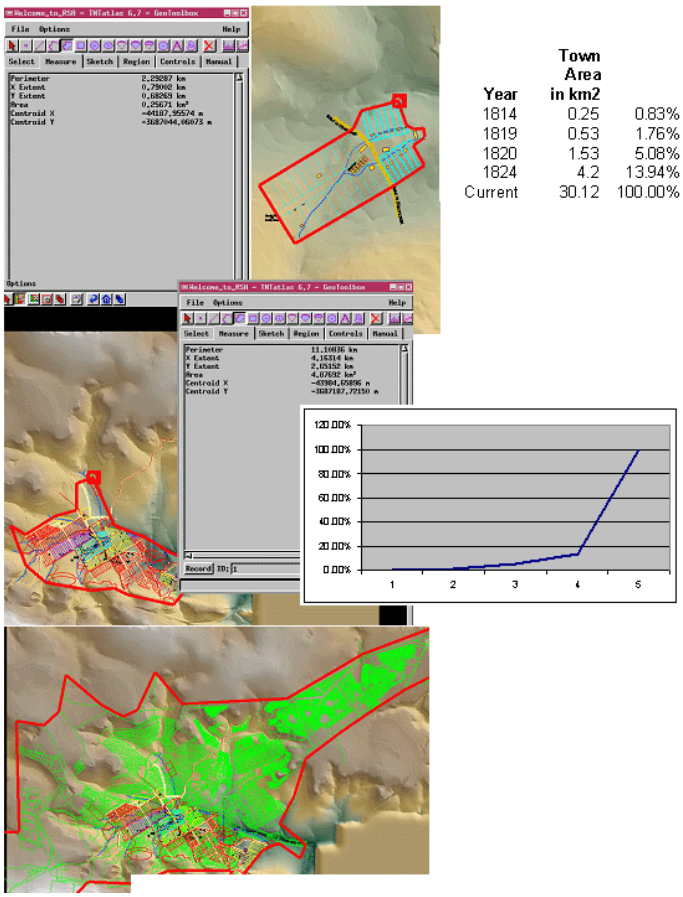

Year	Town Area in km2	
1814	0.25	0.83%
1819	0.53	1.76%
1820	1.53	5.08%
1824	4.2	13.94%
Current	30.12	100.00%

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Task 8

Draw sketch of the area surrounding where you live, indicating (roughly) the plots and any watercourses. Is there a strong relationship between the rivers / streams and the siting of plots?

Task 9

Look at satellite pictures of the following major cities – London, Paris and Washington (at the end of this worksheet). What do you think the influence of these rivers has been on the pattern of development of these cities?

Task 10

Go back to the Atlas and switch on all the river layers. Draw a rough sketch showing how these watercourses have changed over time. How many watercourses have moved or ceased to exist? How has man altered the water drainage patterns over time? Why would they have done this?

Discussion Question

- Is the influence of rivers on the pattern of settlement of town, greater or less than the influence the settlement has on natural watercourses and rivers?

Examples showing cross-curricula nature of the learning materials

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Interactive Exploration – Mathematics

Layer Name	Activity / Question	Tools to use	Concept/s	Assessment Standards
Prelude 1D	Calculate how long it would have taken Colonel Willshire to return to Grahamstown after facing the Xhosa. (On horseback). How long would it have taken the Xhosa to follow him to Grahamstown? (On foot).	Surface distance measurement (GeoTool Box)	Time – Distance - Speed	M2 M3 M8
Prelude 1B	60 men were left to defend Fort England. Measure the area and perimeter of the Fort. What area would each soldier have had to defend? How large is your school, and how many students are there? How could you lay a defence for your school, and what area would each learner have to defend?	Measurement	Area & perimeters Densities	M1 M2 M3 M9
Initial 2A	How long would it have taken for the cannons to be transported from Fort England to their battle site?	Measurement	Time – Distance -	M2 M3 M8

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Interactive Exploration – Geography

Layer Name	Activity / Question	Tools to use	Concept/s	Assessment Standards
Prelude 1A & flyover	How would 6000 Xhosa have travelled across the Fish River and amassed for battle without being detected? Where would they hide?	Profile 3D-Sim	Line of sight 3D-Visualisation	G1 G3 G4
Prelude 1B	Draw profiles across the Kowie ditch. How and where would you position the soldiers to obtain the best defence strategy, in terms of the terrain available? (Bear in mind the weapons used in the battle)	Profile	Cross Profiles Line of sight Landscapes	G1 G3 G4
Initial 2A	Plan, and draw a sketch map, of the most viable route for transporting the cannons from Fort England across the Ditch to their battle site. Take into consideration not only the surface distance travelled, but also the slope and the type of terrain to be crossed (e.g. is it likely there were areas of dense vegetation, or swamps to be avoided)? Include a cross section of where you cross the Kowie river.	Profile Surface distance measurement	Gradients Problem Solving Creating Maps	G1 G2 G3 G4 G5
Prelude & Battle	The Prelude scenes are presented at a coarser scale than the Battle scenes. Discuss the issue of scale and how it influences the way we can represent landscape / events in maps. (What detail to include, symbols...)	Scale Bar	Scale Map work	G1 G3 G4

Advanced questions

Question	Extract of Rhodes University Data
What is the difference between the distance that athletes would run on the inside lane of the track as opposed to the outside lane of the track, assuming that the athletes started and ended along a straight line? Give your answer in m. If there were a full complement of athletes running in individual lanes, completing 1 circuit, at what interval would they be spaced at the starting line in order that they each ran an equal distance?	
Name four sports that are catered for according to this photograph	
If an athlete were to compete in a 100m race, starting on the straight length of the track, next to which feature would the race end?	
The grounds person needs to order top dressing for the three cricket nets that are in poor condition. Top dressing is usually 2cm deep. Calculate how many cubic meters of topdressing needs to be ordered.	

Lesson 3: Discussion and Collation of Information		
Assessment Standards Covered: M1 – M6; G1 – G4; CO1, CO4, CO6, CO7		
Assessment Method: Self and/or Peer and/or Teacher		
Learner Activity	**Time**	**Proposed Evidence to Be Presented**
Comparison of the three sets of measurement – estimate, real, and GIS	15 mins	• A collated set of measurements • A report on the various measuring methods used and the differences between each • Participation in a discussion on the application of different measuring methods in different situations (linked to the effect of scale)
Discussion of the different methods used – accuracy and time elements of each	15 mins	
Discuss the effect that scale would have on the different methods of measurement	15 mins	
Assessment note: Self and Peer assessment: The Learners can compare their tabulated answers with fellow Learners. Where answers differ radically from each other, the Learners can be encouraged to revisit the GIS and measure again to determine which measurement is more correct. Teacher assessment: The Teacher can assess the Learner's ability to apply the knowledge and skills gained by supplying a number of measuring scenarios to which the Learner should recommend a measuring method.		

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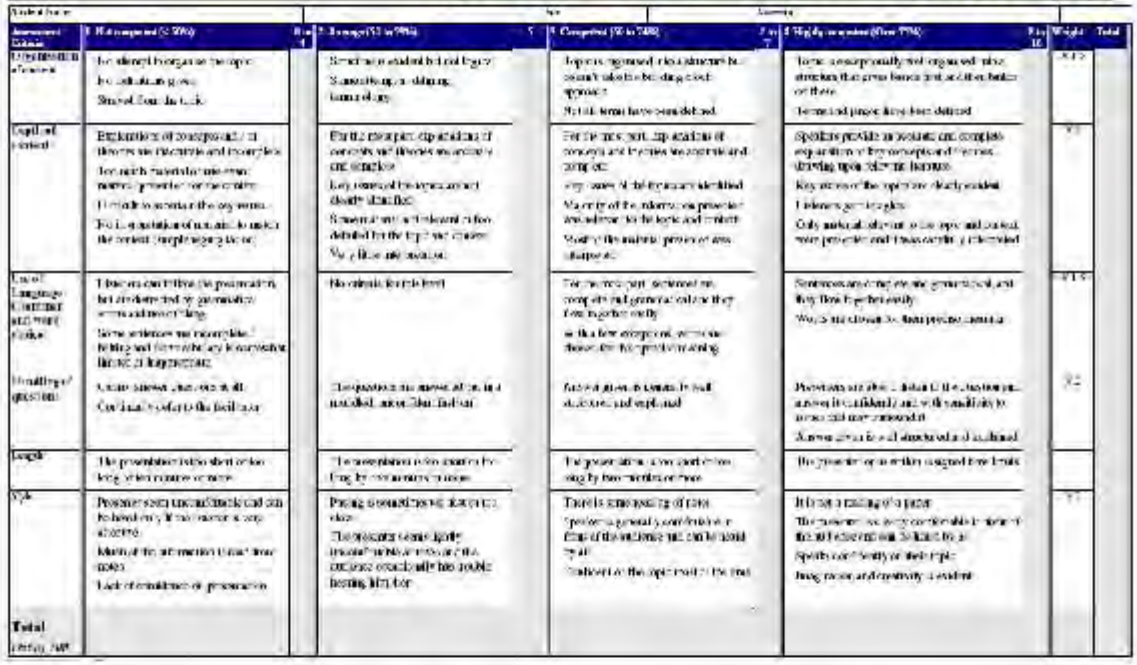

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