CURRICULUM DEVELOPMENT FOR AN INQUIRY APPROACH TO CONSTRUCTION EDUCATION

Ephraim Zulu

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CURRICULUM DEVELOPMENT FOR AN INQUIRY APPROACH TO CONSTRUCTION EDUCATION

A thesis submitted to the College of Agriculture, Engineering and Science, the School of Engineering, Construction Studies program, University of KwaZulu-Natal, South Africa, in fulfilment of the degree of

DOCTOR OF PHILOSOPHY IN CONSTRUCTION MANAGEMENT

By

Ephraim Zulu

Supervised By

Professor Theodore C. Haupt

March 2019

DECLARATION OF ORIGINALITY

As the candidate's supervisor, I agree/disagree to the submission of this thesis

Signed:

Supervisor:  Date: March 12, 2019

I, Ephraim Zulu, hereby state that this thesis represents the original work of myself the author, and is submitted for the degree of Doctor of Philosophy in Construction Management at the University of KwaZulu-Natal, Durban. Where the works of other authors have been used, they have been duly acknowledged and referenced. This research has not been submitted before for any degree or examination to any other university.

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DECLARATION 2 - PUBLICATIONS

Details of contribution to publications that form part and/or include research presented in this thesis (include publications in preparation, submitted, *in press* and published and give details of the contributions of each author to the experimental work and writing of each publication)

Publication 1

Zulu, E. and Haupt, T. (2017). An Analysis of Types of Assessment Questions and Cognitive Loading in Undergraduate Students of Construction Studies at the University of KwaZulu-Natal. *Proceedings of the 11th Built Environment Conference,* organised by Association of Schools of Construction in Southern Africa (ASOCSA) held at the Department of Public Works, Durban, South Africa from 6th to 8th August 2017

Publication 2

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Publication 3

Zulu, E. and Haupt, T. (2017). The Influence of Cognitive Loading on Schema Construction and Automation and Approaches to Learning in Students Studying Construction. *Proceeding of 7th World Engineering Education Forum,* hosted by the Society of Engineering Education Malaysia (SEEM), Universiti Teknologi Malaysia, held at the Berjaya Times Square Hotel, Kuala Lumpur, Malaysia from 13th to 16th November 2017

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Publication 5

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Publication 6

Zulu, E. and Haupt, T. (2018). CHAID Modelling of Schema Construction Explained by Approaches to Learning. *Proceedings of the South African International Conference on Education (SAICEd),* edited by M. M. Dichaba and M. A. O. Sotayo, organized by the African Academic Research Forum (AA-RF), held at the Manhattan Hotel, Pretoria, South Africa

Publication 7

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(Recipient of one of five best presentation awards)

Signed:

Student:________________________ Date: ____________

DEDICATION

To my parents, Annie Anned Joseph Kanyemba and Richard Lupiya Zulu for the sacrifices they made so I could have a good education; for raising me so I could dream big dreams and dare great things.

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ABSTRACT

University graduates have been criticised for failing to make a meaningful contribution to professional practice in the construction industry in South Africa and across the world generally. Deficiencies have been reported in the ability of graduates of construction programmes to think critically, solve problems or apply theoretical knowledge in practical situations. Among other factors, the traditional didactic lecture approach to teaching and learning has been blamed for not providing students with an appropriate learning experience to adequately prepare them for professional practice. This is because the didactic lecture approach is characterised by attempts to transmit knowledge from the lecturer to the student which has been found to be inadequate in achieving effective learning. The traditional didactic approach to teaching is based on theories of learning which assumed that knowledge can be transmitted from the minds of lecturers to the minds of students. Contemporary theories of learning have rebuffed this assumption and demonstrated that knowledge and understanding are achieved by students actively engaging with the study material and constructing their own knowledge structures rather than passively receiving knowledge and understanding. Based on these contemporary theories of learning, several different pedagogy has been suggested and incorporated in educational practice. However, predominantly, contemporary pedagogy has been haphazardly applied within the traditional framework of segregated modules. Also, different pedagogy based on different contemporary theories has been researched and applied independent of each other. This has led to some contradictions in some pedagogy and a lack of synergistic collaboration among the contemporary pedagogy.

Against this background, this thesis researched the problem that the traditional didactic lecture teaching approach to construction education at undergraduate level does not adequately prepare students for construction professional practice and therefore requires an alternative curriculum model which incorporates different contemporary theories of learning synergistically in a student centred inquiry based learning (IBL) pedagogical framework. To achieve this, the research established factors from the contemporary theories of learning which significantly contribute to the creation of knowledge structures in students studying construction programmes in South Africa. Subsequently the research proposed a curriculum model for construction programmes which incorporated the identified antecedents to effective learning underpinned in the contemporary pedagogical framework of IBL.

The research followed a positivist epistemological philosophy and a subjective ontological philosophy, a deductive research approach, a survey research strategy, a cross sectional time horizon and a data collection technique and procedure of a questionnaire using the non-probability sampling technique of convenient sampling. The research procedure included an extensive literature review of three contemporary theories of learning namely, constructivism from philosophy, connectionism from behaviourism and cognitive load theory from cognitive science. Subsequently, an instrument measuring the concepts from the conceptual model was developed, pre-tested and then administered to undergraduate students studying construction programmes at a convenient sample of public universities in South Africa.

The results show that the factors from the three contemporary theories of learning which directly influence the extent to which students studying construction programmes are able to create knowledge structures and achieve effective learning are individual learning, scaffolding, reflective thinking and group learning in that order. Repetition, reinforcement, readiness, self-directed learning and the use of worked examples have indirect relationships with the ability for students to create knowledge structures. Complex questions and authentic questions were also found to indirectly contribute to effective learning. Cognitive loading was found to interfere with learning and complex questions were found to induce cognitive loading while authentic questions did not.

Subsequently, an IBL curriculum framework for construction programmes was proposed which integrated most of the topics which directly relate to construction practice. Based on the findings, the IBL class should involve students in both individual and group learning activities which should be appropriately scaffolded and students explicitly directed towards reflective thinking as they engage in the IBL projects. Complex questions and authentic questions should be used in collaboration with extra scaffolding in order to reduce the impact of the consequent cognitive loading induced by complex questions. The IBL projects should be simple initially and increase in complexity as the student's advance.

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CHAPTER 1

INTRODUCTION TO THE RESEARCH

1.1 Introduction

The quality of university construction graduates worldwide is being criticised for being at variance with what the construction market expects (Aryakwa, Desoh, Adinyira and Amoah, 2011; Chileshe and Haupt, 2007; Love and Haynes, 2001). Several differences have been identified between skills and competences possessed by construction graduates and those demanded by the construction industry. For example, while analysing the perception of the Ghanaian construction industry on the performance of industry entry level graduates, Aryakwa *et al.* (2011) noted that graduates lacked practical building knowledge, problem solving skills, communication skills such as inter-personal skills in general among several other skills. Love and Haynes (2001) equally noted the absence of most of these skills and competences in a survey of construction managers and construction companies in Australia. Other fields of education have equally faced criticism of the quality of graduates emerging from universities (Mihaela, Amalia and Bogdan, 2015; Teijeiro, Rungo and Friere, 2013) indicating that the problem is not necessarily with construction programmes only.

The traditional didactic lecture approach to university education with its associated student learning experiences have been blamed for the observed poor quality of graduates. For example, on clinical nursing education, Candela, Dalley and Benze-Lindley (2006) noted that content driven curricula hardly leaves any time for the development of critical thinking and clinical reasoning. Further, the traditional discipline specific content is noted as doing little to give learners the context for the content (Savery, 2006 citing research evidence). Mihaela *et al.* (2015) noted deficiencies in university curricula relative to the needs of the Romanian economy and cited this as one of the causes of the gap between competences possessed by graduates and those demanded by industry.

The traditional didactic lecture approach to education is modelled around theories of knowledge and learning derived from the epistemology branch of philosophy. Traditionally, educators have focused on transferring knowledge from their minds into the minds of learners based on the traditional epistemological views of knowledge that the mind is a "black box" whose contents cannot be established for sure (Bodner, 1986; Clark, 2013). This view postulates that in acquiring knowledge, the mind simply tries to discover the existing knowledge of the world by building mental images of it. Based on this conception, educators traditionally try to show learners pictures of this existing world as it is in their minds. Through the lessons and with emphasis and repetition, the educators expect leaners to replicate these images in their own minds. This view of learning is based on the 400 BC philosophy of realism which holds that truth is objective and can be attained through observable data. This view was postulated by the philosopher Aristotle who is credited with being the father of the scientific method. Realism was in contrast to Plato's idealism which postulated that knowledge lies in a persons' soul at birth (*a priori process*) and education simply brings consciousness to this latent knowledge. Aristotle's realism therefore rejected Plato's idealism. This was perhaps the first epistemological paradigm shift since no other change in the philosophical world view of epistemology is recorded. Other philosophical schools of thought emerged from realism including empiricism and positivism all of which are philosophies of science which believe in empirical evidence to achieve knowledge. Based on Aristotle's realism and subsequent theories of empiricism and positivism, education curricula emphasised scientific subject matter of the physical world. The content is orderly and discipline specific in tandem with defined scientific disciplines. Teaching methods emphasised gaining factual knowledge through demonstrations and recitation and learners are expected to think scientifically. The curricula are therefore scientific, standardised and distinct-discipline based.

Contemporary epistemology theories have since rebuffed the proposition that the mind is a "black box" and what goes in it cannot be accurately judged and so what is happening inside can only be guessed (Bodner, 1986; Clark, 2013; Field, n.d.). It is now fairly accepted that each one knows all too well what is happening in their minds; it is the world which is a "black box" and the relationship between what is in the mind and the world can only be guessed. This is the pragmatic view, which unlike realism, further postulates that reality is constantly changing and that learning happens best through applying experience and thoughts to problems. With pragmatism, there is no absolute truth since the world is viewed as changing (Yacobi, 2013).

Applying pragmatism, (Dewey, 1910) in his "Theory of Inquiry" postulated that knowledge is created by an active response to the environment and not a passive observation of the environment and drawing correspondence with reality (Field, n.d.). Knowledge creation is therefore a process which starts when human action is impeded and proceeds with the creation of hypotheses tested by an active manipulation of the environment and ends with the re-adaptation to the environment allowing for action to proceed (Ibid). Subsequent work on pragmatism by Maria Montessori and Jean Piaget led to a new paradigm in the philosophy of learning called constructivism (Ultanir, 2012). Constructivism, which is the contemporary paradigm in the philosophy of knowledge and learning postulates that learners are creators of their own meaning and knowledge (Kolb and Kolb, 2008; Ultanir, 2012). Learning and knowledge construction happens by experiencing reality and reflecting on these experiences to construct understanding (Ibid). The best way to learn and create understanding is therefore to experience reality and reflect rather than to passively receive information (Ultanir, 2012).

Constructivism has since been incorporated in pedagogy in different ways and yielding varying results (Richardson, 2003). Based on evidence from its application so far, constructivist approaches to learning have been advanced as solutions to some of the quality problems facing education today. This is because it has been established that problem solving, critical thinking, teamwork skills and interpersonal skills generally, among other skills, significantly improve when constructivist approaches to learning are used (Bayram, Oskay, Erdem, dinçol özgür and Şen, 2013; Brandon and All, 2010; Chu, Tse, Loh and Chow, 2011; Naylor, 2011; O'Shea and Young, 2014; Supasorn, Kamsai and Promarak, 2014; Wang, 2012). For these reasons, various forms of constructivist approaches to learning have been used at different levels of education. For example, Bayram *et al.* (2013) found that the use of inquiry based learning (IBL), which is a constructivist approach to learning, resulted in first year university students of education being highly motivated. Naylor (2011) used IBL as a strategy in an imaging science module to promote learner autonomy and enhance student experience. The majority of students found teamwork to be beneficial to learning because of support from team members. Wang (2012) found significantly increased student independence, autonomy, critical curiosity, meaning making, creativity, learning engagement, among other outcomes while implementing a coaching strategy in IBL in a United Kingdom (UK) main stream secondary school. Supasorn *et al.* (2014) used IBL to effectively teach grade 12 students organic chemistry practical lessons in seven experiments all lasting a total of 21 hours which students were highly satisfied with. Chu *et al.* (2011) introduced IBL to improve the reading ability of primary school learners and found a positive effect on reading ability and attitudes of the learners. Reading comprehension, reading speed and vocabulary were also improved. The merits of a constructivist approach to learning at different levels of education are many and well documented.

Comparison has been made between constructivist approaches and the traditional instructive approach to learning (Raidal and Volet, 2009; Savery, 2006: citing Albanese and Mitchel, 1993). Albanese and Mitchell, (1993 cited in Savery, 2006) concluded that while the problem based learning (PBL) approach, which is a constructivist approach to learning, was equal to the traditional instructive lecture approach in terms of conventional tests of knowledge in medical sciences, the PBL approach was better in clinical problem solving skills. This is when medical board examination scores for medical doctors taught through the PBL approach were compared with scores for doctors taught through the traditional instructive approach. Daton *et al.* (2000 cited in Savery, 2006) also showed that students using the PBL approach performed equally well when compared to the traditional approach but students preferred the PBL approach.

However, notwithstanding that the traditional approach has, in some instances, been found to fairly equal the constructivist approaches in terms of knowledge gained, its emphasis on content and instruction leaves it with some shortcomings when compared to the constructivist approaches. For example, on clinical nursing education, Candela *et al.* (2006) noted that content driven curricula hardly leaves any time for the development of critical thinking and clinical reasoning. The traditional discipline specific content is also doing little to give learners the context for the content (Savery, 2006 citing research evidence).

Owing to the shortfalls of the traditional instructive teaching and the many advantages offered by a constructivist approach to learning, curriculum development literature has been advocating a shift towards more constructivist forms of teaching and learning (Brandon and All, 2010; Cunha, Contento and Morin, 1999; Dopson and Tas, 2004; Huit, 2003; Mazhar and Arain, 2015). Several attempts have been made at integrating constructivist learning concepts in existing curricula (Cunha *et al.*, 1999; Dopson and Tas, 2004; Eliot and Joppe, 2009). For example, when integrating an e-tourism module into an existing tourism management programme, Eliot and Joppe (2009) incorporated both instructive and student centred constructivist approaches in the module. Students were taught theory and industry practice in preparation for a student centred group activity which simulated a real world problem. The group activity also required students to apply background knowledge to recommend a strategic solution to a problem. Industry experts were invited to judge the work of the students. The judges were impressed by the students' work and acknowledged the amount of analytical work and strategic thought which the students had put into the exercise.

While "patching" existing curricula to incorporate constructivist approaches to learning is widespread and shows signs of benefits, Giddens and Brady (2007 cited in Brandon and All, 2010) suggested a shift from traditional linear courses to concept based courses where concepts are presented across the life span of a profession arguing that a non-linear approach can improve students critical thinking abilities. A complete shift from traditional courses will entail a complete change in the way curricula are packaged from the traditionally accepted programme core modules to more integrated modules that innovatively combine key concepts across a programme to be taught through a constructivist approach.

The problem with the traditional education experience is that it emphasises aspects of education that are either not required or are at odds with industry (Haupt, 2012 citing Cook and Cook, 1998). While the industry demands skills such as problem solving, team work and lifelong learning, the traditional education experience often offers facts, individual effort, and passing exams as can be seen in the comparison of traditional education experience and the workplace in Table 1-1.

Table 1-1: Traditional education vs. Workplace

	Traditional Education	
Requirements	Facts	Problem solving
	Individual effort	Team skills
	Passing a test	Learning how to learn
	Achieving a grade	Continuous improvement
	Individual courses	Interdisciplinary knowledge
	Receive information	Interact and process information
	Teaching separate from learning	Technology

Source: Haupt (2012 citing Cook and Cook, 1998)

Perhaps nowhere is the importance of team skills more profoundly important than in the construction industry because of the nature of the industry which relies heavily on several different specialised firms to deliver a project. The nature of the construction industry requires graduates who can work in teams of differently specialised professionals, solve problems that are often unstructured and ill defined, and have a good understanding of interdisciplinary knowledge if the graduates are to make any meaningful contribution to the workplace. Therefore, a construction educational experience focused on transferring facts, based on receiving information and characterised by individual effort is unlikely to provide students with knowledge and skills of real value in the workplace.

Further compounding the problem of an inappropriate construction education experience is the nature of the industry in which construction graduates are expected to perform. The construction industry is dynamic owing to rapidly changing technology and legislation (Jiao, Wang, Zhang, Li, Yang and Yuan, 2013; Petri, Beach, Rezgui, Wilson and Li, 2014). Compared to other industries, it has a rather bleak outlook. It has been criticised for being very fragmented owing to its reliance on separation of design specialisations and tendency towards subcontracting thereby needing several different entities to deliver a project (Chiang and Tang, 2003; Fulford and Standing, 2014; Love, Gunasekaran and Li, 1998). The practice prevailing does not encourage communication among the participants (Love *et al.*, 1998). The industry is further criticised for being unstable, characterised by low productivity, poor quality, time and cost overruns and occasionally punctuated with conflict (Janipha and Ismail, 2013; Xue, Wang, Shen and Yu, 2007).

While integration and coordination of supply chains have been established to be important and are well recognised in many industries (Cheng, Law, Bjornsson, Jones and Sriram, 2010), Baiden, Price and Dainty (2006) found that seamless integration of teams within construction projects is not fundamentally necessary for an integrated team performance. Love *et al.* (1998) suggested a holistic approach to the design, development and production of construction projects to achieve acceptable integration. Fulford and Standing (2014) also postulated that processes in the construction supply chain need to be viewed holistically if productivity is to improve.

Table 1-2: Curriculum Development Models

Author(s)	Date of publication	Model designation	Elements of curriculum model and steps of the curriculum planning
Bobbitt F.	1924	Bobbitt's Model	selecting, increased and/or elimination goals > involvement of the community > setting differentiated objectives > stages implementation plan to attain the objectives
Charters C.	1923	Charters's Model	setting a set of principles > using compartmental objectives > derivation of the objectives from the learners need > developing subject matter
Tyler R.	1949	Rational Planning Model	objectives > selecting learning experiences > organizing learning experiences > evaluation
Taba H.	1962	Induction Model	diagnosis of needs > objectives > methods > subject matter > evaluation
Goodlad and Richter	1966	Planning Levels Model	follows the Tyler's model in three levels of planning: instructional, institutional and societal level
Johnson	1967	P-I-E Model	planning elements > implementation elements > evaluation elements
Schwab J.	1969	Schwab's Model	clear separation of ends and means > deliberation > commonplaces (subject matter, learner, teacher, milieu)
Walker D.	1971	Naturalistic Model	platform > data > deliberation > policy > design
Cohen	1974	Interaction Model	non-linear approach to selecting objectives, selecting learning experiences, organizing learning experiences and evaluation
Skilbeck	1976	Situational Analysis Model	situational analysis > goal formulation > programme building > implementation and monitoring.
Saylor, Alexander and Lewis	1981	Saylor, Alexander and Lewis Model	goals and objectives > curriculum design > curriculum implementation > curriculum evaluation
McGree C.	1997	Dynamic Model	situational analysis > goals, objectives > subject matter > instructive strategy > evaluation strategy
Wiggins and McTighe	1998	Understanding by Design Model	identify desired results > consider evidence of understanding needed > plan learning experiences and instruction
Potolea D.	2002	Model comprehensive approach	structural plan (objectives, subject matter, time, instructive strategy, evaluation strategy) > processual plan (planning, implementation, evaluation) > product plan
Oliva P.	2005	Oliva's Model	specification of needs (students, community, subject) > curricular goals > curricular objectives > organization and implementation of the curriculum > instructional goals > instructional objectives > selection of strategies > preliminary selection of the evaluation techniques > implementation of strategies > final selection of evaluation techniques > evaluation of instruction > evaluation of curriculum

Source: Ilie, (2013)

Integration and a holistic approach in the construction supply chain is important if the industry is to address some of the many criticisms it is facing. However, segregation does not start in the industry. It starts in the way the construction education is delivered. Modules are segregated based on different specialisations rather than presented holistically according to how a construction project is delivered. Integration of different specialisations in the education of future practitioners should therefore be the first step in efforts to encourage closer integration of different construction practitioners. The existing construction education experience therefore fails to prepare students adequately for practice and has been criticised for giving students little of value in the industry beyond a credential (Haupt, 2012). There is therefore a need to close the gap between the academic preparation of construction practitioners and industry job requirements (Ibid). To start with, a conceptual model linking module objectives with work based outcomes modelled around a project life-cycle would help improve understanding of the appropriate linkages between academic preparation and job requirements (Haupt, 2012 citing Schaafsma, 1996). Coupled with an IBL approach to learning, a holistic integrated approach with modules modelled around a project life-cycle would better prepare students for industry since, as Mazhar and Arain (2015) noted, design and construction students learn more when they get involved in the life-cycle of a building project.

To develop such an integrated curriculum for construction education would require a curriculum model that is suited to IBL. Curricula development is guided by curriculum development models. Several curricula development models have been developed since the early 1920s with varying approaches to the creation of curricula as seen in Table 1-2. However, they all have one thing in common, namely the development of curricula which are standardised and distinct-discipline based. This approach is consistent with Aristotle's realism and the subsequent theories of empiricism and positivism which spawned the curricula that are standardised and distinct-discipline modularised with emphasis on gaining factual scientific knowledge through demonstrations and recitations. Therefore, the curriculum development models largely revolve around the best way to identify, arrange and assess module content. The method of delivery was by default didactic lectures.

Tylers' rational planning model in 1949 was the first model to specifically address the need to select an appropriate learning experience. Nearly all models developed after Tylers' model include the need to select an appropriate learning experience (Ilie, 2013). However, notwithstanding the prescription for curriculum developers to select appropriate learning experiences, these experiences remained largely through the didactic approach with sporadic use of student-centred approaches in later years. While some of the models can be applied to the development of an entire curriculum of a programme, they are largely designed to populate modules within a programme. For example, Eliot and Joppe (2009) and Cunha *et al.* (1999) both used a systematic model approach for the development of curricular content for specific modules for nutritional education and tourism management respectively.

1.2 Problem Statement

Construction graduates have been criticised for failing to make meaningful contributions to construction practice without first being further schooled by practitioners (Haupt, 2012). Key competences necessary for a meaningful contribution to the construction practice are often found missing from graduates at entry level to practice (Aryakwa *et al.*, 2011; Love and Haynes, 2001). One of the most significant competences missing from the graduates is the ability to apply theoretical knowledge in a practical situation which is a precursor to effective problem solving skills. The graduates also usually do not possess the ability to proficiently work in a team of multidiscipline members. A practical understanding of construction, problem solving and working in teams are perhaps some of the most important aspects of working in the construction industry because the industry is a highly practical team effort which revolves around problem solving on a daily, if not hourly, basis.

The failure of university graduates to effectively participate in the workplace without further industry schooling at entry level can be blamed on the inadequate learning experience offered by university education (Candela *et al.*, 2006; Mihaela *et al.*, 2015; Savery, 2006). The university learning experience is mainly characterised by the traditional didactic lecture approach which is largely modelled around transmission of facts to students. The emphasis on teaching factual knowledge rather than students understanding concepts leaves no room for students to reflect and put the factual information into beneficial context (Candela *et al.*, 2006a). For these reasons, the traditional instruction based curricula have been cited as cause for the poor quality of university graduates (Candela *et al.*, 2006; Mihaela *et al.*, 2015; Savery, 2006).

Epistemological theories of learning have shaped the way education is structured. The hidden assumption that knowledge can be transmitted from the mind of the teacher to that of the student in a lecture characterised traditional epistemology. Several influences of these traditional beliefs of learning on university construction education are apparent. Firstly, the modules are segregated in tandem with the theory of empiricism which is the scientific theory which demands ordering learning into distinct disciplines. For this reason, it is standard practice in construction programmes to have, for example, modules such as construction technology, measurements, structural design and analysis, construction law, building economics, estimating and tendering and professional practice. Secondly, the spatial arrangement of a lecture room is designed for the transmission on knowledge with the "sage-on-the-stage" didactic lecture approach where the lecturer is positioned in front and the learners all facing and listening to the "sage-on-the-stage". Thirdly, the transmission nature of teaching is a catalyst to the creation of large class sizes since learners are viewed as passive recipients of knowledge. Fourthly, the role of the lecturer is source and transmitter of knowledge and the approach is centred on delivering as much content to the learners. These features profoundly influence the resulting students learning experiences and subsequently, the quality of the graduating students.

The consequences of the traditional didactic approach to learning are that it impedes the creation of an educational experience which promotes the creation of learners of own meaning and understanding based on their experiences and reflections on the subject matter in tandem with the theory of constructivism. For example, module segregation often leaves learners struggling to place the content in the context of their specialisation and consequently, the students fail to construct contextual understanding and links with other modules. Also, questions arise as to the relevance of certain modules to the particular professions and disciplines. For example, learners often wonder about the relevance of structural designing and analysis to quantity surveying and construction management or about the relevance of measurements and bills of quantity production to construction management. These are valid questions from learners who may not immediately see their relevance because the modules are segregated and often taught by lecturers from other specialisations who often do not place the content in the required context or let alone make the appropriate link between the specialisations.

Further criticisms of the traditional didactic approach to learning are that the spatial arrangement of the classroom favours passive reception of knowledge rather than active participation and inquiry which are necessary for effective learning. Also, the resulting large classes are not ideal for learner interaction and inquiry which are necessary for effective learning. The transmission nature of the traditional approach does not align with the manner in which learning actually takes place whereby the learner actively builds their own understanding rather than passively receive an understanding. Further, the segregated modules are very often content heavy creating a fairly heavy work load for the learners with the end result that learners are left very little time to reflect on what they are learning. Consequently, learners are often forced to reproduce text book material through rote learning in order to cope with a high work load.

It has been established that students develop a deeper understanding of concepts when they are given the opportunity to discover knowledge and build their own understanding (Bayram *et al.*, 2013; Brandon and All, 2010; Chu *et al.*, 2011; Naylor, 2011; O'Shea and Young, 2014; Supasorn *et al.*, 2014; Wang, 2012). This has been the basis of several student-cantered approaches to learning, which are the contemporary pedagogies. The inquiry nature of IBL lends itself well to construction education because of its proven ability to improve students' critical thinking and problem solving skills and its use of team work develops the ability for students to work and learn from others and to inculcate better communication skills – all of which skills are pre-requisite to an effective construction industry career.

To take advantage of IBL and produce graduates with the above competences, a shift from the existing educational experience based on didactic lectures would be necessary. Some of the changes that would be necessary to achieve this include:

i. a shift from the traditional segregated modules to integrated concept based modules were the integrated concepts are presented across the life span of a construction project;
ii. a change in the spatial layout of a lecture room to allow for the inquiry nature of social constructivism in IBL;
iii. a capping of the number of students admitted to a programme of study to figures appropriate for IBL;
iv. a shift in the role of the lecturer from source and transmitter of knowledge to provider of stimulation and reinforcement for learners' knowledge construction and

v. a shift from emphasis on the information content of the modules to learning and understanding the concepts and lifelong learning.

However, existing curriculum models were not designed to specifically produce curricula to be delivered through an IBL approach. Existing models were designed to populate content within existing standardised discipline specific modules and are therefore not ideal for integrating construction curricula to be presented across the lifespan of a project and delivered through an IBL approach

Further, the existing paradigm in construction education is based on refuted epistemological theories of learning that assume that knowledge can be transferred from the mind of the teacher to the student passively. Therefore, the traditional construction education curriculum centred on the didactic lecture approach with its associated student learning experiences is not suited to the manner in which learning and understanding are actually achieved. Consequently, the educational experience offered by the traditional didactic lecture approach does not adequately prepare students for construction practice. The problem that this study therefore investigates may be stated as:

"The didactic lecture teaching approach to construction education with its associated learning experiences at undergraduate level does not adequately prepare students for construction professional practice and therefore requires an alternative curriculum approach and model in the form of IBL to address this deficiency."

1.3 Research Questions

In examining the above problem, the study responds to the following main question:

What is the appropriate IBL model for educating students of construction programmes?

The sub questions are as follows:

1. What should be considered in the design of an IBL programme for the effective teaching and learning of a construction programme?
   1.1. What are the antecedents to effective teaching and learning from contemporary theories of learning?
   1.2. Which of the antecedents from the contemporary theories of learning impact learning the most?
2. What is the best way to integrate construction subject specialisations in an IBL approach to learning of construction programmes so as to provide learners with appropriate contextual understanding?
   2.1. What is the appropriate range of construction knowledge which should be included in a construction programme curriculum?
   2.2. What type of construction knowledge is best learnt through the didactic approach?
   2.3. What type of construction knowledge is best learnt through IBL?
   2.4. What construction areas of specialisations are best integrated and taught together in an IBL approach?
3. How can antecedents to teaching and learning from contemporary theories of learning be used for the effective teaching and learning of construction programmes in an IBL curriculum?

1.4 Study Objectives

The primary objective of this research is to establish the most appropriate way to educate students of construction programmes by identifying important antecedents to teaching and learning from theories of learning and integrating them into an IBL curriculum appropriate for construction programmes. In achieving this objective, the following theoretical and empirical objectives will be pursued:

1.4.1 Theoretical objectives

a. To identify contemporary theories of learning and derive from them antecedents to effective teaching and learning in undergraduate construction programmes
b. To establish the relative importance of the antecedents to effective teaching and learning in undergraduate construction education in South African universities
c. To recommend a teaching and learning model for undergraduate construction education based on antecedents to effective teaching and learning

d. to suggest the appropriate range of curricula content for an integrated IBL construction education curriculum and the most effective way to integrate the content;
e. to establish the best way to deliver the integrated content in an IBL environment ensuring affective coordination of differently specialised lecturers;

1.4.2 Empirical objectives

a. To develop a curriculum development model for IBL construction education which integrates construction knowledge so that it can be learnt across entire concepts rather than in pockets of specialisation

The findings for the research are based on both the review of extant literature and empirical evidence. Based on extant literature, the antecedents to teaching and learning from the theories of constructivism, connectionism and cognitive load theory were identified. Based on empirical evidence, in order of importance, engaging students in individual learning activities, scaffolding student learning activities, encouraging reflective thinking, engaging students in group learning activities were found to significantly impact learning directly. Based on empirical evidence, in order of importance, repetition of key lessons; reinforcement of desirable student behaviour; readiness for learning by students; encouraging self-directed learning; complexity and ambiguity of questions administered to students; administering worked examples to students; administering authentic problems to students and cognitive loading induced in students by learning tasks were found to impact learning indirectly through some other factor. Based on extant literature, the appropriate range of knowledge for a construction programme should include basic, core and optional knowledge areas. Knowledge areas best learnt through didactic lectures, and those best integrated and delivered through IBL were identified. Based on the review of extant literature and empirical evidence, the IBL curriculum for construction programmes is best delivered based on the three broad stages of a construction project and considering the important antecedents to effective teaching and learning.

1.5 Research Methodology Overview

1.5.1 Research Philosophy

This study followed an epistemological positivist philosophy so that it can empirically test structural relationships among predictors of effective teaching and learning in students of construction programmes. The ontological philosophy preferred is subjectivism because the study is concerned with students as social actors rather that the social entities they create such as the class or group.

1.5.2 Research Approach

The approach favoured for this study was the hypothetico-deductive approach because the research sought to test hypotheses and not to generate them.

1.5.3 Research Design

This study favoured the quantitative design in line with the use of a positivist philosophy following a deductive research approach to examine relationships among the research variables using statistical analyses.

1.5.4 Research Strategy

The descriptive research approach was favoured firstly because it lends itself well to the research problem and secondly because it is suited to hypothesis testing.

1.5.5 Time horizon

The cross sectional time horizon was chosen because a single time description of the research variables was enough to answer the research questions and achieve the research objectives.

1.5.6 Data Collection Method

The choice of data collecting method was guided by the fact that the study questions required quantitative data and so qualitative methods were precluded on this basis. To collect the quantitative data, the questionnaire with close-end questions was the preferred data collection method because of the low cost associated with it, the ease of collecting large amounts of data in the format appropriate for the chosen data analysis approach.

1.5.7 Sampling Method

The non-probability sampling method was preferred to conveniently select three public universities which were closest the research domicile.

1.5.8 Data Analysis

Because the study had several research variables to consider, multivariate analysis was the preferred data analysis method while univariate statistics were also reported. The preferred multivariate analysis was Structural Equation Modelling (SEM) because it is very well suited to analysing multiple relationships simultaneously.

1.6 Research Process Overview

The research had five distinct processes namely, literature review, conceptual model development, questionnaire development, questionnaire administration and data capturing and data analysis.

1.6.1 Literature Review

The process research started with an extensive review of literature to identify antecedents to teaching and learning from theories of learning. The reviewed literature also identified generic knowledge areas and topics which are important for a construction programme in tandem with the objectives of the research so as to establish how best they can be incorporated in an IBL curriculum for a construction programme.

1.6.2 Conceptual Model

The antecedents to teaching and learning established from the review of literature were developed into a conceptual model theorising how they are related in practice.

1.6.3 Questionnaire Design

The concepts in the theoretical model were operationalised and developed into a research instrument. Where appropriate instruments were available for the constructs under study, they were adopted for this research. where there were no suitable instruments, new instruments were developed.

1.6.4 Questionnaire administration

The resulting research instrument was circulated to a sample of students undertaking construction programmes at three public universities in the KwaZulu-Natal province of South Africa.

1.6.5 Data Analysis

The data collected were then analysed using IBM SPSS Modeller for data preparation, IBM SPSS v25 for exploratory factor analysis and IBM SPSS AMOS v24 for structural equation modelling.

1.7 Research Limitations

The research had several limitations. Firstly, the survey was based on a convenient sample and so the results may not be completely generalizable to populations beyond the sample. Secondly, the research is based on survey instruments which have not been extensively validated. Therefore, the reliability and validity of the research instruments may be questioned. For example, the research instruments were not sufficiently assessed for face validity through a panel of experts and other forms of reliability and validity such as predictive validity and constancy were not assessed. Thirdly, the data are based on a self-report questionnaire and the results therefore have all the limitations associated with self-reporting. The limitations associated with self-reporting include honesty in response or social desirability, introspective ability, understanding, rating scale and response bias. Social desirability is the tendency of respondents to make responses which they perceive as being socially acceptable rather than the absolute truth. Introspective ability refers to the ability for the respondents to accurately respond to the questions when they intend to be do honestly but are unable to do so accurately due to limitations on the ability to accurately introspect. The limitation with understanding comes from the fact that respondents can only respond to their understanding of the questions which sometimes may be different from what the researcher intended. The rating scale presents limitations in that sometimes, even when respondents share exactly the same point of view, they may rate it differently because of a difference in the interpretation of where that point of view lies on the rating scale. Response bias refers to the tendency of some respondents to be predisposed to choosing responses in the middle of the rating scale while others are predisposed to responses at the extremes.

1.8 Research Delimitations

The research is delimited to antecedents to effective teaching and learning derived from constructivism, connectionism and cognitive load theory. Other antecedents to effective teaching and learning from theories other these are not included in the scope of the research. This is because the time constraints on the project did not allow for the inclusion of all possible theories of learning. Therefore, the theories which are most popular from the three popular schools of thought which have contributed to educational development were included the research. Besides theories which underpin learning, other factors profoundly impact on the ability for students to learn effectively. However, due to time limitations, such factors as attributes of students among others, which are not related to the theories of learning under study were not included in the research. Therefore, the research does not address all possible factors which could contribute to effective teaching and learning but draws some of the important ones from constructivism, connectionism and cognitive load theory.

1.9 Research Assumptions

The study will assume that the majority of construction education curriculum can be effectively taught through an IBL approach. This assumption is based on literature which suggests that it is possible to effectively engage learners at any level and in any subject area through IBL (Bayram *et al.*, 2013; Brandon and All, 2010; Chu *et al.*, 2011; Naylor, 2011; O'Shea and Young, 2014; Supasorn *et al.*, 2014; Wang, 2012). It is also assumed that integrating traditional construction education modules based on similarity of concept and delivering them through an IBL approach will lead to better contextual understanding of the different construction related specialisations. It is also assumed that the IBL approach produces better graduates than the traditional didactic lecture approach due to research evidence suggesting that IBL produces better problem solvers and critical thinkers than does the traditional didactic lecture approach (Raidal and Volet, 2009; Savery, 2006 citing Albanese and Mitchel, 1993) It is also assumed that all the participants will have correctly understood the questions and the information requested from them and that they will respond both accurately and honestly.

1.10 Ethical Consideration

In keeping with accepted research ethical standards, appropriate ethical considerations were made. The major ethics issues in this study were dealt with as follows as recommended by (Chapin, 2004; Hair, Money, Samouel and Page, 2007; Saunders, Lewis and Thornhill, 2012):

a) Right to privacy and confidentiality – the right to privacy and confidentiality was insured by not identifying the questionnaires with any respondents and in the research results by aggregating the research data so that individual participant responses cannot be identified.
b) Informed consent – an informed consent form was given to all the participant with details of the research study, what was required of the participants and that the participants were free to not participate in the study or to with draw at any time if they felt so. A copy of the consent form is annexed to the dissertation. Further, gatekeeper permission was obtained for all participating universities before the students were surveyed through the various university structures.
c) Vulnerable target groups – the study involved university students and excluded all vulnerable groups including, children below 18 years old,
d) Storage and disposal of research data – the data was dealt with in tandem with the university ethics committee requirements of keeping the data in a secure location in arrangement with the supervisor for a period of not less than five years after which the data will be shredded and deleted from all storage devices.

The research was also critically reviewed by both the college and the university ethics committee which specialises in evaluating research ethical matters. The university ethical clearance process required the submission of a 20 paged ethical clearance application which is appended to this dissertation.

1.11 Significance of the study

The performance of construction industry graduates has been criticised for lacking practical building knowledge, problem solving skills and interpersonal skills among several other deficiencies (Aryakwa *et al.*, 2011; Love and Haynes, 2001). The mode of instruction in university education can make a significant impact on the resulting quality of graduates (Raidal and Volet, 2009; Savery, 2006 citing Albanese and Mitchel, 1993).

This research is important because the current learning paradigm with its associated learning experiences in construction education is producing graduates with competences that are at variance with what the construction industry is demanding. An alternative instruction approach in IBL has the potential to produce graduates with better problem solving and critical thinking skills. The research also adds to research on curriculum development and IBL and on ways to improve the quality of construction education in particular and the quality of university education in general.

Specifically, the research contributes to extant literature by establishing the relative importance of factors identified as being important for teaching and learning from different theoretical backgrounds. The practical implication of this is that the design of pedagogy should consider the factors from the different schools of thought in the order of importance as established in the findings of this research in order to be effective. The research also identified a set of knowledge areas critical for construction programmes. This is important considering the extent of knowledge explosion occasioned by rapid advances in technology in the last few decades. The implication of this is that the research highlights what educators need to consider in the design of a curriculum for construction programmes without having to worry about considering all the possible knowledge areas available as it is not possible to include everything in a curriculum. The research further shows that not all knowledge can be delivered through IBL. The research therefore recommended what knowledge areas to deliver through IBL and which should be delivered through the didactic approach. The practical implication of this is that even in a curriculum which is designed to be inquiry in nature, educators should note that not everything is best delivered through IBL. In order to achieve synergy among the various specialisations and improve contextual understanding, the research recommended what different areas of specialisation and topics are best integrated and delivered through IBL. The research also suggested an appropriate criterion for deciding which modules and topics to integrate in order to achieve synergy. The practical implication of this is that educators are guided on what knowledge areas to integrate in order to improve contextual understanding among students.

1.12 Structure of the study

The research is divided into eleven chapters as follows:

1.12.1 Chapter 1: Introduction to the study

The introductory chapter presents a background to the study while justifying the need for developing curriculum for an IBL approach to university construction programmes. The problem statement, questions, objectives, and the methodology for the study are also presented. The research limitations, delimitations, assumptions, ethical considerations, and significance are also highlighted.

1.12.2 Chapter 2: Theories to Learning

The first literature review chapter explores theories of learning. The chapter aims to establish how learning happens in order to derive important antecedents to learning informed by extant theory. The theories reviewed are the theory of constructivism from philosophy, the theory of connectionism from behaviourism and the cognitive load theory from cognitive science.

1.12.3 Chapter 3: Inquiry Based Learning

The second literature review chapter explores the concept of inquiry based learning (IBL). Specifically, it investigates the delivery of IBL and the IBL cycles and processes. The chapter aims to highlight the effectiveness of IBL and identify its best practice used for effective teaching and learning.

1.12.4 Chapter 4: Education

The third literature review chapter explores the concept of education. It establishes what education is and what it hopes to achieve. The chapter aims to establish why and what university students should learn generally. The meaning and purpose of education plus why and what students should learn are important to the question of how students should learn and the resulting format of the curriculum favoured.

1.12.5 Chapter 5: Construction Education

The fourth literature review chapter explores construction education and construction curricula. The chapter discusses the appropriate range of curricular content for construction programmes and the amount of content required in each area of specialisation and the most appropriate way to integrate this content for delivery through IBL. The chapter aims to establish the what students in construction programmes should learn because it is critical to how students should learn. The chapter therefore establishes firstly what should generally be learnt by any 21^{st} century educated person and secondly what should be specifically learnt in a typical construction programme.

1.12.6 Chapter 6: Curriculum

The sixth chapter explores the concept of a curriculum. The chapter aims to establish what a curriculum is in order to contextualise how learning as established in the chapters on education and construction education should be packaged.

1.12.7 Chapter 7: Theoretical and Conceptual Framework

The seventh chapter presents the theoretical and conceptual model of the research. The model suggests how the constructs, which are hypothesised to be important antecedents to effective teaching and learning derived from the different theories of learning are related.

1.12.8 Chapter 8: Research Methodology

This chapter discusses the methodological processes employed to answer the research questions and achieve the research objectives.

1.12.9 Chapter 9: Questionnaire Development

This chapter will provide a detailed description of the development of the measurement instrument used in the study to measure the constructs detailed in the conceptual and theoretical framework. A description of the measurement instruments and their conceptualisation and operationalisation including the measurement items are presented. The chapter also details the procedure followed to pre-test the measurement instrument in order to ensure reliability and validity.

1.12.10 Chapter 10: Research Findings and Discussion of Findings

The multiple and interrelated dependencies in the proposed theoretical model will be tested for fit by structural equation modelling (SEM). Prior to SEM, the data were subjected to exploratory factor analysis (EFA) in order to assess their validity and reliability. Arising from the results of SEM the important antecedents to teaching and learning from the theories of learning will be identified.

1.12.11 Chapter 11: Conclusions and Recommendations

This chapter concludes the research carried out to develop an IBL model for construction programmes. The chapter presents the IBL model and gives recommendations for future research. Contributions to the existing body of knowledge are also presented.

CHAPTER 2

HOW LEARNING HAPPENS

2.1 Introduction

In order to create a curriculum model which will adequately prepare students for construction professional practice, it is necessary to understand how learning happens. This chapter provides an outline of three contemporary theories of learning and how they have influenced education practice. The literature review is used to establish the possible antecedents to effective teaching and learning so that they can be considered for inclusion in the proposed curriculum model. The literature review responds to the question "*What are the antecedents to effective teaching and learning from contemporary theories of learning?"*

2.2 Theories of Learning

Several theories of how learning happens have been suggested since as far back as 500 B.C. Learning theories have been suggested in the fields of epistemology, psychology and cognitive science. The oldest of these theories are from the field of philosophy and are ascribed to Socrates who taught Plato (427 – 347 B.C.) who in turn taught Aristotle (384 – 322 B.C.) (Kivunja, 2014).

The epistemological theories of learning are based on a dialectic process created by Plato whereby generated theories are responded to by one or more people through reasoned argument until consensus is reached. Psychology theories, on the other hand, are based on empirical studies and have largely been opposed to postulations from philosophy (Hilgard, 1956). The currently accepted epistemological theories of learning are broadly classified under the constructivism bracket while the psychology theories are described as behaviourist. More recently, cognitive science emerged from the mid-1980s as a recognised field conceptualising learning theories based on inter-disciplinary evidence from among other fields, neuroscience, anthropology and philosophy itself.

2.2.1 Constructivism

Constructivism is the contemporary theory of learning from the epistemology branch of philosophy. There are two major types of constructivism, namely, cognitive constructivism and social constructivism (Kalina and Powell, 2009). Cognitive constructivism is concerned with the individual creation of ones' own knowledge and understanding and is therefore a personal process while social constructivism acknowledges the role of culture and social interactions in the process of knowledge creation and understanding and is therefore a social process (Ibid). Cognitive constructivism is based on the work of Jean Piaget (1896 – 1980) while social constructivism is based on the postulates of Lev Vygotsky (1896 – 1934) (Kivunja, 2014).

While the theory of constructivism was largely popularised by Piaget and Vygotsky, the pioneering work started with John Dewey (1859 – 1952) in his theory about how learning takes place. Before Deweys' theory, the prevailing theory of learning was based on Aristotle's postulation that:

> "it is absurd to make that fact the things of this earth change and never remain the same[;] the basis of our judgement about the truth. For in pursuing truth[,] one must start from things that are always in the same state and never change" (Dewey, 1938: 130).

Based on this postulate, the then obtaining philosophical view of realism was that learning takes place when the mind, which was viewed as a "black-box", was populated with knowledge and understanding about the physical nature of the world and the mind retained a mental picture of the existing and unchanging world (Bodner, 1986).

While Aristotle thought it was absurd to imagine that the world changes, Dewey (1910) and Dewey (1938) argued that it is in fact absurd to imagine that it does not change. Dewey further suggested that knowledge and understanding were the product of inquiry about experiences that impede human action and therefore create a state of indeterminacy. Knowledge or understanding can, therefore, not be attained without an impediment to action because there would be no need for reflective thinking since actions would smoothly glide along (Dewey, 1910; Kolb and Kolb, 2008). For Dewey, thought was the means through which man came to understand and connect with the world around him. Therefore, "thinking begins in what fairly enough may be called a forked road situation, a situation which is ambiguous, which presents a dilemma, which proposes alternatives" (Dewey, 1910: 3). When in this state of indeterminacy:

> ". . . the next step is suggestion of some way out – the formation of some tentative plan or project, the entertaining of some theory which will account for some peculiarities in question, the consideration of some solution to the problem. The data at hand cannot supply the solution for the problem; they can only suggest it. What then are the sources of the suggestion? Clearly past experience and prior knowledge. If the person has had some acquaintance with similar situations, if he dealt with material of the same sort before, suggestions more or less apt and helpful are likely to arise. But unless there has been some experience in some degree analogous, which may now be represented in imagination, confusion remains mere confusion. There is nothing on which to draw to clarify it. Even when a child (or adult) has a problem, to urge him to think when he has no prior experience involving some of the same conditions, is wholly futile" (Dewey, 1910: 4).

For Dewey (1938), thinking, is the cornerstone of knowledge creation and understanding, is preceded by a situation in which one is unsure how to proceed. A hypothesis or hypotheses is then developed about how to resolve the situation. The suggested solution requires careful consideration in what Dewey called reflection. He described reflection as:

> ". . . turning a topic over in various aspects and in various lights so that nothing significant about it shall be overlooked – almost as one might turn a stone over to see what its hidden side is like or what is covered by it. Thoughtfulness means, practically, the same thing as careful attention; to give our mind to a subject is to give head to it, to take pains with it. In speaking of reflection, we naturally use words weigh, ponder, deliberate – terms implying a certain delicate and scrupulous balancing of things against one another. Closely related names are scrutiny, examination, consideration, inspection – terms which imply close and careful vision. Again to think is to relate things to one another definitely, to put "two and two" together as we say" (Dewey, 1910: 11).

After the suggestion has received careful reflection, it can either be accepted for implementation or rejected as being unsuitable and another solution sought and evaluated. Thinking is required to evaluate a potential solution and Dewey described thinking as:

> ". . . the suggestion of a conclusion for acceptance, and also search or inquiry to test the value of the suggestion before finally accepting it. This implies (a) a certain fund or store of experiences and facts from which suggestions proceed; and (b) promptness, flexibility, and fertility of suggestions; and (c) orderliness, consecutiveness, appropriateness in what is suggested" (Dewey, 1910: 9).

Therefore, the process starting with an indeterminate situation requiring hypothesising a solution and evaluating the suggested solution for suitability and finally implementing the solution if applicable is, according to Dewey, how the mind comes to learn. This postulation is called the theory of inquiry and it can be summarised into three steps namely

- impediment to action,
- ii) hypothesis of solution and reflection and
- iii) hypothesis testing (Kaufman, 1959).

Dewey's theory of inquiry simply put states that knowledge is created by an active response to the environment and not a passive observation of the environment and drawing correspondence with reality (Field, n.d.). It is this postulation which led to the rejection of the earlier accepted notion that since the world is unchanging, knowledge creation is the product of observing the environment.

Empirical evidence by Jean Piaget (1896 – 1980) provided further support for the theory of inquiry and provided additional dimensions to how knowledge creation by individuals takes place. In trying to show that intelligent adaptation was produced by experience similar to evolutionary theory, the evolutionary biologist Piaget observed children to approximate the phylogenetic adaptation of intelligence in species (Kivunja, 2014; Piaget, 1952). He observed his three children from birth several times a day nearly daily for two years (Ibid). He proposed that the cognitive development of children takes place in four main stages namely sensorimotor, preoperational stage, concrete operational stage and formal operational stage (Ibid). The sensorimotor stage lasts from birth to about two years old and is characterised by rapid cognitive growth as children experience the world and construct knowledge through senses and motor movements. The preoperational stage develops from about two to seven years old and is characterised by the ability to manipulate and use symbols in play. The concrete operational stage develops from about seven to eleven years old and is characterised by the application of logical thought. The formal operational stage is the last stage in Paget's theory of cognitive development and it starts from about eleven years old and lasts until adulthood and is characterised by the ability for abstract thought and hypothetical reasoning.

Piaget established that cognitive development in children takes place by an active interaction with the environment which gives rise to contradictions between what they already know and what they discover and adjust their knowledge accordingly thereby creating structures of knowledge which are the foundation of all thinking. These knowledge structures are called schemata or schemas. A schema is a group of common and logical notions which constitute a network of relationships that make up a person's knowledge and understanding structure (Marin, Benarroch and Jimenez Gomez, 2000).

The relevance of experience to knowledge creation can be seen in children right from after birth. For example, as Piaget (1952) noted:

> "Observation 1 – from birth, sucking-like movements can be observed: impulsive movement and protrusions of the lips accompanied by displacement of the tongue, while the arms engage in unruly and more or less rhythmical gestures and the heads moves laterally etc. Observation 3 – The third day Laurent makes new progress in his adjustment to the breast. All he needs in order to grope with an open mouth toward success is have touched the breast or the surrounding teguments with his lips" Piaget (1952: 29).

Cognitive development is also positively reinforced by the desired result a child seeks being successful. In Piaget's observation, pertaining to breastfeeding infants, it appears that success in finding the breast reinforces the actions of searching for it and those actions are therefore repeated. Piaget credited the progressive development to adaptation to the environment resulting in the creation of schemata. Adaptation to the environment through experience can be seen in most of Piaget's observation throughout the development cycle of the children. For example:

> "Observation 141. – at 0;10 (11) [0 year; 10 months and 11 days] Laurent is lying on his back but nevertheless resumes the experiments of the day before. He grasps in succession a celluloid swan, a box etc., stretches out his arm and lets them fall. He distinctly varies the position of the fall. Sometimes he stretches out his arm vertically, sometimes he holds it obliquely, in front of or behind his eyes, etc. when the object falls in a new position (for example on his pillow), he lets it fall two or three more times on the same place, as though to study the spatial relation; then he modifies the situation." (Piaget, 1952: 75)

Notwithstanding the novel nature and significant contribution of Piaget's works to the philosophical understanding of how knowledge and understanding come to be, his work has been criticised for a variety of reasons. His work has been criticised mainly on three accounts. Firstly, because of his research methods, secondly, due to conclusion that children automatically graduate from one level to the next and thirdly, that he underestimated children's abilities. The research methods are criticised for the small number of participants, namely three children and that all the participants were from the same background characterised by a high socioeconomic status (Marchand, 2012). The sample is therefore unrepresentative and cannot be generalised to a larger population. He was further criticised for suggesting that children will automatically move to the next cognitive development level after data emerged suggesting that environmental factors may play a role in the children's cognitive development (Kesselring and Müller, 2011; Marchand, 2012). Piaget was also criticised for the time frames he ascribed to each stage with some evidence suggesting that children can reach some of the cognitive development stages earlier than suggested (Kesselring and Müller, 2011).

However, it is well worth noting that the criticism surrounding Piaget's work is not entirely to discredit the findings, but rather aspects of methodology and some conclusions. The wholesome value of the work has remained valid and spawned various other interpretations of the work. It also attracted other scholars who either added on to it or used it as a starting point for other versions of the theory. For example, Lev Vygotsky (1896 – 1934) largely agreed with Piaget's work but added on a social dimension to it while Ernst von Glasersfeld postulated the theory of radical constructivism which agrees with the notion that knowledge is actively constructed and not passively received but adds that knowledge is constructed rather than existing and discovered (Glasersfeld, 1989, 1991; Liu and Chen, 2010).

Lev Vygotsky (1896 – 1934) argued that cognitive development takes place within a social context (Hickey, 1997; Kivunja, 2014; Vygotsky, 1978). While Piaget established the theory of cognitive development which is an individual's construction of meaning and understanding, Vygotsky's addition of the social aspect to cognitive development established the notion of social construction of meaning and understanding. Social construction of knowledge is responsible for creating cultures and takes place when knowledge is created within groups or cultures by the interaction of the members through discourse rather than individual discovery of knowledge and understanding (Baviskar, Hartle and Whitney, 2009). It has also been accepted that the culture and social interactions taking place while acquiring experience mediate the knowledge and understanding ascribed to these experiences by individual's (Kalina and Powell, 2009). Therefore, according to Vygotsky, cognitive development happens by an active interaction with the environment mediated by social and cultural interactions leading to the creation of knowledge structures (Baviskar *et al.*, 2009; Kivunja, 2014).

Vygotsky further suggested that cognitive development of independent problem solving can be enhanced by adult supervision or in association with more proficient peers. Vygosky called the difference between the level of development of individual capacity for problem solving and that attainable under guidance the zone of proximal development (ZPD). He described it as ". . . the distance between the actual development level [of a child] as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978).

Based on the philosophical works by Dewey, Vygotsky and others and empirical evidence by Piaget and others, for constructivists, it has become accepted that learning and understanding are attained through an active personal process of knowledge construction while interacting with society and the environment (Baviskar *et al.*, 2009; Kivunja, 2014; Loyens, Rikers and Schmidt, 2009; Marin *et al.*, 2000).

2.2.2 Behaviourism in Educational Learning

Behaviourism, which is a branch of psychology, has also postulated theories about how learning happens. Behaviourist theories can be categorised into stimulus-response (S-R) theories which are associated with classical conditioning and response-reinforcement (R-R) theories which are associated with operant conditioning as well as other related behaviour shaping associations (Guey, Cheng and Shibata, 2010). Classical conditioning is largely based on the work of Ivan Pavlov (1849-1936) who showed that an innate and involuntary response can be associated with a stimulus (Büchel and Dolan, 2000). Operant conditioning was first suggested by B.F Skinner (1904 – 1990) and furthered by Edward Thorndike (1874- 1949) who used it to suggest his three laws of learning which are readiness, repetition and effect and application (Guey *et al.*, 2010). While classical conditioning has some educational applications (Rosenbaum, Bui, Marin, Holt, Lasko, Pitman, Orr and Milad, 2015), it will not be considered any further since it does not directly lend itself to higher education.

Hilgard (1956) classified behaviourist learning theories into S-R theories and cognitive theories. For Hilgard, S-R theories were viewed the same as R-R theories. The demarcation between the S-R and R-R theories is therefore subject to individual interpretation. S-R theorists differ from cognitive theorists on the definition of what it is that a person learns. S-R theorists believe that what a person learns are habits while cognitive theorists believe that what is learnt are cognitive structures (Ibid).

Most of the foundation work with educational application in behaviourism was established between the nineteenth and twentieth century. Some of the most influential theorists are Clark L. Hull (1884 – 1952), Edmin Ray Guthrie (1886 – 1959), Edward Thorndike (1874 – 1949), John B. Watson (1878 – 1958), and B.F. Skinner (1904 – 1990) who were S-R theorists and Edward C. Tolman (1886 – 1959) and Kurt Lewin (1890 – 1947) who were cognitive theorists (Hilgard, 1956).

Watson coined the term '*behaviourism*' to describe the study of S-R associations. He advocated the exclusion of thinking and emotions from the field of behaviourism arguing that since such '*private behaviours*' cannot be observed, their S-R associations cannot be determined (Guey *et al.*, 2010). Watson refused aspects of behaviourism that relied on causal or explanatory relations of consciousness which were the basis of cognitive theories in psychology (Kohlenberg and Tsai, 2000). For Watson, psychology was not a science of the mind, but rather, that of behaviour and so he was largely 'anti-mentalist'. Skinner on the other hand acknowledged the influence of 'private events' on behaviour and suggested that the environment controls these internal events as they control observable events.

As opposed to Watson, Skinner acknowledged that the mind plays a role in behaviour but concluded that it is more appropriate to study observable behaviour rather than internal cognitive activities. Skinner experimented with rats and pigeons to show that if the animals were rewarded for an action, they were more likely to repeat the action. Skinner called this reward positive reinforcement to contrast it with a situation where the rats are denied a reward for an unfavourable response or given an unpleasant reward which he called negative reinforcement. These experiments took place in a device which has since been called the 'Skinner box'. Skinner concluded that behaviours that are reinforced tend to be repeated. He called this operant conditioning as opposed to classical conditioning as established by Pavlov, which was too simplistic to explain complex human behaviour. The 'Skinner box' still has modern applications in the study of behaviourism. For example, Nakajima, Hayashi and Kato (2000) used a 'Skinner box' to investigate induced taste aversion in rats while Todd, Winterbauer and Bouton (2012) also used a 'Skinner box' to investigate rats and contextual control of food seeking behaviour and Dibbets, Maes and Vossen (2002) used a modified 'skinner box' for humans to study S-R associations.

Using operant conditioning, Thorndike experimented with animals and produced the first learning curves (Kohlenberg and Tsai, 2000). He observed that responses which were satisfactory became more firmly connected with the situation and were more frequently evoked by the stimulus situation. This observation led to the suggestion of the law of effect which states that responses that create satisfying results in a particular situation are more likely to be repeated in that situation, and responses that create discomforting results are less likely to be repeated in that situation. Thorndike suggested two other laws dealing with readiness and repetition. The law of readiness stated that people learn best when they are physically, mentally and emotionally ready to learn and the law of repetition stated that what is often repeated is best remembered. His observations leading to the law of effect strengthened Skinner's initial theory of reinforcement which became the cornerstone of behaviourism (Ibid). Subsequent experiments by others have since refined the reinforcement theory (Donahoe, 2002). Further arising from Thorndike's three laws was the theory of connectionism. The theory of connectionism is a learning theory which states that learning happens when sufficient S-R associations are positively rewarded thereby creating lasting connections between the S-R associations in tandem with the law of effect, the law of readiness and the law of repetition.

Guthrie, on the other hand, disagreed with the law of repetition arguing that only one S-R association is necessary for learning and that subsequent associations, while leading to improvement associated with repetition, are in fact outcomes of learning which already took place at the initial trial (Hilgard, 1956). He disagreed that reinforcement, positive or negative were necessary for learning. Guthrie's position has largely been disregarded and considered invalid.

Hull adopted and adapted Thorndike's law of effect (Ibid). He developed the drive reduction theory which held that behaviours are a response to drives such as hunger, thirst and feeling cold among others. He postulated that when the goal of the drive was achieved, its drive was temporarily reduced. He argued that the reduction of drive reinforces learning. The drive reduction theory has been criticised for assuming that the experiments with rats, on which it is based, would account for all human behaviour. It has therefore had no significantly influence on educational learning theory.

Behaviourism has proposed several different theories and models with educational application. Guey *et al.* (2010) suggested that there is need for a comprehensive model integrating elements from all theorists arguing that strict adherence to any single theory cannot satisfy the demands of every educational instruction setting. He further argued that instructors already often adopt aspects from various approaches simultaneously.

2.2.3 Cognitive Science Learning Theories

The field of cognitive science has also added to the theories of learning. Cognitive science is the study of the mind, mental processes and the nature of intelligence whose purpose is to develop models and theories that help to explain human cognition, *vis-à-vis,* perception, thinking and learning (Srinivasan, 2011; Talkhabi and Nouri, 2012). It is interdisciplinary in nature and encompasses the fields of philosophy, psychology, artificial intelligence, neuroscience, linguistics and anthropology (Srinivasan, 2011). It follows an information processing approach, cognitive modelling, cognitive neuroscience and embodied and situational cognition (Ibid). However, it is predominantly based on the concept of the computational theory of the mind which has three different levels of operation, *vis-à-vis,* computation, algorithm and implementation (Srinivasan, 2011 citing Marr, 1988). Computations are performed by the mind as a system while algorithms are what are used for performing the computations which are implemented by the physical cognitive system (Srinivasan, 2011).

Cognitive science is also based on the long term and working memory function of the mind. The architecture of working memory is made up of two components of "*visuospatial scratch pad*" which deals with visual or three-dimensional material and the "*phonological loop*" which deals with auditory or verbal material (Kirschner, 2002; Sweller, Merrienboer and Paas, 1998; van Bruggen, Kirschner and Jochems, 2002; Yuan, Steedle, Shavelson, Alonzo and Oppezzo, 2006). Working memory is used for conscious activity in organising, contrasting, comparing and working on information and while it can hold about seven items at a single time, it can only process two or three items simultaneously and is the only memory which can be monitored (Kirschner, 2002; Sweller *et al.*, 1998). Long term memory (LTM) on the other hand is unlimited in capacity but its contents cannot be directly monitored unless they are loaded onto working memory. This postulation is the basis of the information processing theory of cognition which posits that human cognition involves processing of information stored in long term memory which is brought to working memory (Kirschner, 2002; Sweller *et al.*, 1998; van Bruggen *et al.*, 2002). The information processing theory further suggests that knowledge is stored in LTM as schemata. A schema is anything that is learnt and is treated as a single entity by working memory and can incorporate a large and complex amount of information (Kirschner, 2002; van Bruggen *et al.*, 2002). Schema can combine elements of information and production rules and become automated therefore needing less storage capacity and processing (van Bruggen *et al.*, 2002).

Applying the information processing theory to learning, John Sweller (1946 -) postulated the cognitive load theory (CLT) which posits that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock, Chandler and Sweller, 2002; Sweller, 1994; Sweller *et al.*, 1998). The theory suggests that since working memory has a very limited capacity, it can easily be overloaded with activities that impede rather than aid learning. In this regard, three different loads on working memory have been suggested, *vis-à-vis,* intrinsic cognitive load (ICL), extraneous cognitive load (ECL) and germane cognitive load (GCL). ICL is the cognitive load demanded by the intrinsic nature of the subject matter being learnt (Bannert, 2002; Kirschner, 2002; van Bruggen *et al.*, 2002). ECL is generated by the design of the instructional approach used in teaching while GCL is the cognitive load generated by the construction and automation of schemata which only occurs when there is free working memory capacity available (Bannert, 2002; Kirschner, 2002; van Bruggen *et al.*, 2002). CLT therefore suggests that:

$$CL = ICL + ECL + GCL$$

CLT further suggests that reducing cognitive load will make more working memory available for actual learning (Bannert, 2002). ICL, being intrinsic to subject matter being learnt, cannot be reduced while ECL, which does not contribute to learning but instead, especially for poorly designed instructional approaches, reduces working memory capacity, is the only cognitive load which can be reduced (Bannert, 2002; Kirschner, 2002). Instructional approaches that reduce ECL will also increase GCL provided the total CL remains within the limits (Bannert, 2002; Kirschner, 2002).

Learning will hardly take place if there is little or no schemata in LTM on the subject matter because the cognitive load will be too high (Valcke, 2002). Learning involves storing information including large, complex interactions and procedures in LTM and inducing changes in the structure of the schemata (Sweller *et al.*, 1998a). It is achieved by establishing patterns in data sets which are best chosen based on the simplicity with which they explain the data and connected to existing schemata (Chater and Vitányi, 2003). Existing schemata help to interpret new information and link the new information with the existing schemata thereby reducing cognitive load because schemata in LTM can be easily manipulated and stored (Valcke, 2002). Skilled performance is developed by building a large number of complex schemata by combining elements of lower level schemata into high level ones (Kirschner, 2002). Owing to the significance of working memory to schemata construction and automation, Kirschner (2002) posited that working memory plays a more significant role than intellectual ability in learning new skills because cognition does not stem from complex chains of reasoning in working memory which is incapable of any such complex interaction.

Instructional approaches should, therefore, start by focusing on basic schema construction rather than expect students to apply schemata which they do not possess. Only after students have developed sufficient basic schemata may they be presented with complex problems when prior knowledge can be activated (Valcke, 2002). Otherwise, instructional approaches which require complex reasoning processes with combinations of unfamiliar elements before students have mastered the basic schemata are likely to be problematic and not work well (Kirschner, 2002). This is because both ICL and ECL will be high and learners will end up with a high total cognitive load since they will not have sufficient appropriate schemata on the subject with high element interactivity (Bannert, 2002; Sweller *et al.*, 1998).

2.3 Theory Influences on Education

Theories of learning have influenced and shaped how education is structured. From the time of the Greek philosophers Socrates (469 – 399 BC), Plato (427 – 399 BC) and Aristotle (384 – 322 BC) when it was believed that the mind is a "black box" whose contents are not known but gets populated with mental images of the existing world, the corresponding model of learning was the didactic approach where educators focused on transferring knowledge from their minds into the minds of learners (Bodner, 1986). Plato's theories of idealism which held that knowledge lies in a person's soul at birth and education simply brings consciousness to the latent knowledge and Aristotle's realism which held that knowledge is the product of observable attributes of the physical world spawned the didactic approach to learning. Dewey (1859 – 1952) rejected the notion that the mind can passively receive knowledge from another mind and postulated that an active response is required for the mind in order to achieve knowledge and understanding. Dewey (1910) suggested that knowledge and understanding are the product of a process of inquiry and correspondingly suggested a learning approach based on a process of inquiry. Further developments of Dewey's work firmly established the theory of constructivism which correspondingly spawned a number of educational approaches. In behaviourism, the concept of reinforcement of stimulus to strengthen S-R relationships led to the development of educational approaches focused on repetition and reinforcement of student activities to best achieve learning. In cognitive science, the cognitive load theory which suggested the need to reduce non-productive cognitive loading on working memory and improve construction and automation of schemata in LTM led to the creation of the worked example, goal free problems and completion problems approach to learning.

2.3.1 Constructivism Influence on Education

Based on constructivism and the theory of inquiry, Dewey (1910) advocated that education should be centred on the learner rather than the content and that learners should be allowed to experiment actively because learning has its roots in the learner's questions. Building on the foundational work of Dewey, Piaget and others, and in the philosophy of constructivism, Kolb and Kolb (2008) suggested that learning, which is the process of creating knowledge, flourished in an environment rife with conflict and differences and disagreement are the drivers to learning. It was suggested that it is necessary to move between opposing modes of reflection and action and feeling and thinking in order to achieve knowledge and understanding. Culminating from these conceptions of learning, the constructivist learning approach emerged. To be considered constructivist, a lesson should have the following elements from the theory of constructivism (Baviskar *et al.*, 2009):

- Eliciting prior knowledge
- Cognitive conflicting
- Knowledge application with feedback
- Learning reflection

Loyens *et al.* (2009) also suggested four characteristics of a constructivist learning approach, albeit differently worded from Baviskar *et al.* (2009), and these are:

- Knowledge construction
- Cooperative learning
- Metacognition
- Authentic learning tasks

Notwithstanding the differences in wording, both conceptions of a constructivist learning approach emphasise the need for the approach to be centred on the learner as evidenced by the fact that all activities, save for feedback, are performed by the learner. Both conceptions suggest the need for reflecting on material learnt ("Learning reflection" in Baviskar *et al.* (2009) and "Metacognition" in Loyens *et al.* (2009)). The "prior knowledge" which is "applied with feedback" to a "cognitive conflict", suggested by Baviskar *et al.* (2009), is applied to an "authentic learning task", suggested by Loyens *et al.* (2009). Many differently worded instructional approaches under the umbrella of the constructivist approach share these commonalities.

Several versions of constructivist learning approaches have since emerged and include approaches such as Inquiry Based Learning (IBL), Problem Based Learning (PBL), Project Based Learning (PBL), Studio Based Learning (SBL), Case Based Learning (CBL), Discovery Learning and Action Learning.

IBL is an instructional approach based on a process of knowledge discovery with the learner proposing hypotheses and testing them by experimentation or observation (Pedaste, Mäeots, Siiman, Jong, van-Riesen, Kamp, Manoli, Zacharia and Tsourlidaki, 2015). The experimentation part does not have to be empirical in nature. The process is self-directed and is both inductive and deductive in part. There is variation in instructional approaches classified as IBL (Furtak, Seidel, Iverson and Briggs, 2012). However, quite like the variation in approaches classified as constructivist discussed above, several commonalities exist which reduce what initially appear to be different conceptions into fundamentally the same approach.

Problem-based learning is a learning framework that uses authentic problems to frame learning experiences and is similar to challenge-based learning (Erdogan and Senemoglu, 2014). The use of authentic problems necessitates a need to know in the student, which ideally would create a sense of both motivation and context for the learning experience. The effectiveness of problem-based learning has been reported in Ersoy and Başer (2014), Erdogan and Senemoglu (2014) and Alwi, Yusof, Hashim and Zainon (2012) among many other studies.

Project-based learning is a method of framing a curriculum that results in students learning through projects rather than simply completing projects. Students solve real world problems as projects and the lecturer facilitates the process by helping students to frame worthwhile questions, structuring meaningful tasks, coaching both knowledge development and social skills, and carefully assessing what students have learned from the experience (Efstratia, 2014). The effectiveness of project-based learning has been reported in Rodríguez, Laverón-Simavilla, del Cura, Ezquerro, Lapuerta and Cordero-Gracia (2015), Efstratia (2014) and Ríos, Cazorla, Díaz-Puente and Yagüe (2010).

Studio-based learning is an instruction approach which is centred on the collaborative application of modules content and skills in a project the solution of which is presented for peer review and revised based on peer review (Vest, Chapman and Denton, 2011). Hundhausen and Brown (2008) reported evidence of the efficacy of the studio-based learning approach.

Cased-based learning considers cases which are dealt with in small groups and is common in medical education while action learning involves solving authentic problems while learning by taking action and reflecting upon the results. These approaches help improve problem solving skills.

Problem-based learning, project-based learning, case-based learning, studio-based learning and action learning, among others, are quite different from each other when very narrowly defined. However, when only their central tenet is considered, they are all constructivist in nature. Therefore, they can be identified by the knowledge discovery nature of the learning process whereby the learner hypothesises solutions to authentic problems and evaluates the hypothesised solutions through experimentation or observation until an acceptable solution is found. This process can sit in a problem solving environment, a project problem environment, a case study environment or any similar but distinctly different environment. It is therefore the multiplicity of possible environments in which the inquiry process can be set which gives rise to differently defined by ideologically similar instruction approaches. Knowledge discovery by the learner hypothesising solutions to authentic problems and evaluating the hypothesised solutions through experimentation or observation until an acceptable solution is found is also the definition of IBL. Therefore, broadly defined, IBL encompasses all constructivist instruction approaches which share the inquiry ideology.

Kirschner, Sweller and Clark (2006) classified constructivist, discovery, problem-based, experiential, and inquiry-based teaching as minimally guided instruction approaches and argued that they are less effective than instructional approaches which are more strongly guided. Kirschner *et al.* (2006: 75) argued that minimally guided approaches:

> "ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide 'internal' guidance."

In response to Kirschner *et al.* (2006), Hmelo-Silver, Duncan and Chinn (2007) argued that:

> "Many innovative approaches to education such as problem-based learning (PBL) and inquiry learning (IL) situate learning in problem-solving or investigations of complex phenomena. Kirschner *et al.* (2006) grouped these approaches together with unguided discovery learning. However, the problem with their line of argument is that IL and PBL approaches are highly scaffolded".

Hmelo-Silver *et al.* (2007) argue against grouping IBL instruction approaches with discovery learning because discovery learning has largely been discredited in mainstream science education circles due to the absence of any form of scaffolding (Furtak *et al.*, 2012). Hmelo-Silver *et al.* (2007) further argued that scaffolding, which is educational support given to students by the instructor, provided in IBL instruction approaches preclude them from being classified together as "*minimally*" guided approaches. The importance of scaffolding student activities in IBL cannot be over emphasised. Furtak *et al.* (2012) concluded from a meta-analysis of 37 studies that the role of the teacher in actively guiding students in IBL is pivotal to the success of the approach. In a meta-analysis of 72 studies, Lazonder and Harmsen (2016) also concluded that IBL can be more effective than other, more expository instructional approaches as long as students are supported adequately. Scaffolding requires teachers to take a more active role in the inquiry lesson. It was found that inquiry lessons which are led by the teacher have a larger positive effect on student learning than those which are led by the student (Furtak *et al.*, 2012). Hmelo-Silver *et al.* (2007: 105) concluded that "while we are not arguing against various forms of direct and more heavily guided instruction, of the sort that Kirschner *et al.* (2006) advocate, it is still unclear how to balance IL and PBL (which are more constructivist and experiential) with direct instructional guidance".

Several studies have reported the superiority of IBL over other instructional approaches. For example, a meta-analysis of 37 studies found that IBL has a positive effect on student learning when compared to the traditional didactic instruction approach or unstructured student-led activities (Furtak *et al.*, 2012). Şimşek and Kabapınar (2010) found that IBL had a positive effect on the conceptual understanding and scientific process skills of 5th grade pupils but it did not have any effect on their attitude toward science. Korganci, Miron, Dafinei and Antohe (2015) found statistically significant differences between an experimental group using IBL and a control group using the traditional didactic instruction approach when teaching electric circuit models using a water circuit analogy with the experimental group using IBL being more effective than the traditional approach group. Villardón-Gallego (2016b) reported that IBL improved teamwork, technical skills related to their discipline, ability for future performance and professional skill generally in a class of master's degree students. It was emphasised that it is important to monitor and support students throughout the process.

2.3.2 Behaviourism Influence on Education

Behaviourism has also made many contributions to the field of education. Several instructional approaches and influences have arisen from the concept of operant conditioning, which is the cornerstone of behaviourism. Operant conditioning postulates that behaviours which are rewarded are more likely to be repeated (Guey *et al.*, 2010). This postulation led to the development of several other theories with educational application including the theory of reinforcement, the law of effect, the law of repetition and the theory of connectionism among others. All these theories still influence education.

Connectionism still has modern applications in education. For example, Karadut (2012) used the essentials of connectionism in a musical instrument playing class of beginner students aged between 11 and 15 years old. It was observed that the essentials of connectionism play a crucial role in developing musical instrument playing abilities like shifting position and hearing correct intonation. It was concluded that students gained technical efficiency to express unique musical ideas irrespective of social background and individual differences.

The effect of repetition on learning has also influenced educational practice. For example, León-Carrión, Izzetoglu, Izzetoglu, Martín-Rodríguez, Damas-López, Martin and Domínguez-Morales (2010), while studying the physiological effect of repetition of learning on working memory concluded that:

> "our findings show that the temporal integration of efficient verbal learning is mediated by a mechanism known as neural repetition suppression (NRS). This mechanism facilitates cortical deactivation in dorsolateral prefrontal cortex (DLPFC) once learning is successfully completed. This cortical reorganization is interpreted as a progressive optimization of neural responses to produce a more efficient use of neural circuits. NRS could be considered one of the natural mechanisms involved in the processes of memory learning." (León-Carrión *et al.*, 2010: 502).

Axelsson and Horst (2014) also established the effect of contextual repetition on the word learning abilities of three-year-old children who completed an exercise on a touch screen computer with the target group repeating the learning trials while there was no repetition of the control group. It was found that the target group demonstrated word learning. Lange-Küttner and Küttner (2015) also studied the role of repetition in children learning in an experimented with 7 and 9-year-old children with objects-in-places. Accuracy in the repetition group nearly tripled in remembering patterns consistent with other findings about memory for repeated patterns. Further, in testing the involvement of short and long term memory in novel word-form learning, Szmalec, Page and Duyck (2012) found that repetition and the passage of time influence the learning of phonological sequences of novel words-forms and not sleep as reported by earlier findings.

The influence of reinforcement and rewards on education has also received widespread educational application in various scenarios. For example, Valeria and Maria (2013) recommended positive reinforcement for 7 to 8-year-old pupils to encourage them to act on their knowledge of environmental related attitudes and behaviours. Albu (2012) reported that teachers who want to maintain and strengthen control in the classroom predominantly use a punishment reward system while those who pursue the development, emotional support and freedom of the pupil will mostly use love based methods. The effect of reinforcement has also been explored with educational games. In a quasi-experimental research design aimed at reinforcing material learnt in a lecture with an educational game on knowledge gains, Brom, Preuss and Klement (2011) exposed the study group to an educational game after an initial exposure lecture and subjecting the control group to an extra lecture using media-rich material for the same duration as the educational game. It was found that game playing was comparable to the traditional form of teaching in immediate knowledge gains.

However, reward and punishment systems have been reported to contradict motivation theory. Costică (2014) argues that rewards give rise to extrinsic motivation and are effective only in the short term. Reward systems are also likely to erode intrinsic motivation because the more people are rewarded for doing something, the more they lose interest in what they had to do to get the reward. Therefore, a reward system requires about the same precautions as a punishment system.

2.3.3 Cognitive Science Influence on Education

CLT has also recommended a number of instructional approaches such as goal free problems, worked examples and completion problems (van Bruggen *et al.*, 2002). All these approaches to learning are centred on attempts to reduce ECL and increase GCL. These approaches are effective for students with little prior knowledge because they help to reduce cognitive loading (Hoogerheide, Loyens and van Gog, 2014; Mihalca, Mengelkamp, Schnotz and Paas, 2015; Van Gerven, Paas, Van Merriënboer and Schmidt, 2002). However, it should be noted that reduction of cognitive load does not guarantee that the free working memory will be used for schemata construction and automation (Ibid). Free working memory will only be effectively used in learning when the attention of learners is directed away from extraneous cognitive processes towards the germane cognitive processes of schema construction and automation (Bannert, 2002; Sweller *et al.*, 1998).

Solving conventional problems in the absence of adequate schemata requires the deployment of a substantial amount of cognitive effort which generates a large extraneous cognitive load and is therefore not ideal for schemata construction or learning (Sweller *et al.*, 1998). For example, a student with inadequate prior knowledge will find the following question difficult: *a car is uniformly accelerated from rest for 1 minute. Its final velocity is 2 Km/min. How far has it travelled?* Sweller *et al.* (1998) argued that in this scenario, too much cognitive effort resulting in a high ECL will have to be expended by the student for a relatively large period with very little associated schema construction or learning taking place and the student may not even achieve the goal of calculating the distance travelled. What is described as a goal free problem is recommended. In the example, rather than ask the student to find the distance travelled, the student will be asked to calculate as many variables as they can. No specific goal to arrive at is incorporated in the question therefore the designation "*goal-free problem*". The objective of the goal-free problem is to eliminate the need for a "means-ends search" (Ibid). Sweller *et al.* (1998) argued that the means-end search is what increases ECL. In an experimental study with 67 junior high school students, Ayres (1993) found that a goal free 2-move mathematics problem was solved with much fewer errors than when the same problem was presented conventionally. This was attributed to a general reduction on cognitive load. Wirth, Künsting and Leutner (2009) replicated findings from other researchers in an experimental study of 233 fifteen-year-old students in a computer based learning environment. It was concluded that goal-free problems reduce cognitive load and foster learning with minimum effort. Sweller *et al.* (1998) concluded that the goal-free effect occurs because ECL is reduced which facilitates schema construction in contrast to means-ends analysis.

Another strategy for reducing ends-means analysis is studying worked examples which focuses attention on problem states and associated operators therefore reducing cognitive load and helping students to create schemata (Ibid). The effectiveness of worked examples has been demonstrated by several authors (Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke, Renkl, Krieg, Wittwer, Aleven and Salden, 2009; Sweller, 2006). For example, in an experimental study comparing worked examples, tutored problems erroneous examples, which also represented high assistance instruction approaches, and untutored problem solving, which represented a low assistance instruction approach, McLaren, van Gog, Ganoe, Karabinos and Yaron (2016) found that there was no difference based on the instruction approach in learning outcomes. However, significant differences in learning outcomes were found in both instructional approaches based on the worked examples which showed that students expended far less time and effort to achieve the learning outcomes. The reduction in time was between 46% and 68%. Mulder, Lazonder and de Jong (2014) also reported the effectiveness of worked examples in an inquiry based learning scenario. In an experimental study design of IBL through a computer simulation programme where students were required to produce computer models. The experimental group was given heuristic worked examples to refer to while the control group was not given. It was found that the heuristic worked examples improved the students' inquiry behaviour and improved the quality of the computer models produced. However, few students produced a model with evidence of full understanding. It was proposed to improve the worked examples used.

However, some studies on worked examples have found little or no advantage in worked examples over conventional examples. In an experimental study aimed at assessing the efficiency of worked examples over conventional practice problems in both young and elderly adults, Van Gerven *et al.* (2002) found that young students did not profit from worked examples with mean scores even suggesting a negative effect when training with worked examples. In this instance, it was also found that studying using both worked examples and conventional problems produced relatively little cognitive load and led to nearly the same level of performance. However, it was concluded that the young may have attained their upper performance limit.

Completion problems have also been found to reduce cognitive load. In a series of experimental studies comparing completion problems, conventional problems and learner controlled condition van Merriënboer, Schuurman, de Croock and Paas (2002) found that completion problems reduce cognitive load and the completion problems group showed the highest training efficiency but a disappointing transfer performance. Mihalca *et al.* (2015) also found that completion problems were effective for students with low subject prior knowledge while students with higher subject prior knowledge performed better with conventional problems.

In another effort to reduce ECL and therefore reduce total CL and create free working memory for learning, Pollock *et al.* (2002) suggested a methodology whereby information is presented in two stages. Firstly, only individual elements which can be processed serially were presented and then later all the information was presented. By doing so, it was found that understanding improved compared to when all the information was presented throughout. This approach is good for beginners who do not have sufficient schemata on the subject. However, the advantage of this approach over the conventional approach was found to disappear in experienced learners with sophisticated schemata on the subject matter (Bannert, 2002).

All the suggested instructional approaches which consider CLT are applicable to students with little prior knowledge. Goal-free problems, worked examples, and completion problems are all reported to lose their advantage in more experienced learners (Hoogerheide *et al.*, 2014; Mihalca *et al.*, 2015; Sweller *et al.*, 1998; Van Gerven *et al.*, 2002). Therefore, if learners in lower years of university undergraduate programmes can be considered to have little prior knowledge and students in higher years considered to be experienced, then Goal-free problems, worked examples, and completion problems are best suited to lower year university students as opposed to higher year students. Ideal instructional designs incorporating theses three approaches may therefore require an accurate assessment of the level of experience of students (Sweller *et al.*, 1998).

Notwithstanding the suggested instructional approaches arising from CLT, so far, CLT has not advocated a change in the didactic approach to learning but rather a consideration of the limits of working memory in the design of instructional approaches. CLT theorists have argued that the limits of working memory are very often not considered in the design of conventional instruction approaches which often leads to introducing high ECL (van Bruggen *et al.*, 2002). CLT can, therefore, be used to guide the design of instructional formats that consider the limits of working memory and therefore encourage learning (Kirschner, 2002).

2.4 Relationships among the Theories

Notwithstanding that all the three fields conceptualise how learning takes place, distinct and notable differences in their postulations can be found. Philosophy generally postulates that learning involves the personal and social construction of understanding and knowledge by the learner and that what is learnt are schemas (Baviskar *et al.*, 2009; Dewey, 1938; Kalina and Powell, 2009; Piaget, 1952). Behaviourism differs in its conception of learning with the others fields and within itself. One school of behaviourism generally posits that learning is the acquisition of behaviour and what is learnt are habits while the other school of behaviourism, while agreeing with the first school that learning is the acquisition of behaviours, however posits that what is learnt are cognitive structures (Büchel and Dolan, 2000; Guey *et al.*, 2010; Kohlenberg and Tsai, 2000; Rosenbaum *et al.*, 2015). Cognitive science postulates that learning is the creation and automation of schemata in LTM and what is learnt are schemas (Kirschner, 2002; Pollock *et al.*, 2002; Sweller, 1994; Valcke, 2002; Van Gerven *et al.*, 2002; van Merriënboer *et al.*, 2002). Therefore, the main defining feature which divides the three fields conceptualising learning is the conception of what constitutes learning and what is learnt. Since modern epistemology conceives of learning as the creation of schemata, it has evolved its theories focusing on processes of how the mind acquires the schemata. Behaviourism on the other hand conceives of learning as a behaviour or habit formation and has subsequently concentrated on studying and analysing the relationship between behaviour and learning. Cognitive science, likewise, because of its conception of learning as schemata construction and automation, has directed its line of inquiry towards activities and features which promote schemata construction and automation. All the fields are therefore correct in their theories of how learning takes place based on their conception of what constitutes learning and what is learnt.

Notwithstanding the differences among the three fields, similarities also exist. Both constructivism and cognitive science consider knowledge as being stored in schemata. The two fields differ only in that cognitive science has focused on the role of memory in schemata construction while constructivism has not delved into the relationship between memory and schemata construction. Since cognitive science is multi-disciplinary, it has the benefit of collating different research into one theory. With its similarity to constructivism regarding its conception of learning and cognition through schemata construction, it can be considered to be an extension of constructivism. Behaviourism on the other hand initially completely chose to disregard cognition in its study. The exclusion of cognition and its contribution to both learning and behaviour formation is perhaps the largest difference between behaviourism and both constructivism and cognitive science. However, contemporary behaviourists have since acknowledged the obvious part which cognition plays in shaping behaviour but have chosen not to consider it in studying and analysing behaviour. Notwithstanding, commonalities can still be seen between behaviourism and constructivism. For example, with reference to observations of Laurent (Piaget, 1952: 29):

> "Observation 1 – from birth, sucking-like movements can be observed: impulsive movement and protrusions of the lips accompanied by displacement of the tongue, while the arms engage in unruly and more or less rhythmical gestures and the heads moves laterally etc. Observation 3 – The third day Laurent makes new progress in his adjustment to the breast. All he needs in order to grope with an open mouth toward success is have touched the breast or the surrounding teguments with his lips".

Piaget concluded that the sucking schema of Laurent has adapted to the environment after interaction with the environment. However, it can also be concluded that after repeated interactions on feeding receiving positive reinforcement by successful results, the child, in response to stimuli, learns how to search for the breast.

Therefore, while the child, through experience, constructs own knowledge structures and understanding (constructivism and cognitive science), this is also aided by positive reinforcement from successful repetition (behaviourism). The dual role of experiential knowledge construction and repetition of positively reinforced activities can be seen in most of Piagets' observations. Positive reinforcement and repetition while experiencing the world are necessary for children to create schemata. Differences in theories are primarily a matter of difference of interpretation (Hilgard, 1956). Neither behaviourism nor constructivism can ultimately reject each other's theories because both depend on inferences from observed behaviour which are not directly verified (Ibid). Also, all groups fit the facts acceptably well and behaviourists are able to deduce from the laws of habit formation what constructivists and cognitivists support by interpretation (Ibid).

Therefore, notwithstanding the differences among the different theories, what may initially seem to be diametrically opposed views may in fact be based on preference differences with each theory being justifiable to a point (Ibid). The complexity of the concept of learning gives rise to different explanations and interpretations and therefore theories. Tolman (1886-1959) at one point suggested seven different kinds of learning and concluded that "perhaps by using the common name 'learning' to cover the acquisition of motor skills, the memorization of a poem, the solving of a geometrical puzzle, and the understanding of a period in history, we deceive ourselves by looking for common laws to explain processes that have very little in common" (Hilgard, 1956 citing Tolman, 1943). While all theories fit the facts reasonably well, some aspects of learning are best explained by behaviourism while others by constructivism and yet others by cognitive science. However, whether it be behaviourism or constructivism or cognitive science, what is clear is that knowledge and understanding are created by an active process of interaction and not a passive process of reception.

Differences in definition of learning also create differences in theory application to learning. For example, constructivists defined learning as a process of construction of knowledge and so leave students to inquire and explore on their own so that they can construct their own understanding. Cognitive scientists define learning as the construction of schemata and have suggested instructional approaches which are centred on improving the retention of factual knowledge. Behaviourists define learning as a change in behaviour which is best achieved by sufficient R-R associations and have subsequently suggested instructional approaches which emphasise reinforcement and repetition (operant conditioning).

In educational application, all groups of theorists have suggested one form or another of instructional design in tandem with their theories. Each group has largely only considered its own set of theories in recommending instruction design thereby creating instances where specific approaches or rationale behind an approach is fundamentally opposed to a set of theories in another group. For example, IBL in constructivism often involves solving fairly ill-defined problems in an information rich environment. While research from constructivist has found this approach to be effective, cognitive science argues that it generates very high cognitive loading (Valcke, 2002). According to cognitive load theory therefore, constructivist learning approaches, which depend on solving ill-defined problems actually impede the construction of schemata. At least two arguments against inquiry based learning can be found from cognitive science. Firstly, the posing of ill-defined problems with rich information which creates a complex environment with high element interactivity and lots of redundant information. CLT argues that posing ill-defined problems to learners with inadequate prior knowledge will hardly result in schemata construction due to the consequent high cognitive loading. Therefore, van Bruggen *et al.* (2002) argued that in IBL, the need to reduce ECL is dire if learning is to take place. Secondly, van Bruggen *et al.* (2002) argued that collaborative learning, which is also the basis of IBL, appears to induce high cognitive load on an individual (van Bruggen *et al.*, 2002).

In response to criticism from cognitive scientists, constructivists have argued that the scaffolding provided in IBL is designed to appropriately direct the learner and therefore help reduce cognitive loading (Hmelo-Silver *et al.*, 2007). The importance of scaffolding student activities in IBL has also been emphasised by Villardón-Gallego (2016), Lazonder and Harmsen (2016) and Furtak *et al.* (2012) among others.

While the application of the theories to education practice has yielded a few contradictions, some studies have attempted to be interdisciplinary. For example, León-Carrión *et al.* (2010) investigated the effects of repetition on learning and working memory. Repetition is a central tenet of behaviourism while working memory falls in the realm of cognitive science. Behaviourism had initially and traditionally opted not to delve into the workings of the mind and so the application of behaviourism theories to educational practice had neglected the influence of concepts from other theories. Mulder *et al.* (2014) studied the use of worked examples in an IBL lesson. The concept of worked examples which reduces cognitive load suggested by cognitive science is being applied to

IBL which is from constructivism. Worked examples have been suggested by cognitive scientists as being ideal for reducing cognitive loading and improving schemata construction in learners with low prior knowledge. IBL has been criticised for inducing a high cognitive load on students and therefore, application of concepts from cognitive science is likely to help reduce cognitive loading in IBL and subsequently improve its efficacy.

Interdisciplinary application of the learning theories is probably the most likely approach to improving educational practice because concepts from one set of theories can be used to improve weaknesses in the educational application of another set of theories. This would yield a hybrid set of instructional approaches which can be located conceptually in the intersection region of the three sets of learning theories as shown in Figure 2-1. An instruction approach would therefore be located in either:

$C \cap S$ = intersection set of constructivism and cognitive science.

$C \cap B$ = intersection set of constructivism and behaviourism or

$B \cap S$ = intersection set of behaviourism and cognitive science or

An ideal instruction approach would be located in:

$C \cap B \cap S$ = intersection set of all three learning theories

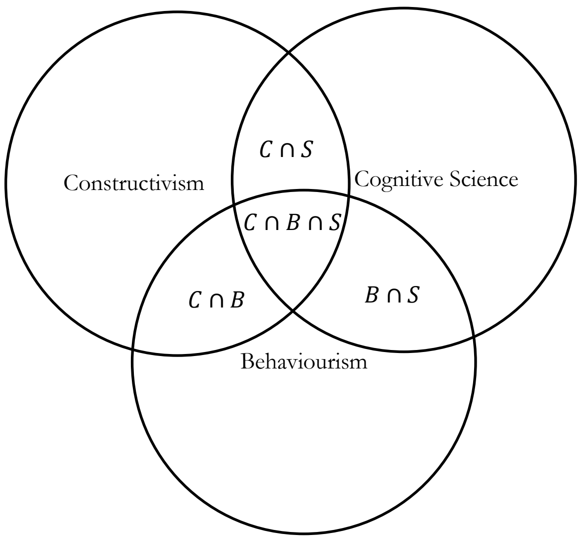


Figure 2-1: Relationships among the Theories

2.5 Chapter Summary

This chapter reviewed three contemporary theories of learning with a view to establish how learning takes place. The chapter also established how these theories have been applied in education practice. There are three major distinct fields which have studied theories of learning and these are from the branches of epistemology in philosophy, behaviourism in psychology and cognitive science. Constructivism, which is the contemporary theory of learning from epistemology, posits that learning takes place through an active process of knowledge construction and not a passive process of knowledge reception as previously postulated. Behaviourism posits that learning involves the development of habits which is achieved by repetition and reinforcement of responses. Cognitive science posits that learning involves the creation and automation of schemata in long term memory, which is limitless in capacity, from short term memory, which is very limited in capacity. Differences among the theories arise from differences in the definition of what constitutes learning and what is learnt.

All the theories of learning have proposed educational instruction approaches based on their conception of learning. Constructivism has suggested the inquiry based approach while behaviourism has stressed the need for repetition and reinforcement based on the concept of operant conditioning. Cognitive science has suggested approaches including goal-free learning, worked examples and completion problems whose central aim is to reduce the amount of non-value adding cognitive loading on working memory.

Notwithstanding the apparent differences among the theories of learning and their application to educational instruction approaches, there are similarities among the theories. What therefore initially appear to be diametrically opposed views are in fact different interpretations of the facts. However, the application of these theories to educational instruction practice has yielded some models which are opposed to each other. This is in part due to theorists considering only their theories and interpretations in the design of instructional approaches. Instructional design must account for all theories if it is to best achieve learning.

Arising from the review of how learning takes place, important antecedents to teaching and learning were identified from literature and these were subsequently subjected to empirical testing in tandem with the research question *"What are the antecedents to effective teaching and learning from contemporary theories of learning?"* While literature from the various contemporary theories of learning is awash with what can be considered important elements for effective teaching and learning, none has condensed them into a comprehensive list nor have discussed them in relation to the other schools of thought.

CHAPTER 3

INQUIRY BASED LEARNING

3.1 Introduction

Based on contemporary theories of learning, student centred teaching and learning is far superior to the traditional didactic lecture approach. In tandem with the objective of establishing how best to educate students of construction programmes, this chapter evaluates the student centred teaching and learning philosophy. Specifically, the chapter reviews literature on inquiry based learning (IBL) which is the central tenet of student centred pedagogy so as incorporate some of the important tenets of IBL in the proposed IBL curriculum for construction programmes. This is in tandem with the research question *"How can antecedents to effective teaching and learning from contemporary theories of learning be used for the effective teaching of construction programmes in an IBL curriculum?"* The chapter defines IBL and discusses literature on the IBL cycle and processes. The effectiveness of IBL is also highlighted and further, the chapter discusses student and instructor experiences with IBL and factors which impact on these experiences. The chapter closes by discussing types of inquiry problems appropriate for IBL and assessment of students when using IBL.

3.2 IBL Definition

Inquiry-based learning (IBL) is a pedagogical approach where students engage in active learning through asking questions on a topic and proposing hypotheses about the questions and collecting, investigating and analysing available information to answer the questions thereby discovering knowledge previously unknown to the student (Hmelo-Silver *et al.*, 2007; Kori, Mäeots and Pedaste, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon, Anastopoulou, Kerawalla and Mulholland, 2011; Spronken-Smith, Bullard, Ray, Roberts and Keiffer, 2008). In IBL, inquiry is the *modus operandi* teaching and learning vehicle (Lim, 2004). Inquiry is the experimental process of discovering knowledge previously unknown to a student (Pedaste *et al.*, 2015). The process demands the active participation of students in their learning and so it is student centred opposed to the teacher centred traditional didactic teaching approach (Meijerman, Storm, Moret and Koster, 2013). IBL is often arranged in phases which form a cycle called the inquiry cycle of which there are different variations (Pedaste *et al.*, 2015).

Several different descriptions of IBL processes can be found in literature. Some inquiry processes are classified under other names such as active learning, experiential learning and problem based learning (Furtak *et al.*, 2012; Spronken-Smith *et al.*, 2008; Spronken-Smith and Kingham, 2009). IBL is therefore an umbrella term which encompasses a range of approaches centred on the teaching and learning philosophy which engages students in learning through an inquiry process (Kahn and O'Rourke, 2004; Spronken-Smith and Kingham, 2009). Pedaste *et al.* (2015) concluded that differences in the descriptions of the inquiry processes mostly emanate from differences in use of terminology for processes which are essentially the same. Therefore, while some literature draw distinction between inquiry processes such as active learning, problem-based learning, case-based learning and studio based learning among others, this study defines IBL more broadly to encompass all forms of inquiry processes that exhibit all the characteristics of an inquiry cycle.

3.3 The IBL Cycle

The first inquiry cycle was developed by John Dewey (1859-1952) and had five phases shown in Figure 3-1. The inquiry learning cycle was conceived in tandem with the theory of inquiry by John Dewey which proposed that for effective learning to take place, students must be allowed to actively pursue knowledge rather than passively receive it from educators (Dewey, 1910). The model proposed that learning should start with the curiosity of the students who should be allowed to ask questions or inquire. Dewey said about inquiring that "when the question is not discharged by asking of another, when the child continues to entertain it in his own mind and be alert for whatever will help answer it, curiosity has become a positive intellectual force" (Dewey, 1910: 9).

After the curiosity of the student raises questions, Dewey proposed that the students should investigate the questions. In this stage of the inquiry cycle, the student should collect information and experiences relevant to the problem and investigate the question through experimentation. This process should actively engage the student and lead to the creation stage of the inquiry cycle where the collected information and the application of prior knowledge and experiences leads to the creation of solutions to the questions. Dewey further suggested that the student should discuss their findings with peers, firstly to share knowledge and experiences, secondly to compare findings and understanding with others and thirdly to ascertain from others whether the findings and understanding gained are valid. The final step in Dewey's inquiry circle of learning is reflection on the experiences relating to the question under investigation. The inquirer looks through the whole process of inquiry and determines whether the indeterminate situation created by the question has been transformed into a determinate one.

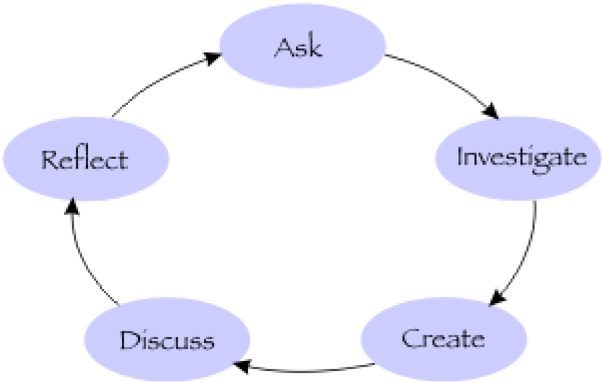


Figure 3-1: Deweys' Inquiry Cycle (Dewey, 1910)

Following on from Deweys work, many inquiry cycles have since been developed with contemporary cycles still reflecting aspects of earlier frameworks (Pedaste *et al.*, 2015). For example, the inquiry cycles found in Scanlon *et al.* (2011), Spronken-Smith and Kingham (2009), White and Frederiksen (1998) and Lim (2004) among many others can be seen to reflect aspects of the Dewey inquiry cycle. More recently, Pedaste *et al.* (2015) developed an inquiry cycle by identifying and summarising the core features of other contemporary inquiry cycles. Using a systematic literature review, 32 articles describing the inquiry cycle were analysed and synthesised into a cycle which combined the strengths of these frameworks. The synthesis was achieved by answering two key questions: "what inquiry phases are necessary for completing IBL?" and "How should the inquiry phases be arranged into inquiry cycles and in an IBL framework?" The resulting inquiry cycle has five phases and nine sub-phases as shown in Figure 3-2.

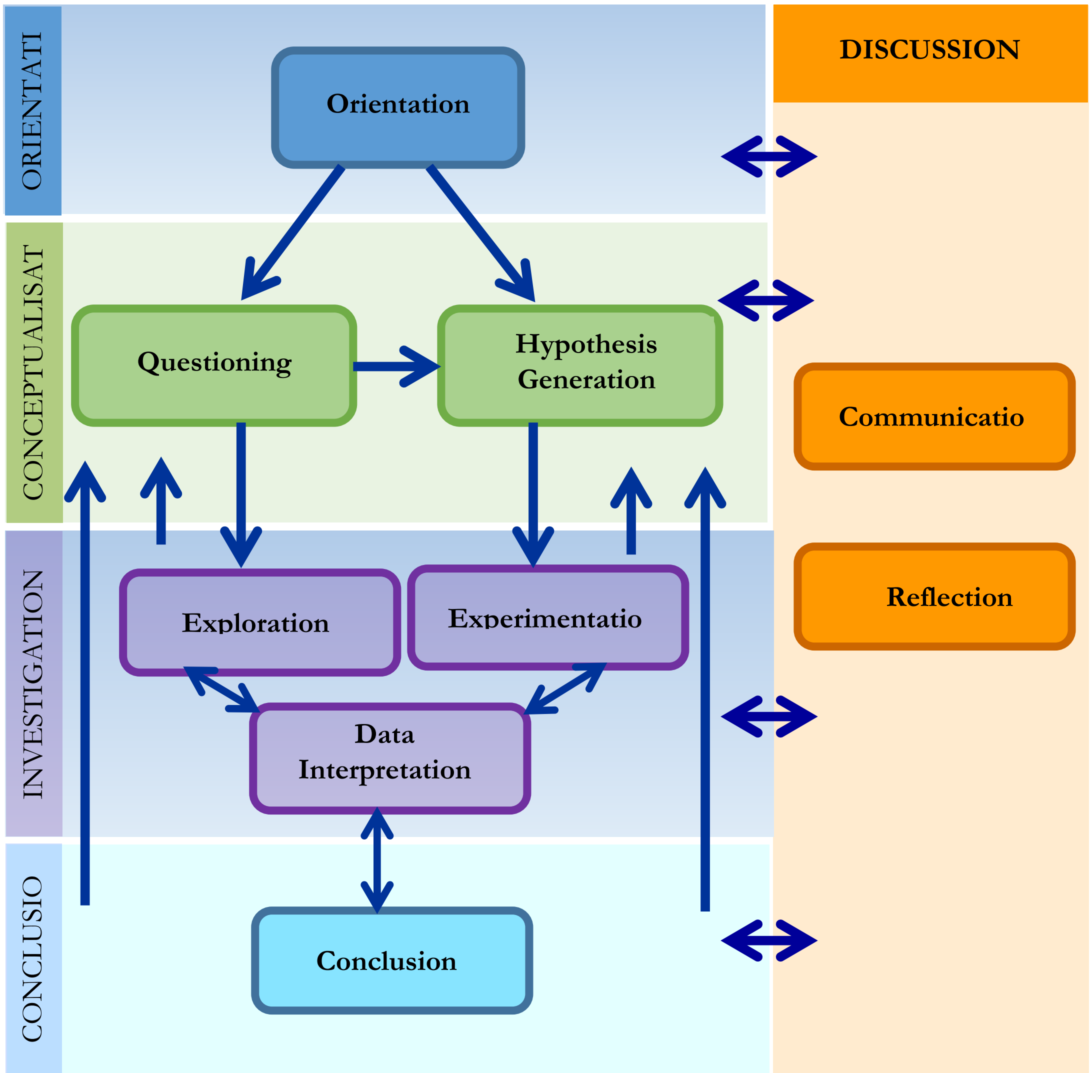


Figure 3-2: Inquiry Learning Framework (Margus Pedaste *et al.*, 2015)

Orientation – The orientation phase is the introduction phase of the inquiry process and serves to introduce the students to the problem. The introduction must be in such a way that the interest and curiosity of the student are stimulated (Lim, 2004; Pedaste *et al.*, 2015; White and Frederiksen, 1998). The outcome of the phase is a problem statement (Pedaste *et al.*, 2015). Lim (2004) suggested that the students may be left to articulate their own problem statement. The problem may be a project, case study or any type of problem for students to investigate (Lim, 2004; Spronken-Smith and Kingham, 2009; White and Frederiksen, 1998).

Conceptualisation – The conceptualisation phase involves the identification and clarification of concepts belonging to the stated problem. This phase also proposes research questions and/or hypotheses (Pedaste *et al.*, 2015; White and Frederiksen, 1998). The outcome of this phase are research questions and/or hypotheses. While the instructor identifies and clarifies concepts, the students generate their own research questions and/or hypotheses about the problem. When students only have a general plan of what to do, it is better to start with open questions (Pedaste *et al.*, 2015). If, on the other hand, students have a more specific theory-based idea to explore, then it is better to use hypotheses. Otherwise, from questions, students can collect background information and state a hypothesis (Ibid). The instructor also provides some just-in-time help when required by the students.

Investigation – The investigation phase involves action-response to the research questions and/or hypothesis through exploration, observation, and design of experiments by changing variables and prediction and interpretation of outcomes by students (Lim, 2004; Pedaste *et al.*, 2015). The students generate a work plan for addressing the research problem proposed in the orientation phase (Lim, 2004; Scanlon *et al.*, 2011). To achieve this, the students work in groups or pairs to develop their questions and hypotheses, collect information, data or evidence which is analysed using available tools to answer their questions or validate their hypotheses while the instructor helps clarify points (Scanlon *et al.*, 2011; White and Frederiksen, 1998). The outcome of this phase is data interpretation which allows for a reaction to the research questions or hypotheses raised and conclusions about the questions or hypotheses (Pedaste *et al.*, 2015).

Conclusion – In the conclusion phase, students establish whether their line of inquiry has addressed the research problem (Pedaste *et al.*, 2015; Scanlon *et al.*, 2011). The outcome of this phase are final conclusions about the findings of the inquiry process (Pedaste *et al.*, 2015). Students present their final work showing the inquiry problem, the questions and/or hypotheses generated, the investigation plan followed, the data collected and the analyses performed. The final work may be presented in form of a report, a poster, a presentation or a video (Scanlon *et al.*, 2011).

Discussion – The findings of the inquiry process are presented and communicated by the students to the rest of their peers and to the instructor and the students receive feedback and comments (Pedaste *et al.*, 2015; Scanlon *et al.*, 2011). Students present their work to peers and the instructor in a 'crit' session. These sessions allow students to reflect on their work in view of comments and criticisms from both the instructors and peers. Reflection is a metacognitive process which allows students to think about and become aware of what they have just learnt and how it relates with knowledge they already possessed (Kori *et al.*, 2014). Schon (1987) and Schon (1983) underscored the importance of reflection both in achieving deep learning and in effective professional practice. Kori *et al.* (2014) found that guided reflection improves the quality of reflection and the inquiry skills of students. Reflection on the inquiry process, informed by past experience, is effective for resolving an unfamiliar scenario (Schon, 1987).

The presence of sub-phases in the Pedaste *et al.* (2015) inquiry cycle means that the inquiry process can proceed in several different ways. Pedaste *et al.* (2015: 56) suggested three desirable pathways, albeit not the only possible ones, and these are:

a) Orientation–Questioning–Exploration–Questioning–Exploration–Data Interpretation–Conclusion (the loop between Questioning and Exploration can be repeated several times, but it is also possible to move directly from the first Exploration to Data Interpretation; Communication and Reflection can be added to every phase);

b) Orientation–Hypothesis Generation–Experimentation–Data Interpretation–Hypothesis Generation–Experimentation–Data Interpretation–Conclusion (the loop between Hypothesis Generation–Experimentation–Data Interpretation can be repeated several times, but it is also possible to move directly from the first Data Interpretation to Conclusion; Communication and Reflection can be added to every phase);

c) Orientation–Questioning–Hypothesis Generation–Experimentation–Data Interpretation–(Questioning) Hypothesis Generation–Experimentation–Data Interpretation–Conclusion (the loop between Hypothesis Generation–Experimentation–Data Interpretation can be repeated several times, but it is also possible to move directly from the first Data Interpretation to Conclusion; after Data Interpretation it might be necessary to revise Questions, but more often only Hypotheses are revised; Communication and Reflection can be added to every phase).

Generally, the inquiry cycle by Pedaste *et al.* (2015) is very similar to several other inquiry cycles (see for example Scanlon *et al.* (2011), Spronken-Smith and Kingham (2009), White and Frederiksen (1998) and Lim (2004) among many others). However, Pedaste *et al.* (2015) created their cycle by analysing the strengths of many cycles and the terms used have been extracted from the many cycles analysed and therefore cover processes in most inquiry processes so far conceived. The resulting inquiry cycle therefore represents a contemporary view of the IBL process. Activities in the inquiry cycle can be performed for a single class activity in a module, for an entire module within a programme, for several modules within a programme and even as the general philosophy for an entire programme (Spronken-Smith *et al.*, 2008). Regardless of the level at which it is used, one of its' central tenant is that is based on an iterative cycle of propose-critique-reflect (Harinarain and Haupt, 2016).

3.4 Effectiveness of IBL

There are many reports of the effectiveness of the IBL approach. For example, White and Frederiksen (1998) reported significantly improved student assessment performance when IBL was used. Low achieving students improved their assessment scores so that they were closer to those of high achieving students than in a control group. It was concluded that IBL can improve the performance of low achieving students while still being beneficial to high achieving students. The IBL approach is being applied extensively to teaching and learning and its effectiveness has been widely reported (Alwi *et al.*, 2012; Efstratia, 2014; Erdogan and Senemoglu, 2014; Ersoy and Başer, 2014; Furtak *et al.*, 2012; Harinarain and Haupt, 2016; Hmelo-Silver *et al.*, 2007; Hundhausen and Brown, 2008; Korganci *et al.*, 2015; Ríos *et al.*, 2010; Rodríguez *et al.*, 2015; Şimşek and Kabapınar, 2010; Vest *et al.*, 2011; Villardón-Gallego, 2016b). In spite of the many reported benefits and effectiveness of IBL Spronken-Smith *et al.* (2008) recommended that changes in quantitative and qualitative learning in students need further rigorous studies. Lambert and Biddulph (2015) also argued that IBL learning programmes are difficult to achieve due to "epistemological fog" and conventional knowledge supported by strong summative assessment systems.

3.5 IBL Experiences

The effectiveness of IBL can be attributed to, among other things, the academic teaching and learning experience it offers to students. IBL offers a different teaching and learning experience from what both students and teachers are often used to. The difference is created by the change in the teaching and learning approach from the 'sage on the stage' to the 'guide on the side' (Mazzolini and Maddison, 2003). The different experience often takes both the students and teachers out of their teaching and learning style comfort zone (Haupt and Harinarain, 2015). Given this 'discomfort' appropriate support is therefore required for both students and teachers to make a comfortable transition to IBL (Spronken-Smith and Kingham, 2009).

3.5.1 Student Experiences with IBL

Students initially experience a cultural shock from the different learning experience offered by IBL and find difficulties in adjusting to the approach and coping with group dynamics (Haupt and Harinarain, 2015; Meijerman *et al.*, 2013). Harinarain and Haupt (2016) reported that students felt reticent about the IBL approach and doubted whether the knowledge they acquired through IBL was sufficient for their future careers. Other studies also reported student dissatisfaction with the IBL approach arguing that it is more demanding and time consuming and that the total amount of study time both in and out of class was larger for IBL (Spronken-Smith, 2005; Spronken-Smith *et al.*, 2008). This is consistent with the conclusion by Lazonder and Harmsen (2016) that IBL can be too complex for students and consequently induce very high cognitive loading and therefore require more time and effort to assimilate. Meijerman *et al.* (2013) also found that students spend more time on the IBL module and pay less attention to other modules. However, Spronken-Smith *et al.* (2008) concluded from experience that there is no particular difference in student study time but attributed the reported extra study time to students driving themselves and their peers to work harder on the IBL projects. Nevertheless, while the total amount of study time may be similar to non-IBL approaches, the relatively higher cognitive loading in IBL is likely to demand more effort from the students.

Group dynamics and group sizes were found to be an issue in IBL (Spronken-Smith, 2005; Spronken-Smith *et al.*, 2008). Owing to the constraint on the number of instructors available and the general tendency to relatively large classes, it is sometimes inevitable to make groups of up to eight students. Generally, groups of seven – eight students were thought to be too large while groups of four – five were considered good practice (Harinarain and Haupt, 2015; Haupt and Harinarain, 2015; Meijerman *et al.*, 2013; Spronken-Smith, 2005). Students experienced some undesirable elements of IBL such as groups drawing on the strengths of individuals to get the group work done rather than addressing weaknesses of the groups (Spronken-Smith, 2005). For example, groups often nominated the same person to give presentations and make posters meaning that other group members did not get the chance to develop the particular skill (Ibid). Students also expressed concern that they were not getting value for money since they were not being explicitly taught (Harinarain and Haupt, 2016; Spronken-Smith, 2005). Students also expressed concern about how the work done in groups was assessed with suspicion that it was possible for a member of the group to not contribute equitably to the outcome/product and yet receive the same grade as other group members (Harinarain and Haupt, 2016). To obviate this concern, a strategy of peer assessment might be useful.

In order to address some of the concerns from students, Spronken-Smith *et al.* (2008) suggested new students need to be oriented on contact time, self-directed learning, outside classroom activities and describe the rational for the IBL approach, among other interventions, so that students understand what to expect and is expected of them in the IBL approach. To specifically deal with problems around group dynamics, Spronken-Smith *et al.* (2008) suggested providing a specific opportunity for groups to discuss how they will function effectively. Haupt and Harinarain (2015) rotated the role of group leader to allow each student develop the skill of leading. Work load issues and cognitive loading must also be considered since IBL can result in some anxiety for students as they tend to get fully engaged in these courses at the expense of other modules (Hmelo-Silver *et al.*, 2007; Mäeots and Pedaste, 2014; Spronken-Smith *et al.*, 2008).

3.5.2 Instructor Experiences with IBL

There is a dearth of research on instructor experiences of IBL (Spronken-Smith *et al.*, 2008). White and Frederiksen (1998) reported that instructors found the IBL curriculum difficult to teach and time consuming mostly because they lacked the training and support needed to implement the curriculum well. Harinarain and Haupt (2016) equally expressed the sentiment that instructors are initially unsure about their role and involvement when they have not been properly oriented to the IBL approach. Effectively, the transition from the familiar teacher-centred approach to the less familiar student-centred approach creates a cultural shock owing to the different experience offered. However, Spronken-Smith and Harland (2008) reported that teachers found problem-based learning relaxing and enjoyable and the students were motivated and enthusiastic even though some teachers reported cultural shock evidenced by anxiety and stress. This was in a case study on the transition to IBL supported by a community of practice (COP) where the teaching staff formally and informally shared IBL teaching experiences. Therefore, supporting teaching staff and sharing experiences on IBL is necessary to equip instructors with the relevant skills to effectively deliver IBL (Spronken-Smith *et al.*, 2008; Spronken-Smith and Harland, 2008; White and Frederiksen, 1998). Spronken-Smith *et al.* (2008) suggested from experience that teachers should share experiences and feelings about how group work and group dynamics are progressing, possibly in formal and regular meetings as this may help inexperienced tutors who may struggle with the IBL approach. It is also important to involve as many of the teaching team in planning the course to give a sense of ownership and reduce problems of transition from the more familiar teacher centred approach to the often less familiar student centred IBL approach (Spronken-Smith, 2005; Spronken-Smith *et al.*, 2008).

3.6 The Role of the Instructor in the IBL Class

In order to deliver an effective IBL learning experience to students, a good instructor should empower and trust the students and engage with and act as a consultant (Goldring and Wood, nd). A good instructor should also have good presentation skills, a sense of humour, approachable, friendly, is positive, has empathy and fairness and is able to give and receive feedback (Ibid). The instructor can draw on a different number and combination of initiatives to help students at different stages of the IBL process. For example, to develop students creative thinking, the instructors can use such tactics as brainstorming, role playing, metaphorically thinking, free association, asking what if questions and improvisation and can also engage in structured debates, rebuttals, reading reactions, guided reflection logs, case analyses, discussion summaries and reflection or minute paper (Lim, 2004). To deepen discussion and further inquiry, the instructor may "guide students to identify main points, discuss pros and cons, rank or vote on ideas, find patterns and relationships and examine cost benefits" (Lim, 2004: 632).

Therefore, the specific role of the instructor varies depending on several factors including subject area, teaching style and student characteristics among others (Ibid). However, the major role of the instructor is to provide guidance to the students as they engage in the self-directed process of IBL. Guidance given to students is generally referred to as scaffolding. Scaffolding is a temporary support provided by an instructor to students to help them accomplish a task and is a requirement for all IBL processes (Lim, 2004; Spronken-Smith *et al.*, 2008). It is used to help student make progress in an inquiry process when faced with sticking points and to manage complex problems that often have attention-draining details (Lim, 2004). It is also used heavily at the beginning of the IBL approach to provide students with the skills required to get started with the inquiry process especially that students will often have had little or no experience with the approach (White and Frederiksen, 1998). Scaffolding may be given to the class generally or individually as direct and specific guidance in the form of responding to emails, reviewing test scores, assessing participation and providing contact lectures and workshops (Lim, 2004; Meijerman *et al.*, 2013). Other forms of scaffolding may include questioning, direct instruction, modelling/examples, feedback/praise, cognitive task structuring, cognitive elaborations/explanations, a push to explore, fostering reflection/self-awareness, encouraging articulation/dialogue, prompting general advice/scaffolding/suggestions and private emails or discussion (Lim, 2004). The amount of scaffolding provided needs to be weighed against the amount of self-directed learning desired. The balance between the freedom of students to explore and the guidance from instructors is delicate but depends on experience and confidence of both the students and the instructor (Spronken-Smith *et al.*, 2008). Scaffolding students is critical to the success of an IBL lesson (Pedaste and Sarapuu, 2006). For example, Meijerman *et al.* (2013) reported the benefits of scaffolding that students were highly motivated and stimulated by the IBL approach. This was attributed to the elaborate scaffolding provided which included a series of lectures, workshops on report writing, scheduled group meetings and poster discussions at different stages of the inquiry process. Also, students who receive guidance become more skilful during the IBL lesson, more successful at investigating information and score higher on post-tests. This was established from a meta-analysis of 72 articles on IBL where Lazonder and Harmsen (2016) concluded that while IBL is a self-directed process, guidance in the process is pivotal to the success of the approach.

3.7 IBL Assessment

Instructors need to provide formative assessment to provide students with adequate guidance and summative assessment to comply with regulations for progression. The reliance on group working in IBL means that some of the individual assessment methods may not be appropriate. Assigning marks to a group may pose its own challenges and so a number of individual assessments should be considered. Table 3-1 shows a number of assessment methods appropriate for IBL. Generally, IBL outputs should form part of the assessment and a final unseen examination may also be used for summative assessment (Kahn and O'Rourke, 2004). Structured group processes such as group meetings, if recorded, may also form part of the assessment (Ibid). In an IBL module, Meijerman *et al.* (2013) gave grades for group work and an individual grade for participation in discussions of other groups. A final individual assessment was also used to judge individual capacity. The total assessment comprised of 60% from group products and 40% from an individual assignment. In addition to group assessments of presentations and reports, Harinarain and Haupt (2016) used confidential peer assessment to assess the individual contribution of each group member. The final student grade was made up of an internal assessment of group submissions, peer assessment and individual performance during pin ups and an external assessment by a panel of industry practitioners of the group presentation of the final project.

Table 3-1: IBL assessment methods

Type of assessment	Connection with learning outcomes
Examinations	Only likely to be able to assess a limited range of the relevant learning outcomes.
Group assessment	Directly addresses team-working skills. May either address the group process or a product created by the group as a whole.
Patchwork texts	Addresses reflective, synoptic abilities, as well as the ability to piece together an extended argument. These are key abilities for the conduct of an inquiry.
Peer assessment	Aligns with group-based processes, and allows students to understand marking criteria (and thus the criteria by which of the success of the inquiry will be judged).
Personal accounts	The ability to manage an inquiry is closely related to the ability to consider and evaluate its progress.
Portfolios	Evidence selected in order to demonstrate the required learning outcomes.
Presentations	This provides an effective means to assess team working skills as well as other outcomes.
Reports	A report on the enquiry as a whole (e.g. project report or dissertation) or on one or more aspects of the inquiry (e.g. feasibility study or research proposal) provides a straightforward way to assess its outcomes.

Source: adapted from Kahn and O'Rourke (2004)

3.8 IBL Questions

IBL problems that may be investigated can be a group or individual project, a case study, field work, research activities or any type of problem for students to investigate (Lim, 2004; Meijerman *et al.*, 2013; Spronken-Smith and Kingham, 2009; White and Frederiksen, 1998). For example, Spronken-Smith (2005) used an authentic problem developed with a potential employer while Spronken-Smith and Kingham (2009) used a question. There is some disagreement about the most appropriate types of problems to address in an IBL class. Kahn and O'Rourke (2004) suggested that IBL question should be complex and open ended with a variety of solutions. Haupt and Harinarain (2015) suggested that problems should be authentic, ill-structured, complex, open ended, messy and ambiguous in beginnings, means and ends with neither correct nor incorrect multiple solutions. However, Haupt and Harinarain (2015) reported that students felt negatively about this type of inquiry problem. Spronken-Smith *et al.* (2008) felt that it was not necessary to have a variety of solutions. Lim (2004) argued against having too many diverse tasks stating that this may not help students focus on learning tasks and if activities are too complex, students may easily lose interest in the module. Lim (2004) therefore suggested that it is important to avoid too many complex questions and necessary to make tasks or processes manageable because too complex tasks easily overwhelm the student. Spronken-Smith *et al.* (2008) felt that questions need to broad to allow for multiple perspectives and exploration scope. In allowing for multiple possible answers, Spronken-Smith *et al.* (2008) presented an analogy to math saying that it is similar to asking students for the relationship between x and y as opposed to asking what is $x + y$? This approach is similar to the goal-free problem approach suggested by cognitive scientists as one of the measures which can reduce cognitive loading and promote learning (Sweller *et al.*, 1998). The efficacy of this approach has be reported by Wirth *et al.* (2009) and Ayres (1993) among others. While there is general disagreement on the appropriate nature of IBL problems to be investigated, there is unanimous agreement about the need for open ended questions and no disagreement about the need for questions to be broad. There are differences in the need, importance and appropriateness of having multiple possible solutions. Regardless of the type of problem used, Spronken-Smith *et al.* (2008) suggested that the IBL work activities should progressively build upon each other so that students get increasingly more autonomy and responsibility in determining the nature and method of inquiry.

Contemporary views and research from cognitive science have highlighted the importance of managing cognitive load and that situations of high cognitive loading do not allow for any meaningful learning to take place (Kirschner *et al.*, 2006; Srinivasan, 2011; Sweller *et al.*, 1998; Yuan *et al.*, 2006). Since solving or attempting to solve complex problems leads to high cognitive loading, more so in students with little prior knowledge, highly complex problems may not be the most appropriate IBL problems.

3.9 Factors Affecting IBL Curriculum Design

IBL is affected by several factors which can be placed in three groups namely student factors, instructor factors and other factors not emanating from either students or instructors. These factors can be seen graphically in Figure 3-3. Student factors include assessment, group work, workload and culture shock (Spronken-Smith, 2005; Spronken-Smith *et al.*, 2008). Instructor factors include training, support, experience and cultural shock (Spronken-Smith, 2005; Spronken-Smith *et al.*, 2008; Spronken-Smith and Harland, 2008; White and Frederiksen, 1998). Factors which neither emanate from students or instructors include learning space and cognitive loading (Hmelo-Silver *et al.*, 2007; Lazonder and Harmsen, 2016). These factors need explicit consideration in the design of an IBL curriculum.

Other than the factors which affect the delivery of an IBL curriculum, the contents of the IBL curriculum need careful examination to establish the best way to arrange them into an IBL curriculum. Traditionally, content has been arranged in distinct specialisations which can be fairly easily manipulated into a corresponding IBL curriculum by replacing much of the material covered through didactic instruction with appropriate student inquiry activities. For example, in changing the teaching and learning approach of a module from the traditional didactic approach to IBL, Meijerman *et al.* (2013) replaced much of the content perilously delivered by didactic instruction with four group projects and one individual assignment with supportive learning activities such as lectures, workshops, consultations and project meetings.

However, the case may not be as simple when it is desired to model an entire programme, and not a single module, for delivery through the IBL philosophy. When designing a programme curriculum for delivery through IBL, the number of modules needs to be kept to a manageable few owing to the demand imposed on students by IBL (c.f. Spronken-Smith, 2005; Spronken-Smith *et al.*, 2008). Preferably, several traditionally segregated modules may need to be integrated and learning objectives and outcomes aligned to come up with a module to be delivered through IBL. This way students will end up with a more integrated understanding of concepts from different specialisations and how these interact with each other which is more representative of what a good education should deliver (c.f. Brandon and All, 2010 citing Gidens and Brady, 2007; Mazhar and Arain, 2015). To achieve this, a case by case detailed analysis of the contents of the programme to be delivered through IBL needs to be undertaken to establish the most effective way to integrate and arrange the programme content.

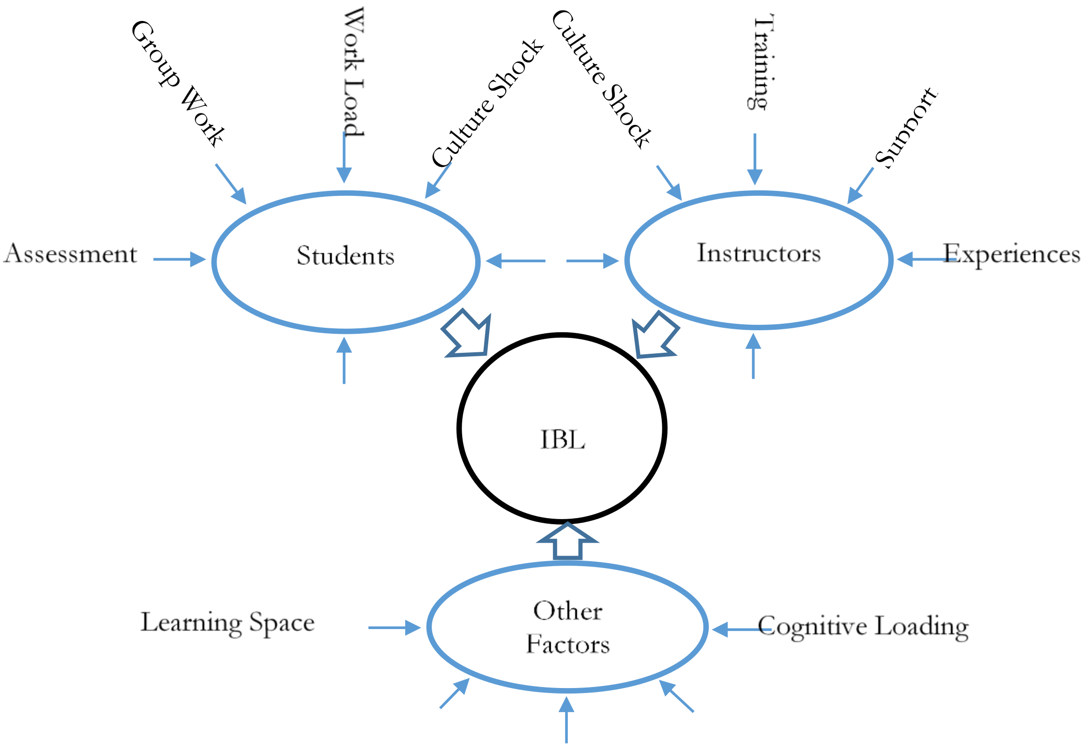


Figure 3-3: Factors affecting IBL

3.10 Chapter Summary

This chapter reviewed literature on inquiry based learning (IBL) which is the contemporary student centred teaching and learning philosophy. IBL has been reported to be far superior to the traditional didactic lecture approach to teaching and learning. The review of the IBL cycle provided the basis for the proposed IBL curriculum for construction programmes in response to the question *"How can antecedents to effective teaching and learning from contemporary theories of learning be used for the effective teaching of construction programmes in an IBL curriculum?"* While literature is replete with IBL models, none of the models are based on an integration of antecedents to effective teaching and learning derived from various theories of learning. The chapter started by establishing a definition of IBL since several variations of student centred pedagogy exist but share some distinct similarities. The IBL teaching and learning process was discussed and both student and lecturer experiences arising from the process were highlighted. The chapter also alluded to the role of the lecturer in the IBL process and the appropriate assessment methods and questions for IBL.

For this study, IBL has been defined as a broad philosophical teaching and learning approach which exhibits attributes of an inquiry process characterised by the active participation of students in the learning process. The inquiry process is always modelled into a cycle with phases that include students asking questions, collecting information, analysing the information thereby discovering knowledge previously unknown to the students and reflecting on the process. The effectiveness of the IBL approach is widely reported but qualitative and quantitative gains need further rigorous studies.

IBL offers a different teaching and learning experience to both the students and the teachers. The students experience more group work, an increased work load and a culture shock due to the change in the teaching and learning philosophy from the more familiar teacher centred approach to the less familiar student centred approach implicit in IBL. Students need support in the form of guidance and scaffolding to successfully navigate through the often unfamiliar IBL and deal with the resulting culture shock. Teachers also have a different experience which is characterised by a change in their role from being the 'sage on the stage' to the 'guide on the side'. In the transition from the former to later, teachers also experience a cultural shock. Therefore, teachers also need training and support to successfully make the transition from teacher to instructor.

Inquiry problems to be dealt with in IBL may be a case study, a project or any problem to investigate. There are conflicting recommendations on whether questions should be complex with diverse tasks or not but there is agreement that questions should be open ended, broad with multiple possible solutions. Consideration of cognitive loading suggests that it is better to avoid complex questions with diverse tasks as they lead to high cognitive loading. Since IBL often takes place in group settings, all group assessment methods including reports, presentations, portfolios and peer assessments may be used. In addition, individual assessment methods such as examinations based on the inquiry process may also be used. Generally, outputs from IBL should form part of the assessment.

IBL is affected by a number of factors including student and instructor factors which need consideration when designing an IBL curriculum. The curriculum content also need careful forethought if it is to be effectively delivered through IBL. Creating content for a single IBL module is quite simply achieved by replacing much of the content traditionally taught by instruction with appropriate IBL projects with relevant scaffolding. On the other hand, creating a curriculum for a programme to be delivered through IBL is much more demanding. The programme content needs to be integrated so that it can be effectively delivered through IBL. This requires a careful case by case analysed to establish the most effective way to integrate and arrange the programme content.

CHAPTER 4

THE CONCEPT OF EDUCATION

4.1 Introduction

The meaning and purpose of education are important to the question of how students should learn and the resulting format of the curriculum favoured. Therefore, this chapter reviews the concept of education by establishing what education is and what purpose it intends to achieve.

4.2 The Meaning of Education

The word 'education' is derived from the Latin word 'educare' which means 'to raise' and 'to bring up' (Kumar and Ahmad, n.d.; Rao, 2014; Yero, 2002). It also derives from the Latin word 'educere' which means 'to lead forth' or 'to come out' (Ibid). Others believe that the word education is derived from another Latin word 'educatum" which means to the act of teaching or training (Kumar and Ahmad, n.d.; Rao, 2014). The concept of education derives from the epistemology of idealism forwarded by Socrates and Plato who postulated that knowledge lies in the soul of a persons at birth (*an a priori process*) and education simply brings consciousness to this latent knowledge. Education has therefore for a long time sought to develop the innate or inner potentials of humans (Kumar and Ahmad, n.d.).

The dictionary of education (cited by Rao, 2014: 15) defines education as "the aggregate of all the processes by which a person develops abilities, attitudes and other forms of behaviour of practical values in the society in which s/he lives; the social process by which people are subjected to the influence of selected and controlled environment (especially that of the school), so that they may obtain social competence and optimum individual development". This definition carries two views of education, namely a narrow view and a broader view (Kumar and Ahmad, n.d.). The narrow view can be seen in the latter part of the definition which emphasises social process in a controlled environment aimed at creating social competences. The narrow view only considers the instruction offered in school as education and views it as the production of the literate or professionals such as, for example, doctors and engineers (Kumar and Ahmad, n.d.; Rao, 2014). The broad view lies in the first part of the definition which suggests that education is an aggregate of experiences which help shape abilities, attitudes and behaviour. This view considers education to include the narrow view and all other experiences which impact on the narrow view (Kumar and Ahmad, n.d.).

> "It is considered to be a lifelong process, where all the experiences, knowledge and wisdom that an individual acquires at different stages of one's life through different channels (i.e., formally, informally and incidentally) are termed as education. The broader view considers education as an act or experience that has formative or additive effect on the personality of an individual. It is believed that education is not only an instrument of social change, but also an investment in national development. Such a view of education encompasses all life experiences, as there is a shift in emphasis from individual development to national development. It is considered that education is a lifelong process that includes all experiences that the child receives in the school or at home, in the community and society through interactions of various sorts and activities. The broader meaning of education implies the process of development, wherein the individual gradually adapts himself/herself to various ways to his/her physical, social and spiritual environments" (Rao, 2014: 12).

Based on the two views, education is formal, non-formal or informal (Dib, 1987) and both a product and a process. The sum of what is received through instruction namely knowledge, skills, values, abilities constitute the product of education (Rao, 2014). As a process, education is "the act of developing the intellect, critical thinking abilities, social and cultural understanding, and understanding of one's own self" (Rao, 2014: 6).

> "Education is considered as an active and a dynamic process which takes place continuously during one's life by way of various experiences through either in a formal or in an informal manner. The individual continuously learns. In this process, he or she learns to utilise one's experiences in learning new things and also to reconstruct new things in the place of old ones "(Rao, 2014: 6).

Formal education is systematic, structured and organised in a model administered according to a prescribed set of rigid curricula rules of objectives, content and methodology (Dib, 1987). Non-formal education exists when most activities take place outside of school with no requirement for class attendance and fairly little contact between students and lecturers. This system is flexible to the needs and interest of the students (Ibid). Non-formal education exits in a number of frameworks including correspondence learning, distance learning and open systems (Ibid). Informal education does not aim to award certificates, but to supplement both formal and non-formal education through provision of activities such as listening to radio broadcasting or watching television programmes on educational themes; participating in scientific contests among others (Ibid).

4.3 The Purpose of Education

The primary purpose of education is based on either of the two philosophies of idealism or pragmatism. Idealism advocates for the purpose of education to be the pursuit of knowledge for the sake of knowledge which is for the general and moral development of a person (Kumar and Ahmad, n.d.). In this view, education is a privilege (Lambert and Biddulph, 2015). Pragmatism takes the stance of realism wherein the existing social-economic and political conditions are taken into account (Kumar and Ahmad, n.d.). In this view, the existing conditions of life are taken into account when establishing the purpose of education which generally is to prepare students for the economic and social development of the country (Ibid). This view advocates that education should prepare young people for work rather than the mere privilege of learning-to-learn (Lambert and Biddulph, 2015). Subsequently, the pragmatic stance suggests that each country should consider its social economic situation which leads to some variability in the specific purpose and objectives of education from country to country (Ibid).

In tandem with the pragmatic view, empirical studies have reported the positive relationship between higher education and economic development such as, for example, Cremin and Nakabugo (2012), Kruss, McGrath, Petersen and Gastrow (2015) and Menon (2008). Ankudinov, Biktemirova and Khairullina (2014) found a positive economic outcome of attainment of a tertiary education. This is in tandem with many other studies on the topic. However, a declining economic benefit arising from more advanced tertiary degrees was also reported (Ibid). Pritchett and Banerji (2013) also found that average wages for workers who had stayed longer in school are not always associated with higher economic growth in some countries. Economic benefits of education accrue to the nation at large, the company worked for and the individual as well. Therefore, the pragmatic view of education demands that an educated person be able to make a meaningful economic contribution to the enterprise without the need for further schooling. The social benefits of education include trust at both the individual and aggregated country level (Charron and Rothstein, 2016). Education can therefore be used to foster social change (Jerrard, 2016).

4.4 Educational Views

There are three broad views on education namely the classical views, liberalists' views and the progressivist views (Rao, 2014; Dupuis and Gordon, 2010). Classical views of education assert that "only 'academic subjects' are worthy of the name 'education'; any activities involving the body such as manual skills, crafts, and vocational preparation are not education, but training. This classical view asserts that only the activities of mind designed to develop the rational part of the composed being are truly educative" (Dupuis and Gordon, 2010: 10). The liberalists' views are diametrically opposed to the mind-body dichotomy of the classical views and assert that all facets of human life are the concerns of education (Rao, 2014; Dupuis and Gordon, 2010). Progressivist views postulated by among others, John Dewey, assert that education is the 'reconstruction of experiences' whereby the experiences of learners are reshaped by formal education to achieve knowledge which enhances understanding (Ibid).

This study therefore considers education to be both a product and a process limited to the formal level only and to the narrow view. The education advanced in this research therefore reflects only on the activities which take place in class but acknowledges the influence of factors outside the classroom which significantly impact on learning and therefore takes the progressivist view. It considers education as a product in that the graduate should be ready to take up responsibilities and make a meaningful contribution to industry at graduation without the need for further extensive training. It is a process because to engender critical thinking and problem solving skills among others, requires a development of these skills at an individual level, which requires a process of constant reflection on experiences. The study limits education to the classroom since it is not possible to study the entire system simultaneously but acknowledges the significance of the broader view by taking a progressivist stance which in itself acknowledges experiences outside of class. The progressivist view is also favoured because the study views the educated student as one with skills, competences and knowledge to function in the construction industry. Based on this conception, for a person to be educated, s/he should also have some body of knowledge and some kind of conceptual understanding to rise above the level of a collection of disjointed facts (Rao, 2014). In attaining the body of knowledge and conceptual understanding, one must also know the 'why' of things (Ibid).

4.5 Chapter Summary

This chapter reviewed literature on the meaning and purpose of education as these are important to the overall question of how and what students should learn and be taught. The dictionary of education (cited by Rao, 2014: 15) defines education as "the aggregate of all the processes by which a person develops abilities, attitudes and other forms of behaviour of practical values in the society in which s/he lives; the social process by which people are subjected to the influence of selected and controlled environment (especially that of the school), so that they may obtain social competence and optimum individual development". This definition carries two views, namely the narrow view and the broad view of education. The narrow view only considers education to be the instruction offered in school as education and views it as the production of the literate or professionals such as, for example, doctors and engineers. The broad view, on the other hand, considers education to include the narrow view and all other experiences which impact on the narrow view of education.

Based on the philosophical view adopted, the purpose of education can either be the pursuit of knowledge for the sake of knowledge, which is based on the philosophy of idealism. The purpose of education can also be that it should prepare young people for work rather than the mere privilege of learning-to-learn, which is based on the philosophy of pragmatism. Education can be broadly viewed as being classical, liberalists or progressivist. The classical view holds that only 'academic subjects' are worthy of the name 'education' and so education should only be concerned with developing the mind. Activities which involve the body are viewed as training rather than education. The liberalist view holds that all facets of human life are the concerns of education while the progressivist view holds that education is the 'reconstruction of experiences'.

While this study acknowledges the importance of the broad view of education, it limits its focus to the narrow view only since the research is concerned with the school curriculum only. The study advocates for the pragmatic philosophy because the thesis argues for the need to produce graduates who can make a meaningful contribution to professional practice on graduating. The study also does not limit education to the classical view and acknowledges the significance of the liberalist view. However, based on the theory of constructivism, which is the contemporary theory in epistemology, this study takes the progressivist view of education.

CHAPTER 5

CONSTRUCTION EDUCATION

5.1 Introduction

The previous chapter explored the meaning and purpose of education with a view to establish what education is and how that influences how students should learn. It established that education should be more than just a collection of disjointed facts but should also include skills and abilities in addition to a body of knowledge. This chapter considers what students should learn because it is critical to how students should learn. The chapter therefore establishes, firstly, what should generally be learnt by any educated person and, secondly, what should be specifically learnt in a typical construction programme. The chapter starts by highlighting the key skills required of a 21st century educated person and then establishes what topics should be taught in construction programmes and closes by looking at how the construction programmes are delivered. The chapter responds to the research questions *"What is the appropriate range of construction knowledge which should be included in a construction programme curriculum?; What type of construction knowledge is best learnt through the didactic approach?; What type of construction knowledge is best learnt through IBL? and What type of knowledge is best integrated and taught together through an IBL approach?"*

5.2 21st Century Key Education Skill

A plethora of studies have reported on the competences which are required of an educated person based on skills and abilities. Table 5-1 summarises some of these skills and abilities as being necessary for a graduate in the 21st century. The skills and abilities have been conceptualised and labelled differently by different authors but all point to soft skills.

Most of the skills and abilities fit in with the four clusters of skills domain of an educated person in the 21st century created by Trilling and Fadel (2009), namely, core subjects and skills including reading, writing and numeracy (3Rs) which are needed to be educated; learning and innovation skills which are critical thinking, problem solving, communication and creativity and innovations; career and life skills which are collaboration and teamwork leaderships and responsibility, initiative and self-direction, flexibility and adaptability, social and cross cultural interaction, career and learning self-reliance; and digital literacy skills which are computer literacy, information literacy, information and communications technology (ICT) literacy and media literacy. Based on these key skills domain, Kivunja (2014) summarised the key skills required as:

JR 21CS = f(TCS + LIS + CLS + DLS)

where:

JR 21CS = Job Readiness with 21st Century Skills

f = is a function of:

TCS = Traditional Core Skills

LIS = Learning and Innovation Skills

CLS = Career and Life Skills

DLS = Digital Literacy Skills

Therefore, for a graduate to be job ready with 21st century skills, they need to possess traditional core skills, learning and innovation skills, career and life skills and digital literacy skills. Any teaching and learning approach should therefore have an in-built methodology for ensuring that it does not only end up teaching the core skills also known as the 3Rs (**r**eading, w**r**iting and a**r**ithmetic) but also delivers the remainder of the requisite skills.

Table 5-1: 21st Century Skills

Reference	21st Century Skills
Trilling and Fadel (2009)	Four key domains - core subjects and skills (reading, writing and numeracy (3Rs)); learning and innovation skills (critical thinking, problem solving, communication and creativity and innovations); career and life skills (collaboration and teamwork leaderships and responsibility, initiative and self-direction, flexibility and adaptability, social and cross cultural interaction, career and learning self-reliance); and digital literacy skills (computer literacy, information literacy, information and communications technology (ICT) literacy and media literacy)
Osman, Soh and Arsad (2010)	ICT skills; inventive thinking; effective communication; and high productivity
Turiman, Omar, Daud and Osman (2012)	Four main domains – digital age literacy; inventive thinking; effective communication; and high productivity
Pheeraphan (2013)	Collaborative communication; information literacy; media literacy; and ICT literacy
Fong, Sidhu and Fook (2014)	ICT skills; collaborating; lifelong learning; critical thinking; creative thinking; effective communication; and high productivity
Zulu and Haupt (2015)	Independent thinking; problem solving; innovative and creative thinking; independent learning; lifelong learning; communicating
Egan, Maguire, Christophers and Rooney (2017)	Creativity

5.3 Construction Knowledge Areas

While emphasis in the 21st century is on skills and abilities, these need to be applied within a profession. Therefore, comprehension of background scientific theory is also important for engineering education (Nickchen and Mertsching, 2016). Subsequently, a typical engineering programme comprises of the teaching of basic science in the first year and reinforced in subsequent years and specialisations taught in the fourth and fifth years of a five-year programme (Cachim, 2015). In addition to engineering science, practical engineering experience with real world relevance is also beneficial for students (Nickchen and Mertsching, 2016). However, the typical curriculum places emphasis on science while ignoring engineering practice (Crawley, 2001). Crawley (2001) noted that from the 1950's emphasis was placed on science rather than engineering practice. This was blamed on the fact that fewer teaching staff had worked as engineers (Crawley, 2001).

Table 5-2: Construction Core Knowledge Areas

Reference	Building Construction Core Knowledge Areas
RICS (1998)	**Basic** Conduct rules, ethics and professional practice; Client care; Communication and negotiation; Health and safety; Accounting principles and procedures; Business planning; Conflict avoidance management and dispute resolution procedures; Data management; Sustainability; Team working. **Core** Design economics and cost planning; Contract practice; Construction technology and environmental services; Procurement and tendering; Project financial control and reporting; Quantification and costing of construction works **Optional** BIM management; Capital allowances; Commercial management of construction; Conflict avoidance management and dispute resolution procedures; Contract administration; Corporate recovery and insolvency; Due diligence; Insurance; Programming and planning; Project evaluation; Risk management; Sustainability.

Table 5-2: Construction Core Knowledge Areas (Continued)

Reference	**Building Construction Core Knowledge Areas**
Nkado and Meyer (2001)	Computer literacy and information technology; Procurement and financial management; Economics of construction; Construction contract practice; Measurement; Professional practice; Marketing; Personal and interpersonal skills; Development appraisal; Advanced financial management; Leadership and general management skills; Project management; Skills to work with emerging contractors; Skills in managing a business unit; Construction technology and environmental services; Arbitration and other dispute resolution procedures; Law; Property investment funding; Management of joint quantity surveying appointment; Mapping; Macro-economic perspectives; Facilities management; Research methodologies and techniques
Said, Shafiei and Omran (2010)	Meta-competences (personal and interpersonal skills); construction economics, cost and financial management; management of construction project procurement and contract; measurement, quantification and documentation; construction technology and engineering; information and communication technology; project management principles and practice; international QS practice
Perera, Pearson and Dodds (2012)	In addition to the recommendation by RICS (1998) included - sustainability, business management and planning, accounting, communication (language, report writing and team working), new building technologies, pre-fabrication, civil and infrastructure
Sonson and Kulatunga (2014)	**Traditional role** Quantification and costing of construction works, Project financial control and reporting, Procurement and tendering, Contract practice, Cost planning, Construction technology and environmental services, **Evolved Role** Valuation (property, rental, etc.), Contract administration, Consultancy services, Project Management, Insurance, Facilities management, Risk management, Management and Dispute Resolution procedures, Development/investment Appraisal, search Methodologies and Techniques, **Emerging Role** Whole Life Costing Assessment, Strategic Management and Leadership, value management studies, Sustainability, BIM Management
Dada (2014)	Feasibility/viability studies; Development economics; Economic management of urban infrastructure; Cost planning and control; Estimating; Construction procurement system; Contract documentation; Contract administration; Project management; Financial management; Facility management; Risk management; Valuation; Life cycle costing; Arbitration and dispute resolution

There is a plethora of literature on specific knowledge areas required by professionals working in the construction industry to build such as, for example, Nkado (2000), Nkado and Meyer (2001), Perera, Hemaijth and Ginige (2007), Perera *et al.* (2012), Said *et al.* (2010), Shafiei and Said (2008) and Sonson and Kulatunga (2014). Most of these are very similar to the RICS (1998) model of skills and competences for construction professionals. Some of these are summarised in Table 5-2. The competences suggested by Trilling and Fadel (2009) are very similar to those suggested by RICS (1998) except for the classification and the fact that those by Trilling and Fadel (2009) are more comprehensive.

Some differences can be noted among the suggested knowledge areas even though most of them are based on the conception by RICS. This can be attributed to fact that since the RICS model does not give lengthy descriptions, they are open to interpretation (Perera *et al.*, 2012). Therefore, differences and omissions from one suggested list to another is mostly due to different semantics as they all more or less converge on the same knowledge set.

The key skills domain for construction programmes adopted for this study is based on Trilling and Fadel (2009) due to its comprehensiveness while the construction key knowledge areas adopted are as advanced by RICS (1998). The Royal Institute of Chartered Surveyors (RICS) model is adopted because it is widely recognised and regarded in the construction profession and most of the literature classifying key knowledge areas in construction disciplines makes reference to it.

5.4 Delivery of Construction Education

Traditionally, construction programmes are largely delivered through a didactic approach. The didactic approach has come under constant criticism due to it being more centred on the lecturer than the students and more so due to its emphasis on knowledge transmission (Jalani and Sern, 2015). These attributes make the didactic approach predisposed against the delivery of the requisite skills and abilities (Rouvrais, Ormrod, Landrac, Mallet, Gilliot, Thepaut and Tremenbert, 2006). Subsequently, other pedagogy which are centred on the student and are arguably better able to teach the required skills and abilities are becoming popular (Erdogan and Senemoglu, 2014; Rodríguez *et al.*, 2015). In most instances, these contemporary pedagogies are being applied sporadically within the traditional didactic paradigm.

However, some universities have moved from applying student centred pedagogy within the traditional paradigm to offering entire programmes through student centred approaches. One such notable programme is the CDIO (Conceiving-Designing-Implementing-Operating) pedagogical approach. It is an innovative educational system characterized by a cycle modelled around students providing engineering solutions to problems in a manner akin to actual engineering practice. This is achieved by, firstly conceiving the engineering solution by defining customer needs and considering all relevant aspects incidental to the conception of the solution; secondly by being able to design the appropriate solution; thirdly by being able to implement the design by transforming it into a product; and finally being able to operate the product to achieve the intended value (CDIO, 2014). The CDIO pedagogy models real world products, processes and systems while teaching engineering programmes (CDIO, 2017). It was conceived on the basis that "graduating engineers should be able to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment" (Crawley, 2001: 2). The approach was developed at the Massachusetts Institute of Technology (MIT) in response to criticisms of engineers lacking many abilities required in real world engineering practice (CDIO, n.d.-b; Crawley, 2001). It was developed to enhance the learning of skills and attributes desired in contemporary engineers which the traditional didactic teaching and learning approach is unable to achieve (Crawley, 2001). The approach is becoming an accepted best practice in engineering education and has since spread across many leading universities in the world. Developments in the approach are monitored and spearheaded by an association with a membership of more than 120 universities organised in seven regions namely, Europe, North America, Asia, UK-Ireland, Latin America, Australia, New Zealand and Africa (CDIO, n.d.-a).

The CDIO approach has been reported to offer many advantages to engineering education (Lantada, Olmedo, Felip, Fernández, García, Alonso and Huertas, 2016; Osipova, Stepanova and Shubkina, 2016; Wei, Zhixiang and Jiayang, 2016; Yew, Anwar and Maniam, 2016). Lantada *et al.* (2016) reported that students were better prepared for professional practice after going through a complete development process of engineering systems in Biomedical Engineering in Spain. Osipova *et al.* (2016) reported benefits of the CDIO approach in a programme in Russian while Wei *et al.* (2016) reported significant improvements in the ability of students to prepare Environmental Impact Assessment Reports (EIA) and also improvements in general engineering after reforming the curriculum to a CDIO approach. Rouvrais and Landrac (2012) reported improved program quality and ability to meet accreditation standards at Telecom Bretagne, Institut Mines-Telecom; Université européenne de Bretagne in France after they chose to use CDIO standards for improvement using an integrated curriculum which is student centred and is delivered through an active pedagogy and project based learning (Project-BL) using projects linked to complex pluridisciplinary system.

The CDIO curriculum is distinguished from other pedagogies based on its teaching and learning philosophy, curriculum model, design-build experiences and workspaces for students, new methods of teaching and learning, faculty development and assessment and evaluation (CDIO, 2014). These are fundamentally student centred and hinged on active learning with an integrated curriculum of problem or project based learning (CDIO, n.d.-b; Crawley, 2001). The projects engaged in are often real world engineering problems. For example, Hansman (2009) reported on a year-long student project at the MIT to develop a flight vehicle that would serve as an airborne sensing platform for high precision antenna calibration commissioned by a government entity. Other examples of CDIO student projects based on real problems include a project commissioned by the National Aeronautics and Space Administration (NASA) for students to conceive, design, and build (implement) Estes Model rockets and launch (operate) them with the goal of launching the most massive payload possible to 300ft at minimal cost (CDIO, 2018). Another one was to design and fabricate a skyscraper capable of sustaining a load capable of handling an "earthquake," by first and second year engineering students (Gray, 2011). The CDIO curriculum draws correspondence with contemporary IBL pedagogy which are constructivist in nature. Constructivist pedagogy (for example, IBL), quite like the CDIO approach, often require students to work in groups on real world problems by designing and building solutions in workspaces different from traditional teaching spaces while being appropriately guided (Hmelo-Silver *et al.*, 2007; Kori *et al.*, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon *et al.*, 2011; Spronken-Smith *et al.*, 2008). Constructivist pedagogy which require students to engage in scaffolded student-centred self-directed learning in a cycle of inquiry akin to the CDIO cycle are generally classified as inquiry based learning (IBL). Therefore, the CDIO curriculum is essentially IBL and so owes its efficacy to its inherent IBL nature.

While the CDIO approach offers a very good example of a curriculum based on IBL, it is not the only attempt to model an entire curriculum of an engineering or construction programme on IBL. In the United States of America, California Polytechnic State University at San Luis Obispo and Mississippi State University implemented a student centred programme for their construction management programmes using studio-based learning, which is IBL in nature. This was in response to criticisms surrounding the traditional didactic lecture approach to teaching and learning (Monson and Hauck, 2012). The IBL programmes at California Polytechnic State and Mississippi State universities has been operating for nearly two decades now which is nearly as long as the CDIO programmes (Ibid). The CDIO programmes stand out only because the approach has developed a very successful community of international universities which meets for a conference every year. There are probably other universities using IBL for their entire programmes but have not published much research about the programmes.

5.5 Chapter Summary

This chapter reviewed literature on construction education in particular so as to establish what students in construction programmes should learn. The chapter responded to the following specific questions, *"What is the appropriate range of construction knowledge which should be included in a construction programme curriculum?; What type of construction knowledge is best learnt through the didactic approach?; What type of construction knowledge is best learnt through IBL? and What type of knowledge is best integrated and taught together through an IBL approach?"* Literature if replete with the appropriate range of construction knowledge required in a construction programme. However, in view of the knowledge explosion due to advancements in technology, it was necessary to establish an appropriate range of knowledge. Also, not all knowledge is best learnt through IBL and literature does not explicitly recommend what knowledge is best learnt through IBL and which one is not.

In this century, emphasis is being placed on graduates having problem solving skills, team working skills, communication skills and digital literacy among a few other soft skills as opposed to possessing knowledge only. Construction programmes should at least include the teaching and learning of the following:

a. *Basic knowledge areas*: team working, health and safety, accounting principles and procedure, business planning, conflict avoidance and dispute resolution, sustainability, ethics, client care among others.
b. *Core knowledge areas*: design economics, project planning and management, construction technology, contracts, procurement and tendering, cost control, quantification and computer literacy among others.
c. *Optional knowledge areas:* building information modelling (BIM), project evaluation, risk management, leadership, facilities management, whole life cycle costing, cost analysis, value management and research methodology. The three knowledge areas are modelled around the project nature of the

construction industry. Therefore, they encompass the entire project life-cycle from inception to completion.

While most of the generic construction knowledge is incorporated in the curricula construction programmes, it is most delivered through the traditional didactic lecture approach. A few institutions are diverting from the traditional approach of teaching and the CDIO approach is one example of this shift.

CHAPTER 6

THE CURRICULUM

6.1 Introduction

The previous two chapters explored the concept of education generally and construction education in particular respectively. It was established that education is the aggregate of all experiences, academic or otherwise, through which knowledge, skills and abilities are attained. Educational experiences needed to achieve the desired level of education are designed in a curriculum. This chapter explores the concept of a curriculum. The chapter starts by defining what a curriculum is because the term is used loosely to mean different things by different authors. The definition of a curriculum adopted is based on the understanding of education and its purpose as highlighted in the previous chapter. The chapter further explores the objectives of a curriculum and also evaluates three curriculum development models.

6.2 Curriculum Defined

In literature, the term curriculum is used quite very loosely as a synonym for pedagogy or andragogy, syllabus or curricula content or even reduced to mean a timetable (Kelly, 2004; Lambert and Biddulph, 2015; Shay, 2011). While some equate pedagogy to curriculum, Lambert and Biddulph (2015) argued that they are conceptually distinct with competing priorities. The ambiguity in the definition of a curriculum is very common in literature on curriculum development. This is because literature on curricula is replete with empirical studies on curriculum development. Many such studies apply the term curriculum in tandem with their study focus. The study focus may be on modification, refinement or enhancement of curricular content or different pedagogical approaches each of which ends up being presented as the curriculum (Lambert and Biddulph, 2015; Shay, 2011). In extant literature, curriculum is therefore not a clear cut concept (Lambert and Biddulph, 2015). It is perhaps because of the ambiguity that Barnet and Coate (2005) (cited in Shay, 2011) commented that curriculum is a missing term in higher education; missing from public debate and government policy and even missing from educational text.

Curriculum has been defined differently by different authors. Lambert and Biddulph (2015) defined a curriculum as what to teach. This definition presents a curriculum as an artefact and excludes how the teaching is done and other curricular activities, processes and experiences by students. Tyler (2013) (cited in Kumral, 2016) defined curriculum development as the design of an educational system. This description insinuates that a curriculum is an educational system. This definition is very succinct but at the same time provides a broad definition in that it views the curriculum as a system and so includes all educational activities and processes including extra-curricular activities. However, in the absence of a description of the educational system referred to, it becomes vague. Bernstein (1975) cited in Shay (2011) defined a curriculum simply as valid knowledge. This view considers a curriculum as the artefact knowledge and not a process, system or series of activities. It is therefore quite simplistic because it essentially excludes activities, processes and experiences required to acquire valid knowledge. To avoid the over-simplification, it would be more appropriate to view the curriculum as a system through which valid knowledge is created. Such a conception acknowledges activities, processes and experiences associated with a curriculum and resonates with the definition by Tyler (2013) cited in Kumral (2016) of curriculum development as the design of an educational system. Medland (2010) defined a curriculum as all intended learning experiences within and beyond formal teaching. This definition comprehensively covers all aspects of learning and acknowledges both formal, informal (Dib, 1987) and extra-curricular activities. This definition is in tandem with the definition by Kerr (1968) cited in Kelly (2004) that a curriculum is all the learning which is planned and guided by the school. This definition equally acknowledges both formal and informal education and extra-curricular activities since these are all planned by the school. These definitions are summarised in Table 6-1.

Table 6-1: Curriculum Definitions

Author/s	**Publication Title**	**Curriculum Definition**
Lambert and Biddulph (2015)	The Dialogic Space Offered by Curriculum-Making in the Process of Learning to Teach, and the Creation of a Progressive Knowledge-Led Curriculum	What to teach
Tyler (2013) cited in Kumral (2016)	Specific Approaches in Curriculum Development	Design of an educational system
Medland (2010)	Creating a 21st Century Curriculum: The King's-Warwick Project - Assessment and Feedback	All intended learning experiences within and beyond formal teaching
Bernstein (1975) cited in Shay (2011)	Class, Codes and Control	Valid knowledge
Kerr (1968) cited in Kelly (2004)	Changing the Curriculum	All the learning which is planned and guided by the school

Notwithstanding the ambiguity in some definitions of a curriculum, it is generally unanimously acknowledged that a curriculum is comprised of the content to be taught or learnt and the manner of delivery of the content. The content is referred to as the "What" of the curriculum while the delivery is referred to as the "How" of the curriculum. For example, Lambert and Biddulph (2015) classified the "What" as curriculum and the "How" as pedagogy. It is this conception which reduces the definition of a curriculum by Lambert and Biddulph (2015) to an artefact detailing curricular content. Also, because of this reduction, Lambert and Biddulph (2015) suggest that "What to teach" is the fundamental curricular question. Notwithstanding that the "How" question is relegated from the description of a curriculum, Lambert and Biddulph (2015) acknowledge that the "What" and the "How" are inextricably intertwined though they further argued that these have competing priorities.

Alternatively, the curriculum can be viewed from the larger context of education. Education is the aggregate of all activities and processes which develop the knowledge, skills and abilities of students (Kim, Suh and Song, 2015). Education is therefore both a product and a process. The sum of what is received through instruction, namely, knowledge, skills, and abilities constitute the product of education (Rao, 2014). As a process, education is "the act of developing the intellect, critical thinking abilities, social and cultural understanding, and understanding of one's own self" (Rao, 2014: 6). Viewed broadly, education includes all life experiences which help to gain knowledge, skills and abilities and so develop the intellect. This broad view of education is in contrast to the narrow view which only considers education as the instruction offered in school (Kumar and Ahmad, n.d.). Using a systems thinking approach, the broad view of education, which includes all life experiences, initially breaks down into two educational sub-systems of activities which take place at school and those activities which take place outside school and are not part of any planned school activities (Kim *et al.*, 2015). The activities and processes which take place in school and some of those which take place outside school but are part of the activities planned by the school (the narrow view of education) constitute the curriculum system. Within this system, some activities and processes will be of an academic nature while others will be of a non-academic nature (Ibid). The activities of a non-academic nature but planned by the school are referred to as co-curricular or extra-curricular activities. This conception of the curriculum can be seen depicted graphically in Figure 6-1.

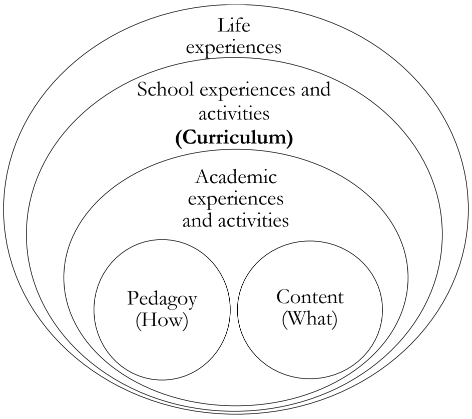


Figure 6-1: Curriculum System

Another way of looking at the curriculum but still with a systems approach view is by starting from the extra-curricular activities sub-system. The readily acceptable notion of extra-curricular or co-curricular activities to refer to non-academic school activities (Medland, 2010) gives impetus to the fact that there must exist a curricular system to which the extra or co-curricular activities relate. Since, in a school system, what remains after isolating extra or co-curricular activities would be academic activities and processes, it suffices that this sub-system would be the academic curriculum. Therefore, from this notion of extra-curricular and academic-curricular activities, it follows that a curriculum is the sum of extra-curricular and academic curricular activities and processes. However, the notion of an academic curriculum is not espoused in literature notwithstanding that the correspondence with extra or co-curricular activities is logical.

Kelly (2004) argued that to be practically effective, the definition of a curriculum needs to be more than just a statement about the knowledge content or the subjects to teach. According to Kelly (2004), the definition should explain and justify the purpose of teaching and explore effects of exposure to the knowledge and subjects which is the student learning experience. It should also capture aspects of the curriculum which are inadvertent, overtly or completely unintended. It should further acknowledge the formal planned activities and processes delivered and received by students. It should also acknowledge formal planned and timetabled activities and informal activities which are outside academic school time activities which are separate from and over and above academic curricular activities. Kelly (2004) further summarised these proposed aspects of a curriculum into four major dimensions which a curriculum definition should embrace. These major dimensions are the intentions of the planners, the procedures for implementation of the intentions, the actual experiences of the students and the hidden intended learning.

This study therefore defines a curriculum as the sum of all academic and non-academic activities, processes and experiences, formal, informal and unintentional, designed to educate students, initiated by the school system, within or outside school. This definition resonates with definitions by Tyler (2013) cited in Kumral (2016), Medland (2010) and Kerr (1968) cited in Kelly (2004) all of whom acknowledge a curriculum as a system (Tyler, 2013) and learning experiences within the system (Kerr, 1968; Medland, 2010). Further, this study definition explicitly states the educational system referred to contrary to Tyler (2013) which does not give a clear indication of the extent of the educational curricular system referred to. The study definition also responds to the four major dimensions of the intent of the curriculum planner, implementation procedures, student experiences and hidden learning suggested by Kelly (2004). However, while the suggested definition of a curriculum covers a fairly broad system comprising both an extra-curriculum and an academic-curriculum, and all their associated learning activities and experiences, the focus of this study is on the academic-curriculum system comprising of the curricular content and the pedagogical methodology.

6.3 Curriculum Objectives

Since a curriculum is meant to deliver an education to students, it should be designed to help students retain lasting new memories or neural connections of knowledge which can be used broadly in any appropriate real-life situation (Watagodakumbura, 2017). This is in tandem with the goals and objectives of education which are to prepare students for work so that they can contribute to the economic and social development of the country (Charron and Rothstein, 2016; Cremin and Nakabugo, 2012; Jerrard, 2016; Kruss *et al.*, 2015; Lambert and Biddulph, 2015; Menon, 2008). Therefore, it must integrate the learning of skills, abilities and creative thinking (Lee and Kolodner, 2011). To achieve this, the curriculum should be compatible with how students learn (Kumral, 2016) so that it can achieve the intended learning outcomes. Therefore, among other antecedents to effective learning, there should be repetition and reflection which will lead students to incrementally become experts (Lee and Kolodner, 2011) in tandem with how professionals develop. Further, it should lead students to higher order learning on the higher end of Blooms' Taxonomy which is the level of evaluation and creation (Watagodakumbura, 2017) so that they can deal with real world problems innovatively. The curriculum should also challenge students in their zone of proximal development and should be appropriately scaffolded (Christmas, Kudzai and Josiah, 2013; Lee and Kolodner, 2011; Murray and Arroyo, 2002; Shabani, Khatib and Ebadi, 2010). The curriculum should further engage students in active learning and self-directed learning appropriately scaffolded in tandem with constructivism (Mathews, 2010; Meijerman *et al.*, 2013; Spronken-Smith *et al.*, 2008). In addition to all this, the curriculum should pay attention to the level of cognitive loading induced in students (Hadie and Yusoff, 2016; Leppink, 2017; Roussel, Joulia, Tricot and Sweller, 2017; Sweller and Paas, 2017).

Owing to these rudiments of a good curriculum, there is a growing demand for curricula to broaden and deepen knowledge and the skill base of the graduate (Shay, 2016). However, the limited time within which students are expected to learn coupled with a large and constantly increasing body of knowledge which the students are expected to master, there is a conflict between the breadth and the depth of the educational experience which should be offered by the curriculum. Therefore, a question arises as to what is more important in a curriculum between depth and breadth or between formative training in basic sciences or the application through problem solving which is also a question of educating the mind or preparing for a vacation (Ibid). This dichotomy of competing priorities in a curriculum hinges on whether education, and so the curriculum, should be about knowing, doing or being (Ibid). While it can be reasonably argued that a good curriculum should balance both depth and width, the constrained time within which educational programmes are offered makes is difficult to do so. Also, any attempts to do so would most likely result in a compromise on both the depth and the width of the curricular content and educational experience.

One way of approaching the dichotomy of depth versus width in a curriculum is to look at the purpose of education. The purpose of education can be viewed from the two philosophies of idealism or pragmatism. Idealism advocates that education should be the pursuit of knowledge for the sake of knowledge while pragmatism argues that education should take account of the social-economic and political situation of a country and therefore prepare students for the social and economic development of the country (Kumar and Ahmad, n.d.). It follows therefore that when one takes an idealistic stance, a curriculum should favour depth first over breadth in order to fully pursue knowledge. On the contrary, a pragmatic stance would demand width over depth since a broad skill base as opposed to a very narrow one is what is needed in industrial practice. This study therefore prefers that an undergraduate curriculum should favour width of curricular content and educational experience over depth in tandem with the desired purpose of education which is to prepare graduates who can make a meaningful contribution to industrial practice on graduating.

This position does not suggest that depth is not important nor does it suggest that a curriculum with a deep knowledge content would not prepare graduate for a meaningful contribution to industry. The position only argues that for an undergraduate education curriculum, width of content should be favoured over depth. The depth of curricular content is still important if graduates are to provide innovation and novel solutions to contemporary problems which a shallow knowledge base may not be able to address. However, depth can be achieved at postgraduate level. In which case, while graduates should be expected to provide novel solutions to contemporary problems, this can be the preserve of postgraduates while undergraduates can still solve conventional problems in industry. This position is further supported by the objectives of undergraduate versus postgraduate education. Generally, undergraduate education is designed to introduce students to the knowledge base within a discipline in preparation for industrial practice. Postgraduate education on the other hand is designed for students who have attained an undergraduate education and need to be equipped with a higher (deeper) level of understanding and mores specialised knowledge than undergraduate students. Therefore, curricula should emphasise width at undergraduate level but emphasise depth at postgraduate level. This follows the natural progression of education through the different levels of undergraduate and postgraduate education.

6.4 Curriculum Models

Development of curricula has traditionally been guided by curriculum models. Models help curriculum developers to conceptualise the process of developing curricula and provide guiding principles and procedures (Lunenburg, 2011). Kumral (2016) recommended that the development of a curriculum should start with the determination of needs and goals followed by the determination of the content and then determination of the techniques and methods to deliver the content and achieve the goals and should include how to assess whether the goals have been achieved. Watagodakumbura (2017) further added that the curriculum should decide on the content while being conscious of the limited time for students to learn, decide on learning material, summarise content or concepts, and decide assessment and balance theory and practice. Ladyshewskya and Taplin (2015) suggested that the curriculum must be informed by research and must be evidence based. All these suggestions are usually contained in curriculum development models.

Among the most prominent curriculum development models are the model by Hilda Taba (1902 – 1967) and Ralph W. Tyler (1902 – 1994) which are the precursors to most contemporary models (Wraga, 2017). Taba proposed a model initially for primary school curriculum but the model evolved and received wide spread use in all levels of education (Lunenburg, 2011).
The Taba model is made up of eight steps namely:

1. Diagnosis of needs
2. Formulation of objectives
3. Selection of content
4. Organising of content
5. Selection of learning experience
6. Organising of learning experience
7. Determination of what to evaluate
8. Checking for balance and sequence (Kalamees-Ruubel, 2013).

While evaluating the effectiveness of progressive education for university students between 1933 and 1941, Tyler developed a model for developing curricular (Kumral, 2016). Tyler's model consists of responding to four questions namely:

1. What needs to be done?
2. What content should be included?
3. What type of learning strategies, sources and activities should be used?
4. What measurement techniques and tools should be used to evaluate results? (Kumral, 2016).

The Tyler model conceptualises education as an experience, assessment as evaluation rather than measurement and approaches curriculum development as a problem solving process (Lunenburg, 2011). The model therefore is much more than the apparent four questions.

Notwithstanding appearing dated, Tyler's and Taba's models are still influential today and still enjoy widespread use despite a few criticisms (Lambert and Biddulph, 2015; Wraga, 2017). Nonetheless, contemporary models have been developed. For example, Feng, Lu and Yao (2015) proposed a 5 step model which uses actual tasks required for a job rather than requisite human skills and abilities. It is argued that focusing education and so the curriculum on the development of professional tasks would be more effective at producing better graduates than focusing on skills and abilities. The Feng *et al.* (2015) 5 step model is comprised of:

1. Vocational analysis
    a. Identify needs of market place and targeted learners
    b. Identify key roles in industry
2. Learner analysis
    a. Identify profile of learners, their prior knowledge and experiences and learning needs
3. Practical competence analysis
    a. Identify professional development stages, typical tasks in each stage and critical professional tasks among the typical ones
4. Curricula planning
    a. Document curricular tasks including content and teaching strategy
5. Implementation, evaluation and revision

a. Use the curriculum and subsequent evaluation to inform necessary revisions for curriculum to remain relevant in a dynamic world.

This approach yields a curriculum with curricular content divided into basic and professional modules. The curriculum is therefore still largely modular and so the teaching strategy is likely to gravitate towards didactic teaching. Notwithstanding, the resulting curriculum would likely respond to industry needs because the approach identifies the industry professional needs and tasks while considering the various stages of professional development.

In tandem with the definition of a curriculum, curriculum development models should address the 'What', the 'How' and also the assessment of resulting academic experience. The 'What' of the curriculum consists of the design of the academic curricular content while the 'How' consists of the design of the pedagogical approach of the curriculum. In the Taba model, the 'What' of the curriculum can be seen in steps 1 to 4 (Diagnosis of needs; Formulation of objectives; Selection of content and Organising of content). The 'How' can be seen in steps 5 and 6 (Selection of learning experience and Organising of learning experience) while the last two steps are dedicated to evaluating the extent to which the learning of the 'What' of the curriculum has been achieved by the 'How'. That is to say, the extent to which the students have learnt in view of the adopted pedagogy. In the Tyler model, the 'What' is contained in the first two questions (What needs to be done? and What content should be included?). The 'How' of the curriculum is contained in question three (What type of learning strategies, sources and activities should be used?) while question four (What measurement techniques and tools should be used to evaluate results?) addresses the assessment of the extent to which the learning objectives of the curriculum have been met.

The Feng *et al.* (2015) model addresses the 'What' in steps 1 to 3 (Vocational analysis; Learner analysis and Practical competence analysis) and addresses the 'How' in step 4 (Curricula planning - Document curricular tasks including content and teaching strategy). The assessment of learning is dealt with in step 5 (Implementation, evaluation and revision).

Kumral (2016) used both the Taba and the Tyler models to develop a student-centred (constructivist) curriculum. The models were used simultaneously in that while addressing each of the eight steps in the Taba model, each of the four questions in the Tyler model were also considered. Results from a pre-test post-test study revealed that the resulting curriculum positively changed the attitudes of the students, decreased anxiety, familiarised the students with the student centred pedagogy while moving from the teacher centred philosophy.

The use of the Taba and the Tyler models, which pre-date constructivist pedagogies, to create a curriculum which is constructivist in nature shows that the models are still relevant and applicable today (c.f. Lambert and Biddulph, 2015; Wraga, 2017). This underscores the fact that curriculum development models are tools for the conceptualisation of the process of developing curricular while providing guiding principles and procedures (Lunenburg, 2011). Therefore, at the centre of all curriculum development models are always questions about the 'What' and the 'How' of a curriculum while considering the appropriate learning experience for the students and the mode of evaluating the subsequent learning.

6.5 Chapter Summary

This chapter reviewed literature on the curriculum with the view to define it and establish its objectives. The chapter also reviewed three curriculum models. The curriculum is ill defined in literature with some authors equating it to a syllabus while other even reduce it to mean the timetable. Several different definition of the curriculum exist but all seem to agree that a curriculum is composed of "What" to teach and "How" to teach. This study uses the broad view of education and conceptualises it into a system comprising of the general system of all life experiences which then breaks down into the school experiences and activities sub-system followed by the academic experiences and activities sub-system and then two sub-systems of "What" to teach and "How" to teach. The sub-system which encompasses all school experiences and activities is treated as the curriculum. This curricular system is defined as the sum of all academic and non-academic activities, processes and experiences, formal, informal and unintentional, designed to educate students, initiated by the school system, within or outside school. However, while the suggested definition covers a fairly broad system, the focus of this study is on the academic-curriculum system comprising of the curricular content ("What") and the pedagogical methodology ("How").

The curriculum should be designed to help students learn effectively so that they can make a meaningful contribution to professional practice on graduating in tandem with the pragmatic view of education. In achieving this objective, curricula have been designed using models or guidelines. The Taba and the Tyler models are the oldest and yet still most influential curriculum models.

CHAPTER 7

CONCEPTUAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

7.1 Introduction

This chapter presents the conceptual model of the research. The conceptual model is based on the review of extent literature provided and so has constructs from the three theories of learning studied namely constructivism from philosophy, connectionism from behaviourism and the cognitive load theory from cognitive science. The conceptual model suggests how the constructs, which are hypothesised to be important antecedents to effective learning from the different theories, are related. The chapter starts by briefly presenting some of the relevant literature in support of the constructs in the conceptual model and then presents the hypothesised relationships among the constructs. The conceptual model with the hypothesised relationships is then presented after which a detailed discussion in support of each hypothesis is presented.

7.2 Conceptual Model

A conceptual model is the proposal of how the research concepts are hypothesised to be related to each other based on theory, logic and an explanation of why the concepts are believed to be related in the proposed manner (Hair *et al.*, 2007; Sekaran and Bougie, 2010). It is also known as a theoretical framework. It consists of defining the concepts under study, developing a proposed model of how they are related and coming up with a theoretical basis explaining the proposed relationships (Hair *et al.*, 2007; Sekaran and Bougie, 2010). The proposed relationships constitute testable hypotheses which can then be analysed statistically (Hair *et al.*, 2007; Sekaran and Bougie, 2010). A conceptual or theoretical framework is the foundation of a hypothetico-deductive research approach which is the favoured research approach for this research.

Based on the definitions and descriptions of constructivism and a constructivist learning environment, constructivism is a multi-dimensional construct. Several conceptions of the dimensions of constructivism are available besides the ones presented in this study. The Constructivist Learning Environment by Tenenbaum *et al.* (2001) is perhaps the most widely adopted conception of the different facets of constructivism. It generally operationalises the facets of constructivism based on their presence in an educational environment. However, this research sought to establish the relative importance of aspects of constructivism rather than only investigate the presence of the constructivist principles. A different conception of the dimensions of constructivism was therefore necessary. This study posits that the important constructivist antecedents to learning are an active learner centred approach, a cycle of propose, critic and reflection, both social and individual learning, challenging learners in the zone of proximal development and scaffolding learners as they engage in learning.

Behaviourism in educational practice is pinned on the theory of connectionism which is supported by three distinct laws of readiness, reinforcement and repetition. Therefore, this study posits that the important antecedents to learning from behaviourism and specifically connectionism are reinforcement, readiness and repetition which are collectively referred to as connectionism.

John Sweller (1946 -) postulated the cognitive load theory (CLT) which posits that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998a). The theory suggests that since working memory has a very limited capacity, it can easily be overloaded with activities that impede rather than aid learning. CLT suggests that reducing cognitive load will make more working memory available for actual learning (Bannert, 2002). Therefore, based on this conception, this study posits that the important antecedents to learning from cognitive science and specifically the cognitive load theory are cognitive loading, schema construction and the types of problems administered to learners.

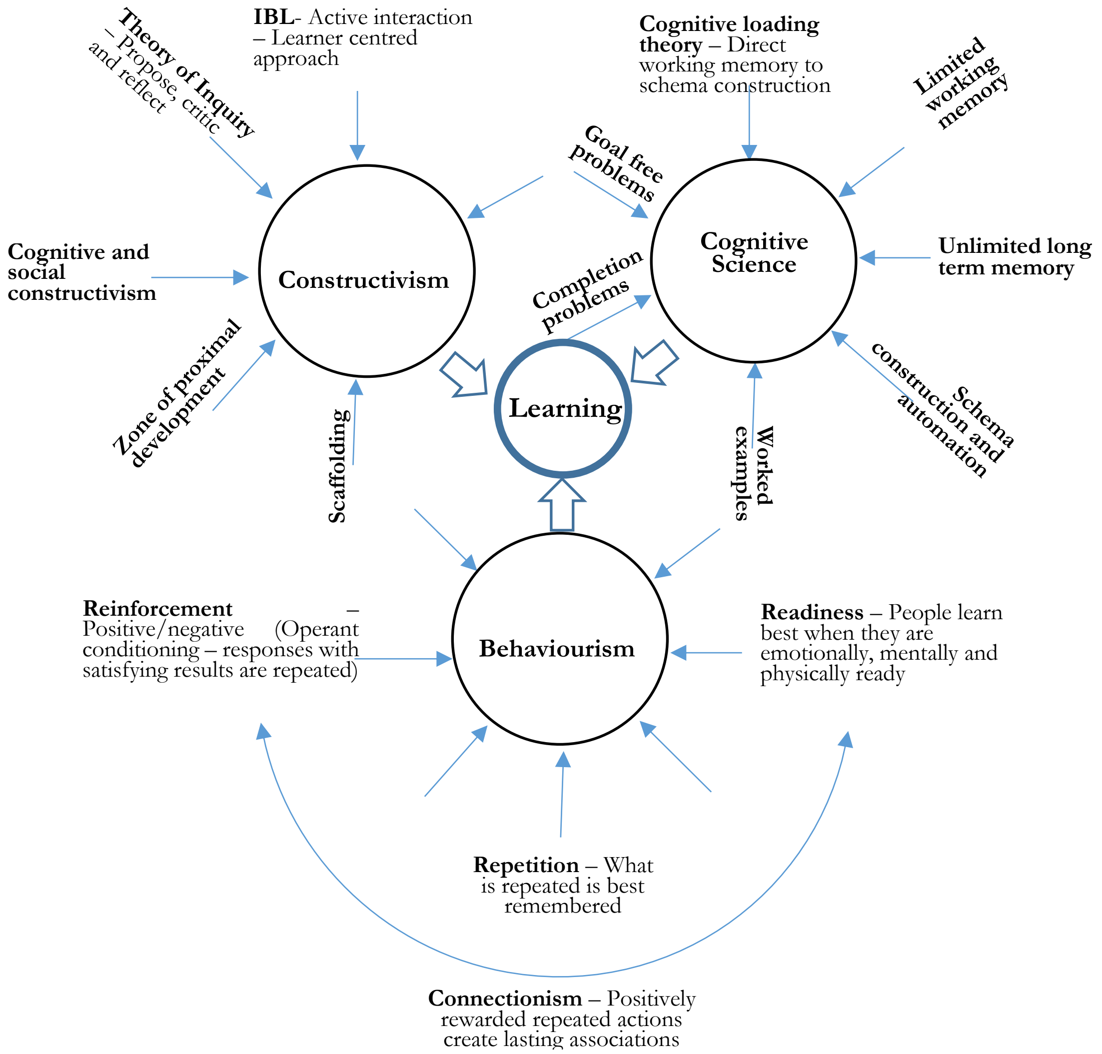


Figure 7-1: Antecedents of learning and relationships among the concepts from the theories of learning

These important antecedents to effective teaching and learning drawn from the theory of constructivism in philosophy, connectionism in behaviourism and the cognitive load theory from cognitive science are shown graphically in Figure 7-1. Based on these elements in Figure 7-1, the identified concepts for this study and their abbreviated notations are as follows:

From Constructivism:

1. Scaffolding — SCAFF
2. Group learning — GRPLN
3. Self-directed learning — SDL
4. Reflective thinking — REFTHK
5. Individual learning — INDLN
6. Active learning — ACTLN
7. Zone of proximal development — ZPD

From Behaviourism:

1. Repetition — REP
2. Reinforcement — REINF
3. Readiness — READ

From Cognitive Science:

1.	Cognitive loading	COGLD
2.	Schema construction	SCMCON
3.	Complex and ambiguous questions	COMPQ
4.	Authentic problems	AUTHPB
5.	Worked examples	WOKEXP
6.	Completion problems	COMPPB

Generally, based on extant literature, the hypotheses linking the concepts are as follows:

SCMCON and Constructivism

1. *SCMCON has a positive significant relationship with SCAFF*
2. *SCMCON has a positive significant relationship with GRPLN*
3. *SCMCON has a positive significant relationship with SDL*
4. *SCMCON has a positive significant relationship with REFTHK*
5. *SCMCON has a positive significant relationship with INDLN*
6. *SCMCON has a positive significant relationship with ACTLN*
7. *SCMCON has a positive significant relationship with ZPD*

SCMCON and Behaviourism (Connectionism)

8. *SCMCON has a positive significant relationship with REP*
9. *SCMCON has a positive significant relationship with REINF*
10. *SCMCON has a positive significant relationship with READ*

SCMCON and Cognitive Science (Cognitive Load Theory)

11. *SCMCON has a negative significant relationship with COGLD*
12. *SCMCON has a negative significant relationship with COMPQ*
13. *SCMCON has a negative significant relationship with AUTHPB*
14. *SCMCON has a positive significant relationship with WOKEXP*
15. *SCMCON has a positive significant relationship with COMPPB*

REFTHK and Constructivism

16. *REFTHK has a positive significant relationship with SCAFF*
17. *REFTHK has a non-significant relationship with GRPLN*
18. *REFTHK has a positive significant relationship with SDL*
19. *REFTHK has a positive significant relationship with INDLN*
20. *REFTHK has a non-significant relationship with ACTLN*
21. *REFTHK has a non-significant relationship with ZPD*

REFTHK and Behaviourism (Connectionism)

22. *REFTHK has a non-significant relationship with REP*
23. *REFTHK has a non-significant relationship with REINF*
24. *REFTHK has a non-significant relationship with READ*

REFTHK and Cognitive Science (Cognitive Load Theory)

25. *REFTHK has a non-significant relationship with COMPQ*
26. *REFTHK has a non-significant relationship with AUTHPB*
27. *REFTHK has a non-significant relationship with WOKEXP*
28. *REFTHK has a non-significant relationship with COMPPB*

COGLD and Constructivism

29. *COGLD has a negative significant relationship with SCAFF*
30. *COGLD has a non-significant relationship with GRPLN*
31. *COGLD has a non-significant relationship with SDL*
32. *COGLD has a non-significant relationship with REFTHK*
33. *COGLD has a positive significant relationship with INDLN*
34. *COGLD has a non-significant relationship with ACTLN*
35. *COGLD has a positive significant relationship with ZPD*

COGLD and Behaviourism (Connectionism)

36. *COGLD has a non-significant relationship with REP*
37. *COGLD has a non-significant relationship with REINF*
38. *COGLD has a non-significant relationship with READ*

COGLD and Cognitive Science (Cognitive Load Theory)

39. *COGLD has a positive significant relationship with COMPQ*
40. *COGLD has a positive significant relationship with AUTHPB*
41. *COGLD has a non-significant relationship with WOKEXP*
42. *COGLD has a non-significant relationship with COMPPB*

SDL

43. *SDL has a non-significant relationship with SCAFF*
44. *SDL has a positive significant relationship with GRPLN*
45. *SDL has a positive significant relationship with INDLN*
46. *SDL has a positive significant relationship with READ*
47. *SDL has a non-significant relationship with COMPQ*
48. *SDL has a non-significant relationship with AUTHPB*
49. *SDL has a positive significant relationship with WOKEXP*

SCAFF

50. *SCAFF has a positive significant relationship with GRPLN*
51. *SCAFF has a positive significant relationship with REP*
52. *SCAFF has a positive significant relationship with REINF*
53. *SCAFF has a non-significant relationship with COMPQ*
54. *SCAFF has a non-significant relationship with AUTHPB*
55. *SCAFF has a positive significant relationship with WOKEXP*

REINF

56. *REINF has a positive significant relationship with GRPLN*
57. *REINF has a positive significant relationship with REP*
58. *REINF has a non-significant relationship with COMPQ*

A conceptual model of these antecedents to learning from the three theories of learning was developed and is shown in Figure 7-2. The conceptual model is based on the hypothesised relationships. The model only shows relationships hypothesised to have statistically significant relations. Therefore, relationships which are hypothesised to have non-significant associations are omitted from model for clarity of the model. A detailed discussion of the proposed hypotheses and their rationale is provided in the section on hypothesis development.

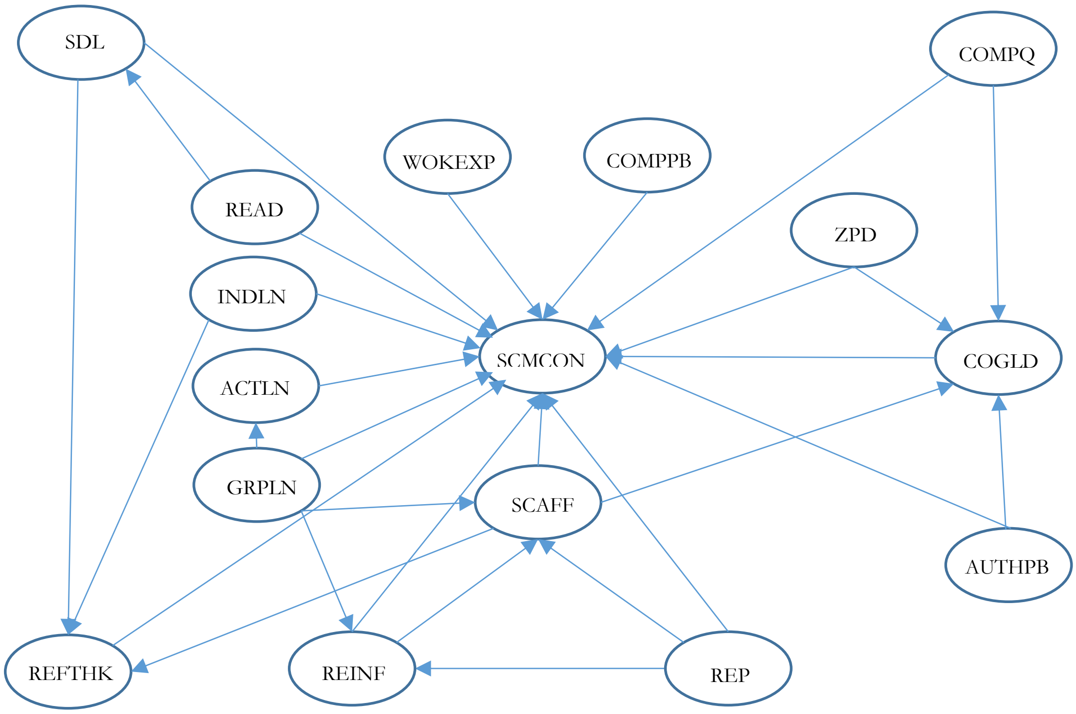


Figure 7-2: Conceptual Model of the Antecedents to Effective Teaching and Learning from Constructivism, Behaviourism and Cognitive Science

7.3 Hypothesis Development

Hypothesis development details the rationale behind the proposed hypotheses. The section is divided into three main section whereby each construct has a hypothesised relationship with the three main endogenous variable namely schema construction, reflective thinking and cognitive loading. Each of the three section is further divided into constructs derived from each of the three theories of learning being investigated.

7.3.1 Schema Construction

Learning consists of storing information including large, complex interactions and procedures in long-term memory (LTM) (Sweller *et al.*, 1998a). The learned information is stored in LTM as schemata. A schema is anything that is learnt and treated as a single entity. Learning is achieved by connecting any new information to existing schemata and inducing changes in the structure of the existing schemata (Chater and Vitányi, 2003). Existing schemata aid in learning by helping to interpret new information and linking it with the existing schemata because existing schemata in LTM can be easily manipulated and stored (Valcke, 2002). Skilled performance is developed by building a large number of complex schemata by combining elements of lower level schemata into high level schemata (Kirschner, 2002). Based on this conception of learning as the construction of schemata, this study operationalised learning as the extent to which students achieve schema construction.

7.3.1.1 Schema Construction and Constructivism

The theory of constructivism advocates that learning is an active process of construction of knowledge and understanding. It has led to the development of pedagogical approaches generally referred to as constructivist learning or inquiry based learning (IBL). They are pedagogical approaches where students engage in active learning through asking questions on a topic and proposing hypotheses about the questions and collecting, investigating and analysing available information to answer the questions (Hmelo-Silver *et al.*, 2007; Kori *et al.*, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon, Anastopoulou, Kerawalla and Mulholland, 2011; Spronken-Smith *et al.*, 2008). The process demands the active participation of students in their learning and so is student centred opposed to the teacher centred traditional didactic teaching approach (Meijerman *et al.*, 2013).

Vygotsky further postulated that after challenging students with work located in the ZPD, cognitive development of independent problem solving can be enhanced by adult supervision or in association with more proficient peers (Vygotsky, 1978). Based on this postulation, the major role of the instructor in IBL is to provide guidance to the students as they engage in the self-directed process of IBL. Guidance given to students is generally referred to as scaffolding. Scaffolding is a temporary support provided by an instructor to students to help them accomplish a task and is a requirement for all IBL processes (Lim, 2004; Spronken-Smith *et al.*, 2008). Lim (2004) notes that it is used to help students make progress in an inquiry process when faced with sticking points and to manage complex problems that often have attention-draining details. It is also used heavily at the beginning of the IBL approach to provide students with the skills required to get started with the inquiry process especially that students will often have had little or no experience with the approach (White and Frederiksen, 1998).

Scaffolding students is critical to the success of an IBL lesson (Pedaste and Sarapuu, 2006). Meijerman *et al.* (2013) reported that students were highly motivated and stimulated by the IBL approach due to the elaborate scaffolding provided which included a series of lectures, workshops on report writing, scheduled group meetings and poster discussions at different stages of the inquiry process. Leaners who receive guidance become more skilful during the IBL lesson, more successful at investigating information and score higher on post-tests. This was established from a meta-analysis of 72 articles on IBL where Lazonder and Harmsen (2016) concluded that while IBL is a self-directed process, guidance in the process is pivotal to the success of the approach.

Because schema construction is achieved when students connect old and new information, it is expected that scaffolding student learning activities when they are struggling to understand will lead them to better learning. Subsequently, in the context of construction education, it was hypothesised that:

Schema construction has a positive significant relationship with scaffolding

Constructivism acknowledges the role of culture and social interactions in the process of knowledge creation and understanding. Social constructivism argues that cognition is also a social process of interaction with others (Powel and Kalina, 2009). It is based on the work of Lev Vygotsky (1896 – 1934). Social interaction has been shown to aid learning and is a major part of constructivist learning. It has provided support for the importance of group interactions in the cognitive development of individuals. It is incorporated in pedagogy by assigning students to work in groups. Based on the theory of social constructivism, and research evidence (for example, Cheng, Wang and Mercer, 2014; de Hei, Strijbos, Sjoer and Admiraal, 2016; Wong, 2018), it is expected that working in groups will lead students to achieve better learning outcome. Therefore, in the construction education context, it is hypothesised that:

Schema construction has a positive significant relationship with group learning

Implicit in the definition of constructivist learning is the element of self-directed learning by students. Students are expected to actively engage in the pursuit of knowledge through experimentation. This requires that the students engage in a process of self-discovery of knowledge which was previously unknown to them (Hmelo-Silver *et al.*, 2007; Kori *et al.*, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon *et al.*, 2011; Spronken-Smith *et al.*, 2008). Therefore, based on this postulation and empirical evidence, it is hypothesised that, in the context of construction education:

Schema construction has a positive significant relationship with self-directed learning

Another important aspect of constructivist pedagogy is reflection. Reflection is a metacognitive process which allows students to think about and become aware of what they have just learnt and how it relates with knowledge they already possessed (Kori *et al.*, 2014; Sánchez-Martí, Sabariego Puig, Ruiz-Bueno and Anglés Regós, 2018). The process of inquiry in constructivist learning (IBL) requires a stage of reflective thinking for the students to evaluate what they have learnt and reflect on their work in view of comments and criticisms from instructors and peers (Kori *et al.*, 2014; Lim, 2004; Pedaste *et al.*, 2015; Scanlon *et al.*, 2011; Schon, 1983, 1987; Spronken-Smith and Kingham, 2009; White and Frederiksen, 1998). Therefore, it is hypothesised that, in the context of construction education

Schema construction has a positive significant relationship with reflective thinking

Cognitive constructivism is concerned with the individual creation of own knowledge and understanding and is therefore a personal process (Powel and Kalina, 2009). Cognitive constructivism argues that students should individually engage in learning so as to create their own knowledge and understanding. It is based on the work of Jean Piaget (1896 – 1980) who showed that the cognitive development of children takes place by a personal active interaction with the environment. Therefore, based on this postulation and empirical evidence, it is hypothesised that, in the context of construction education:

Schema construction has a positive significant relationship with individual learning

Constructivism also suggests that learning should involve the student in an active process of learning rather than a passive reception of knowledge. Active learning is based on Dewey's theory of inquiry which postulates that knowledge is created by an active response to the environment (Field, n.d.). Piaget provided empirical evidence to support the theory of inquiry by establishing that cognitive development in children takes place by an active interaction with the environment which creates structures of knowledge which are the foundation of all thinking. Based on the theory of inquiry by Dewey and empirical evidence by Piaget among many others, in the context of construction education, it was hypothesised that:

Schema construction has a positive significant relationship with active learning

Constructivism also argues that students need to be cognitively challenged to achieve learning. Therefore, it is argued that students should be presented with learning tasks which they would otherwise not already be able to solve on their own which are located in what is referred to as the zone of proximal development (ZPD). Vygotsky described the ZPD as ". . . the distance between the actual development level [of a child] as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). Challenging students with work located in the ZPD enhances the learning of students. Therefore, it was hypothesised that, in the context of construction education:

Schema construction has a positive significant relationship with ZPD

7.3.1.2 Schema Construction and Behaviourism (Connectionism)

Behaviourism is a branch of psychology whose contribution to pedagogy is mainly linked to the theory of connectionism. The theory of connectionism is a learning theory which states that learning happens when sufficient stimulus-response associations are positively rewarded thereby creating lasting connections between the stimulus-response associations (Kohlenberg and Tsai, 2000). Connectionism in based on the three laws of learning which are the law of effect, the law of readiness and the law of repetition suggested by Thorndike (1874- 1949) (Guey *et al.*, 2010). The law of effect states that responses that create satisfying results in a particular situation are more likely to be repeated in that situation, and responses that create discomforting results are less likely to be repeated in that situation. The law of readiness stated that people learn best when they are physically, mentally and emotionally ready to learn and the law of repetition stated that what is often repeated is best remembered (Donahoe, 2002).

Repetition is reported to be a significant antecedent to learning. While studying the physiological effect of repetition of learning on working memory, León-Carrión *et al.* (2010) concluded that:

> "our findings show that the temporal integration of efficient verbal learning is mediated by a mechanism known as neural repetition suppression (NRS). This mechanism facilitates cortical deactivation in dorsolateral prefrontal cortex (DLPFC) once learning is successfully completed. This cortical reorganization is interpreted as a progressive optimization of neural responses to produce a more efficient use of neural circuits. NRS could be considered one of the natural mechanisms involved in the processes of memory learning" (León-Carrión *et al.*, 2010: 502).

Axelsson and Horst (2014) also established the effect of contextual repetition on the word learning of three-year-old children with the target group repeating the learning trials while there was no repetition of the control group. It was found that the target group demonstrated word learning. Also, Lange-Küttner and Küttner (2015), in an experiment with seven and nine-year-old children, found that accuracy in remembering patterns nearly tripled in the repetition group consistent with other findings about memory for repeated patterns. Further, in testing the involvement of short and long term memory in novel word-form learning, Szmalec *et al.* (2012) found that repetition and the passage of time influenced the learning of phonological sequences of novel words-forms and not sleep as reported by earlier findings.

Most of the research on repetition is with children and hardly any with university students. Virtually none can be found with a South African university or a developing country context and more so with a construction student sample. The relationship between repetition and learning in construction students at South African universities is therefore a worthwhile relationship to research. Based on the theory of connectionism and empirical evidence, and this study hypothesises that, in the context of construction education:

Schema construction has a positive significant relationship with repetition

Reinforcement, another element of connectionism, also plays a vital role in learning. For example, Valeria and Maria (2013) recommended positive reinforcement for 7 to 8-year-old pupils to encourage them to act on their knowledge of environmental related attitudes and behaviours. Albu (2012) reported that teachers who want to maintain and strengthen control in the classroom predominantly use a punishment reward system while those who pursue the development, emotional support and freedom of the pupil will mostly use love based methods.

Most of the research on reinforcement seems to be with young children and not with university students. Also, no research with South African university students has been done on reinforcement and learning and more so with students studying construction. It is therefore worth researching the relationship between reinforcement and learning in students studying construction programmes in South Africa. Based on the theory of connectionism and empirical evidence, it is hypothesised in the context of construction education that:

Schema construction has a positive significant relationship with reinforcement

Hardly any research can be found investigating the relationship between readiness and learning therefore making it a worthwhile relationship to investigate. Therefore, based on the law of readiness, it is hypothesised that in the construction education context:

Schema construction has a positive significant relationship with readiness

7.3.1.3 Schema Construction and Cognitive Science (Cognitive Load Theory)

Cognitive science is the study of the mind, mental processes and the nature of intelligence whose purpose is to develop models and theories that help to explain human cognition in the form of perception, thinking and learning (Srinivasan, 2011; Talkhabi and Nouri, 2012). Cognitive science suggested the information processing theory of cognition which posits that human cognition involves processing of information stored in long term memory which is brought to working memory (Kirschner, 2002; Sweller *et al.*, 1998a; van Bruggen *et al.*, 2002). Working memory is used for conscious activity in organising, contrasting, comparing and working on information and while it can hold about seven items at a single time, it can only process two or three items simultaneously (Kirschner, 2002; Sweller *et al.*, 1998a). Long term memory (LTM) on the other hand is unlimited in capacity but its contents cannot be directly monitored unless they are loaded onto working memory.

Applying the information processing theory to learning, John Sweller (1946 -) postulated the cognitive load theory (CLT) which posits that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998a). The theory suggests that since working memory has a very limited capacity, it can easily be overloaded with activities that impede rather than aid learning. Therefore, based on the CLT, metacognitive activities which require a large deployment of working memory capacity are predisposed against learning. This is because the resulting cognitive load will be too high (Valcke, 2002). Arising from this argument, it is hypothesised that, in the context of construction education:

Schema construction has a negative significant relationship with cognitive loading

Following on from the CLT, pedagogical activities which require complex reasoning before students have mastered the basic concepts are likely to impede schema construction because of the resulting high levels of cognitive loading (Kirschner, 2002). Since complex questions and authentic problems would require some level of complex reasoning, it was hypothesised that, in the context of construction education:

Schema construction has a negative significant relationship with complex questions
Schema construction has a negative significant relationship with authentic problems

Owing to the limit in capacity of the working memory and the negative effect of high cognitive loading, CLT has suggested several instructional approaches centred on attempts to reduce cognitive loading (van Bruggen *et al.*, 2002). The approaches include worked examples and completion problems among others. Studying worked examples reduces ends-means analysis and focuses attention on problem states and associated operators therefore reducing cognitive load and helping students to create schemas (Sweller *et al.*, 1998). The effectiveness of worked examples has been demonstrated by several studies (Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke *et al.*, 2009; Sweller, 2006). For example, in an experimental study comparing worked examples, tutored problems erroneous examples which also represented high assistance instruction approaches and untutored problem solving which represented a low assistance instruction approach, McLaren *et al.* (2016) found significant differences in learning outcomes in both instructional approaches based on the worked examples which showed that students expended far less time and effort to achieve the learning outcomes. Mulder *et al.* (2014) also found that heuristic worked examples improved inquiry behaviour of students and improved the quality of the computer models they produced. Therefore, it was hypothesised that, in the context of construction education:

Schema construction has a positive significant relationship with worked examples

Completion problems have also been found to reduce cognitive load. In a series of experimental studies comparing completion problems, conventional problems and learner controlled condition van Merriënboer *et al.* (2002) found that completion problems reduced cognitive load. Mihalca *et al.* (2015) also found that completion problems were effective for students with low subject prior knowledge while students with higher subject prior knowledge performed better with conventional problems. Therefore, it was hypothesised that, in the context of construction education:

Schema construction has a positive significant relationship with completion problems

7.3.2 Reflective thinking

Reflection is a metacognitive process which allows students to think about and become aware of what they have just learnt and how it relates with what they already know (Kori *et al.*, 2014). Schon (1987) and Schon (1983) underscored the importance of reflection both in achieving deep learning and in effective professional practice. The process of inquiry in constructivist learning (IBL) requires a stage of reflective thinking for the students to evaluate what they have learnt and reflect on their work in view of comments and criticisms from instructors and peers (Kori *et al.*, 2014; Lim, 2004; Pedaste *et al.*, 2015; Scanlon *et al.*, 2011; Schon, 1983, 1987; Spronken-Smith and Kingham, 2009; White and Frederiksen, 1998). Kori *et al.* (2014) found that guided reflection improves the quality of reflection and the inquiry skills of students. Reflection on the inquiry process, informed by past experience, is effective for resolving an unfamiliar scenario (Schon, 1987).

7.3.2.1 Reflective Thinking and Constructivism

Constructivism advocates that student learning activity should be appropriately scaffolded in order to achieve the learning outcomes. Scaffolding is support provided by a more knowledgeable person to students when they are unable to proceed with a learning task (Lim, 2004; Spronken-Smith *et al.*, 2008). It is an intervention for students when they are struggling to learn. Therefore, it is expected that scaffolding would lead to reflective thinking because students, who would have been struggling prior, would have been given extra knowledge or information to proceed with the learning task. This is likely to reveal some insights for the student to see the problem in a new way. Therefore, it was hypothesised that, in the construction education context:

Reflective thinking has a positive significant relationship with scaffolding

Social constructivism showed that group learning is ideal for sharing ideas and for students to compare their interpretation and understanding with other students. However, when working in groups, students generally tend to be preoccupied with social interaction rather than deep thinking. Therefore, the social interaction resulting from group work are not likely to create an atmosphere ripe for reflective thinking. Therefore, it is hypothesised that, in the context of construction education:

Reflective thinking has a non-significant relationship with group learning

Self-directed learning allows students to personally engage with the learning material and also to think more deeply about the subject material they are working on (Hmelo-Silver *et al.*, 2007; Kori *et al.*, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon *et al.*, 2011; Spronken-Smith *et al.*, 2008). Consequently, it is expected that the personal engagement resulting from self-directed learning will improve reflective thinking. Therefore, it was hypothesised that, in the context of construction education:

Reflective thinking has a positive significant relationship with self-directed learning

In contrast to when learning groups, when students engage in individual study, there is much more likelihood for deep engagement with the study material. Therefore, it is hypothesised that, in the context of construction education:

Reflective thinking has a positive significant relationship with individual learning

Active learning is based on Dewey's theory of inquiry which postulates that knowledge is created by an active response to the environment (Field, n.d.). Piaget provided empirical evidence to support the theory of inquiry by establishing that cognitive development in children takes place by an active interaction with the environment which creates structures of knowledge which are the foundation of all thinking. However, it is not expected that students will engage in the deep metacognitive activity of reflective thinking simultaneously with active learning. Therefore, in the context of construction education it was hypothesised that:

Reflective thinking has a non-significant relationship with active learning

It is argued that students should be presented with learning tasks which they would otherwise not already be able to solve on their own. Learning tasks which students are not able to solve without guidance are located in the zone of proximal development Vygotsky described the ZPD as ". . . the distance between the actual development level [of a child] as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). It is not expected that merely challenging students with activities which are their ZPD on its own will lead them to reflective thinking. Therefore, it was hypothesised that, in the context of construction education:

Reflective thinking has a non-significant relationship with ZPD

7.3.2.2 Reflective Thinking and Behaviourism (Connectionism)

Connectionism in based on the three laws of learning which are the law of effect, the law of readiness and the law of repetition suggested by Thorndike (1874- 1949) (Guey *et al.*, 2010). Repetition is good for helping students to remember what was taught (Kohlenberg and Tsai, 2000). It helps students create memories of what they are taught. Reinforcement is meant to reward actions which are desirable so that they may be repeated or to punish actions which are not desirable to discourage them. Readiness alludes to the extent of mental, physical and emotional readiness to engage in learning. None of these are expected to directly lead to reflective thinking because they do not necessarily encourage metacognitive thinking. Therefore, in the context of construction education, it was hypothesised that:

Reflective thinking has a non-significant relationship with repetition
Reflective thinking has a non-significant relationship with reinforcement
Reflective thinking has a non-significant relationship with readiness

7.3.2.3 Reflective Thinking and Cognitive Science (Cognitive Load Theory)

The cognitive load theory (CLT) suggests that since working memory has a very limited capacity, it can easily be overloaded with activities that impede rather than aid learning. Therefore, metacognitive activities will not take place when the working memory capacity is exceeded and the resulting cognitive load is high (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998). CLT suggests that reducing cognitive load will make more working memory available for metacognitive activity (Bannert, 2002). Therefore, high levels of cognitive loading will impede metacognitive activities.

The CLT further argues against administering questions which require complex reasoning to students with little subject prior knowledge (Hadie and Yusoff, 2016; Shehab and Nussbaum, 2015). That is, solving complex questions or authentic problems in the absence of adequate schemata requires the deployment of a substantial amount of cognitive effort which generates a large extraneous cognitive load (Hadie and Yusoff, 2016; Shehab and Nussbaum, 2015; Sweller *et al.*, 1998). Complex questions and authentic problems require complex reasoning because students need to collate information from various sources and make connections among different concepts in order to solve them. Therefore, it is expected that the resulting high levels of cognitive loading from complex questions and authentic problems would interfere with reflective thinking. Based on this, it was hypothesised that, in the context of construction education:

Reflective thinking has a non-significant relationship with complex questions
Reflective thinking has a non-significant relationship with authentic problems

Opposed to complex questions and authentic problems, worked examples and completion problems do not induce high levels of cognitive loading (Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke *et al.*, 2009; Sweller, 2006). Notwithstanding, studying solutions to problems which have already been solved is not likely to motivate students to think reflectively. It is more likely to encourage students to memorise processes and procedures for solving problems with quite little understanding. Therefore, it was hypothesised that, in the context of construction education:

Reflective thinking has a non-significant relationship with worked examples
Reflective thinking has a non-significant relationship with completion problems

7.3.3 Cognitive Loading

John Sweller (1946 -) postulated the cognitive load theory (CLT) which posits that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998). The theory suggests that since working memory has a very limited capacity, it can easily be overloaded with activities that impede rather than aid learning (Chang and Yang, 2010; Hadie and Yusoff, 2016; Shehab and Nussbaum, 2015). Therefore, activities which require working memory capacity are likely to burden working memory and lead to high levels of cognitive loading. CLT suggests that reducing cognitive load will make more working memory available for actual learning (Bannert, 2002; Chang and Yang, 2010; Hadie and Yusoff, 2016; Shehab and Nussbaum, 2015).

7.3.3.1 Cognitive Loading and Constructivism

One way of helping students cope with high levels of cognitive loading in constructivist pedagogy is to provide scaffolding (Hmelo-Silver *et al.* (2007). Scaffolding is support provided to students when they are unable to proceed with a learning task without assistance from a more knowledgeable person (Lim, 2004; Spronken-Smith *et al.*, 2008). Since it is assistance when students are cognitively overloaded, it is not expected that scaffolding would overload the cognitive capacity of students but rather help to reduce it. Therefore, it is hypothesised that, in the context of construction education:

Cognitive loading has a negative significant relationship with scaffolding

Learning in groups allows students to learn from each other by sharing their own understanding. It also allows for peer scaffolding whereby students are able to learn from more knowledgeable peers. More knowledgeable students are also able to achieve deeper reflection while explaining concepts to other students. This is all based on the social cognitive theory by Vygotsky (1978) (Powel and Kalina, 2009). Therefore, in the context of construction education, it is expected that group learning will not induce high levels of cognitive loading and so it is hypothesised that:

Cognitive loading has a non-significant relationship with group learning

Cognitive loading is not expected to be associated with self-directed learning. Self-directed learning allows students to direct their own learning (Hmelo-Silver *et al.*, 2007; Kori *et al.*, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon *et al.*, 2011; Spronken-Smith *et al.*, 2008). Because students monitor their own learning, they are not likely to persist with a self-directed learning activity when the activity unduly overloads their cognitive capacity and leads to stress. Therefore, it is hypothesised that, in the context of construction education:

Cognitive loading has a non-significant relationship with self-directed learning

Cognitive loading is not expected to be associated with reflective thinking. Reflective thinking involves students thinking about and becoming aware of what they have just learnt and how it relates with knowledge they already possessed (Kori *et al.*, 2014). Therefore, it is a process which attempts to link any new knowledge learnt with knowledge already contained in LTM. Based on the CLT, working with knowledge already contained in LTM does not significantly burden working memory. Therefore, since reflective thinking involves a portion of new knowledge considered in relation to already existing knowledge, it is not expected that reflective thinking will over burden the working memory capacity and so it is hypothesised that, in the context of construction education:

Cognitive loading has a non-significant relationship with reflective thinking

Individual learning is expected to be associated with Cognitive loading. Jean Piaget (1896 – 1980) showed that the cognitive development of children takes place by a personal active interaction with the environment. Cognitive development is concerned with the individual creation of own knowledge and understanding and is therefore a personal process (Powel and Kalina, 2009). Since cognitive loading is concerned with metacognitive activities and the individual construction of own knowledge and understanding is also a metacognitive process, it is expected that cognitive loading is associated with the process active interaction with the environment. Therefore, based on this argument, it is hypothesised that, in the context of construction education:

Cognitive loading has a positive significant relationship with individual learning

Cognitive loading is not expected to be associated with active learning. Cognitive loading is not expected to be associated with active learning because it is a metacognitive activity while active learning is concerned with the physical activity while learning. Active learning is based on Dewey's theory of inquiry which postulates that knowledge is created by an active response to the environment (Field, n.d.). Piaget provided empirical evidence to support the theory of inquiry by establishing that cognitive development in children takes place by an active interaction with the environment which creates structures of knowledge. Therefore, in the context of construction education it was hypothesised that:

Cognitive loading has a non-significant relationship with active learning

Cognitive loading is expected to be significantly associated with tasks which are in the ZPD. Because the ZPD defines a problem solving region in which students require help in order to solve problems, it is also a zone defining cognitive activity which students cannot perform on their own (Powel and Kalina, 2009). It is therefore expected that problems located in this region will cognitively challenge students and so induce some amount of cognitive loading. Therefore, it was hypothesised that, in the context of construction education:

Cognitive loading has a positive significant relationship with ZPD

7.3.3.2 Cognitive Loading and Behaviourism (Connectionism)

Connectionism is based on the three laws of learning which are the law of effect, the law of readiness and the law of repetition suggested by Thorndike (1874- 1949) (Guey *et al.*, 2010). Repetition helps students to remember what was taught (Kohlenberg and Tsai, 2000). Reinforcement is meant to encourage desired actions so that they may be repeated while the extent of mental, physical and emotional readiness is good for learning. None of these are expected to directly lead to cognitive loading because they do not necessarily require the use of working memory capacity which leads to high levels of cognitive loading. Therefore, in the context of construction education, it was hypothesised that:

Cognitive loading has a non-significant relationship with repetition
Cognitive loading has a non-significant relationship with reinforcement
Cognitive loading has a non-significant relationship with readiness

7.3.3.3 Cognitive Loading and Cognitive Science (Cognitive Load Theory)

Opposed to most proponents of constructivism such as, for example, Harinarain and Haupt (2016), Kahn and O'Rourke (2004) and Spronken-Smith *et al.* (2008), proponents of the cognitive load theory argue against the use of either complex or authentic problems such as, for example, Kirschner *et al.* (2006), Srinivasan (2011) Sweller *et al.* (1998a) and Yuan *et al.* (2006). It is argued that complex and authentic problems demand the use of a substantial amount of working memory capacity and so increase cognitive loading (Kirschner *et al.*, 2006; Srinivasan, 2011; Sweller *et al.*, 1998; Yuan *et al.*, 2006). On the other hand, worked examples and completion problems do not induce high levels of cognitive loading (Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke *et al.*, 2009; Sweller, 2006). However, there is very little empirical evidence supporting or refuting either of the claims or highlighting the effect of these types of problems on cognitive loading. These relationships are therefore worthwhile to investigate. Based on the CLT, it is hypothesised, in the context of construction education, that:

Cognitive loading has a positive significant relationship with complex question
Cognitive loading has a positive significant relationship with authentic problems

Cognitive loading has a non-significant relationship with worked examples
Cognitive loading has a non-significant relationship with completion problems

7.3.3.4 Self-directed Learning

Self-directed learning entails students self-discovering knowledge previously unknown to them by directing their own learning outcomes and the pace at which to work (Hmelo-Silver *et al.*, 2007; Kori *et al.*, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon *et al.*, 2011; Spronken-Smith *et al.*, 2008). Scaffolding is a temporary support provided by an instructor to students when they are struggling with a learning task to help them accomplish the task (Lim, 2004; Spronken-Smith *et al.*, 2008). It is not expected that supporting students when they are struggling with a learning task will lead them to engage in self-directed learning. Therefore, it is hypothesised that, in the context of construction education:

Self-directed learning has a non-significant relationship with scaffolding

Group learning allows students to share ideas with peers with less interference from lecturers. It is therefore expected that the autonomy for self-regulation implicit in group learning will lead students to engage more in self-directed learning. The same can be expected when students engage in individual learning with less direction from lecturers. Therefore, it is hypothesised that, in the context of construction education:

Self-directed learning has a positive significant relationship with group learning
Self-directed learning has a positive significant relationship with individual learning

Based on connectionism, readiness is the extent to which students are physically, emotionally and mentally ready to learn. It is expected that when students are physically, mentally and emotionally ready to learn, they are more likely to engage in the process of self-directed learning as opposed to when they are not. Therefore, in the context of construction education, it is hypothesised that:

Self-directed learning has a positive significant relationship with readiness

Complex and authentic questions are likely to induce high levels of cognitive loading and subsequently stress in students (Kirschner, Sweller, & Clark, 2006; Srinivasan, 2011). Therefore, it is not expected that students will persist with self-directed learning when the learning task is complex. Since worked examples do not induce much cognitive loading, it is expected that they will encourage students to persist with and engage in self-directed learning. Therefore, in the context of construction education, it is hypothesised that:

Self-directed learning has a non-significant relationship with complex questions
Self-directed learning has a non-significant relationship with authentic questions
Self-directed learning has a positive significant relationship with worked examples

7.3.3.5 Scaffolding

Scaffolding is a temporary support provided by an instructor to students when they are struggling with a learning task to help them accomplish the task (Lim, 2004; Spronken-Smith *et al.*, 2008). When students engage in group learning, they are likely to provide help and support for each other with aspects of the learning task which they may find difficult. In essence, the students would in fact be scaffolding each other. Therefore, it is hypothesised that, in the context of construction education:

Scaffolding has a positive significant relationship with group learning

Repeating relevant learning material is likely to help struggling students to deal with difficult learning tasks. Therefore, it is expected that repetition is a form of scaffolding. Reinforcing desirable student action is likely to encourage students to persist with tasks they were struggling with because they get feedback on whether they are on the right track or not. Therefore, it is hypothesised that in the context of construction education:

Scaffolding has a positive significant relationship with repetition

Scaffolding has a positive significant relationship with reinforcement

Since scaffolding is the temporary support provided by lecturers to students when they are struggling with a learning task to help them accomplish the task (Lim, 2004; Spronken-Smith *et al.*, 2008), it not expected to be significantly associated with complex and authentic questions. On the other hand, since worked examples are likely to clarify issues with students when they struggle with a learning task, it is expected that worked examples will be significantly associated with scaffolding. Therefore, in the context of construction education, it is hypothesised that:

Scaffolding has a non-significant relationship with complex questions
Scaffolding has a non-significant relationship with authentic questions
Scaffolding learning has a positive significant relationship with worked examples

7.3.3.6 Reinforcement

The law of reinforcement in education practice posits that actions which are encouraged are more likely to be repeated. Reinforcement is achieved in a number of ways which encourage students to continue in their course of desired action or desist from undesired action. Engaging in group work allows students to compare their work and understanding with others. When they feel that they are doing the right thing, the students will continue in the particular course of action. If not, the students will desist from their initial course of action. Therefore, it is expected that group learning will be associated with reinforcement and so it is hypothesised that, in the context of construction education:

Reinforcement has a positive significant relationship with group learning

Repetition of key learning points is expected to reinforce student understanding by constantly reminding and reassuring the students of the subject matter. Therefore, it is expected and hypothesised that, in the context of construction education:

Reinforcement has a positive significant relationship with repetition

Complex questions induce high levels of cognitive loading and therefore stress the students. It therefore not expected that complex questions will reinforce learning activities. Therefore, it is hypothesised that, in the context of construction education:

Reinforcement has a non-significant relationship with complex questions

7.4 Chapter Summary

This chapter presented the conceptual model of the research which is based on the review of literature. The conceptual model highlights the important antecedents to teaching and learning from the contemporary theories of learning and hypothesise how these relate with each other. The chapter also presented a detailed discussion of the rationale for each hypothesis. A conceptual model, also known as a theoretical framework, is the proposal of how the research concepts are hypothesised to be related to each other based on theory, logic and an explanation of why the concepts are believed to be related in the proposed manner. The hypothesised relationships can be summarised as follows:

Schema Construction and Constructivism

1. *Schema construction has a positive significant relationship with scaffolding*
2. *Schema construction has a positive significant relationship with group learning*
3. *Schema construction has a positive significant relationship with self-directed learning*
4. *Schema construction has a positive significant relationship with reflective thinking*
5. *Schema construction has a positive significant relationship with individual learning*
6. *Schema construction has a positive significant relationship with active learning*
7. *Schema construction has a positive significant relationship with ZPD*

Schema Construction and Behaviourism (Connectionism)

8. *Schema construction has a positive significant relationship with repetition*
9. *Schema construction has a positive significant relationship with reinforcement*
10. *Schema construction has a positive significant relationship with readiness*

Schema Construction and Cognitive Science (Cognitive Load Theory)

11. *Schema construction has a negative significant relationship with cognitive loading*
12. *Schema construction has a negative significant relationship with complex questions*
13. *Schema construction has a negative significant relationship with authentic problems*
14. *Schema construction has a positive significant relationship with worked examples*
15. *Schema construction has a positive significant relationship with completion problems*

Reflective Thinking and Constructivism

16. *Reflective thinking has a non-significant relationship with group learning*
17. *Reflective thinking has a positive significant relationship with self-directed learning*
18. *Reflective thinking has a positive significant relationship with individual learning*
19. *Reflective thing has a non-significant relationship with active learning*
20. *Reflective learning has a non-significant relationship with ZPD*

Reflective Thinking and Behaviourism (Connectionism)

21. *Reflective thinking has a non-significant relationship with repetition*
22. *Reflective thinking has a non-significant relationship with reinforcement*
23. *Reflective thinking has a non-significant relationship with readiness*

Reflective Thinking and Cognitive Science (Cognitive Load Theory)

24. *Reflective thinking has a non-significant relationship with cognitive loading*
25. *Reflective thinking has a non-significant relationship with complex questions*
26. *Reflective thinking has a non-significant relationship with authentic problems*
27. *Reflective thinking has a non-significant relationship with worked examples*
28. *Reflective thinking has a non-significant relationship with completion problems*

Cognitive Loading and Constructivism

29. *Cognitive loading has a negative significant relationship with scaffolding*
30. *Cognitive loading has a non-significant relationship with group learning*
31. *Cognitive loading has a non-significant relationship with self-directed learning*
32. *Cognitive loading has a non-significant relationship with reflective thinking*
33. *Cognitive loading has a positive significant relationship with individual learning*
34. *Cognitive loading has a non-significant relationship with active learning*
35. *Cognitive loading has a positive significant relationship with ZPD*

Cognitive Loading and Behaviourism (Connectionism)

36. *Cognitive loading has a non-significant relationship with repetition*
37. *Cognitive loading has a non-significant relationship with reinforcement*
38. *Cognitive loading has a non-significant relationship with readiness*

Cognitive Loading and Cognitive Science (Cognitive Load Theory)

39. *Cognitive loading has a positive relationship with complex question*
40. *Cognitive loading has a positive significant relationship with authentic problems*
41. *Cognitive loading has a non-significant relationship with worked examples*
42. *Cognitive loading has a non-significant relationship with completion problems*

SDL

43. *Self-directed learning has a non-significant relationship with scaffolding*
44. *Self-directed learning has a positive significant relationship with group learning*
45. *Self-directed learning has a positive significant relationship with individual learning*
46. *Self-directed learning has a positive significant relationship with readiness*
47. *Self-directed learning has a non-significant relationship with complex questions*
48. *Self-directed learning has a non-significant relationship with authentic problems*
49. *Self-directed learning has a positive significant relationship with worked examples*

SCAFF

50. *Scaffolding has a positive significant relationship with group learning*
51. *Scaffolding has a positive significant relationship with repetition*
52. *Scaffolding has a positive significant relationship with reinforcement*
53. *Scaffolding has a non-significant relationship with complex questions*

54. *Scaffolding has a non-significant relationship with authentic problems*
55. *Scaffolding has a positive significant relationship with worked examples*

REINF

56. *Reinforcement has a positive significant relationship with group learning*
57. *Reinforcement has a positive significant relationship with repetition*
58. *Reinforcement has a non-significant relationship with complex questions*

CHAPTER 8

RESEARCH METHODOLOGY

8.1 Introduction

This chapter discusses the research methodology followed to achieve the aim and objectives of the study and respond to the research questions. The methodology adopted is based on the research process suggested by Nachmias and Nachmias (1981) and the research process onion suggested by Saunders *et al.* (2012) and are shown in Figure 8-1 and 8-2 respectively. The research process followed breaks down into the research philosophy used, the research approach, the research design, the research strategy adopted, the time horizon of the study, the techniques and procedures of data collection and sampling adopted, the data analysis methods adopted and also alludes to the reliability and validity of measures. But first, research is defined so as to guide the choice of research philosophy.

8.2 Research definition

The research process is the scientific activities engaged in to produce knowledge (Nachmias and Nachmias, 1981; Saunders *et al.*, 2012; Sekaran and Bougie, 2010). It is a cyclic process and can be depicted as a wheel with seven principle stage as shown in Figure 8-1. 'Research' is any inquiry or investigation on a phenomenon or event conducted to find facts (Saunders *et al.*, 2012; Thakur, 1993). Scientific research is research done following systematic procedures that are controlled, empirical and critical investigations of hypothetical suggestions on supposed associations among phenomenon (Saunders *et al.*, 2012; Sekaran and Bougie, 2010; Thakur, 1993). It is important that research should be systematic and controlled to have greater confidence in the established associations among the tested variables (Saunders *et al.*, 2012; Thakur, 1993). It should also be empirical meaning that the hypothesised relations must be tested against an objective reality (Saunders *et al.*, 2012; Sekaran and Bougie, 2010; Thakur, 1993). Since research is the production of knowledge, it is important to consider the philosophical positions which guide the process of knowledge creation.

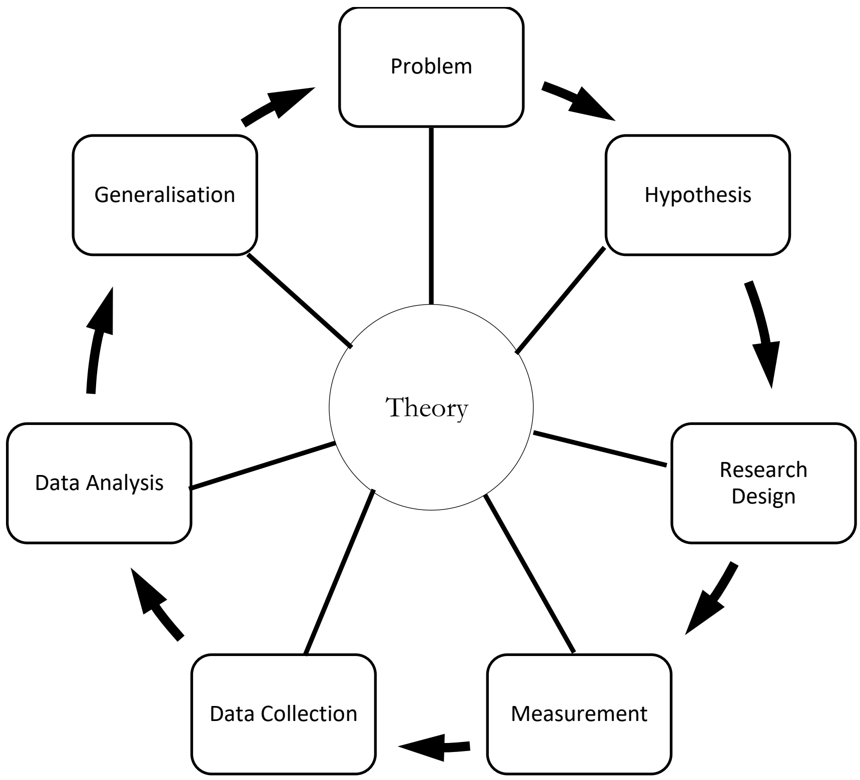


Figure 8-1: The principle stages of the research process (Nachmias and Nachmias, 1981: 23)

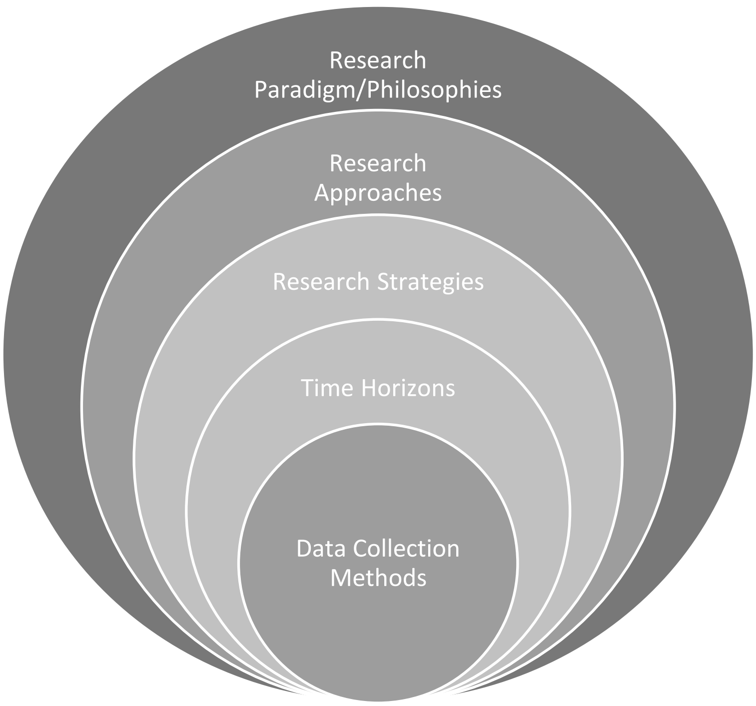


Figure 8-2: The research process onion model - adapted from Saunders et al. (2012)

8.3 Research Philosophies (Epistemology and Ontology)

Research philosophies are concerned with the development of knowledge (epistemology) and the nature of that knowledge (ontology). The philosophy favoured for a study reflects the assumptions made about how the world is viewed (Saunders *et al.*, 2012). Research philosophies are epistemological and ontological positions or "world views" or assumptions or theoretical frameworks about how knowledge should be generated.

Epistemological philosophies are concerned with what constitutes acceptable knowledge in a field of study and determine "whether or not the social world can and should be studied according to the same principles, procedures and ethos as the natural sciences" (Bryman and Bell, 2011: 15). Epistemological philosophies determine the approach to questioning and discovery in research (Saunders *et al.*, 2012). Ontological philosophies are concerned with the nature of reality and the assumptions made about how the world operates (Ibid). The main research epistemological philosophies are positivism, realism, phenomenology and interpretive philosophies while the ontological positions are objectivism and subjectivism. It is worth noting that no one philosophy is better than the other but each is suited to responding to different types of research questions and sometimes a single research question can be answered by more than one philosophical position (Ibid). The important thing therefore is not that a research is philosophically informed but how well the preferred philosophical position can be defended against alternative positions (Ibid).

Sometimes, it is unrealistic to choose a single position on each of the philosophies at the exclusion of others in which case the position is referred to as pragmatism (Ibid). The pragmatic position recognises "that there are many ways of interpreting the world and undertaking research and that no single point of view can ever give the entire picture. Pragmatism posits that there may be multiple realities" and the important consideration in choice of philosophy is the research question and the practical consequences of the generated knowledge (Ibid).

8.3.1 Positivism

Positivism, also referred to as ontological naturalism, suggests that social sciences are similar to natural sciences and should therefore follow the logic and rigor of natural sciences in research (Bryman and Bell, 2011; Mouton, 1996). It also advocates that knowledge should be generated by gathering facts either inductively or deductively (Bryman and Bell, 2011; Saunders *et al.*, 2012).

8.3.2 Realism

Realism argues that there are in fact fundamental differences between the social and natural sciences but similarities also exist which justify the use of similar research approaches (Bryman and Bell, 2011; Mouton, 1996). Realism is therefore pro-positivist in nature (Saunders *et al.*, 2012).

8.3.3 Phenomenology

Phenomenology argues that differences between social science and natural science are so fundamental that the same methods for research would not suffice (Bryman and Bell, 2011; Mouton, 1996). Differences between the two worlds are argued to exist because social reality has a meaning for people and so human action is meaningful which does not hold true for the natural world (Bryman and Bell, 2011). Therefore, based on the philosophy of phenomenology, research approaches in the social world should take cognisance of the difference with the natural world occasioned by human behaviour by employing an epistemology which acknowledges and capitalises on the differences and should be empathetic of the research participants (Bryman and Bell, 2011; Saunders *et al.*, 2012). This position is anti-positivist.

8.3.4 Interpretive

The interpretive paradigm is also anti-positivist like the phenomenological paradigm (Bryman and Bell, 2011; Mouton, 1996). It equally argues against treating social sciences in a manner similar to natural sciences because of the argument that the two worlds are different because the social world is far too complex to be theorised by definite 'laws' (Saunders *et al.*, 2012). Therefore, the interpretive philosophy contends that it is important to use a different logic of research procedures which reflects the distinctiveness of humans as opposed to natural order (Bryman and Bell, 2011).

8.3.5 Objectivism and subjectivism

Objectivism and subjectivism are ontological positions. Objectivism advocates that social entities exist as meaningful realities external to and independent from social actors in the social entities (Saunders *et al.*, 2012).

This position suggests that management, for example, is a meaningful social entity independent from the social actors (managers) who play the management role. Subjectivism on the other hand, advocates that social entities are created by the perceptions and actions of social actors and therefore, objective aspects of social entities are less important than the way in which the social actors attach individual meaning to their roles in the social entities and how they perceive how those roles should be performed (Ibid).

This study followed an epistemological positivist philosophy so that it can empirically test structural relationships among predictors of effective teaching and learning in students of construction studies. The ontological philosophy preferred was objectivism because the study is concerned with students as social actors rather that the social entities they create such as the class or group. The school class to which students belong, which is a social entity created by the students, is viewed as being less important than the social actors themselves in so far as the research problem of identifying antecedents to effective teaching and learning is concerned. The social entity of class, while influenced by the students, does not influence the antecedents to effective teaching and learning of students of construction studies and so the class is not given pre-eminence by being treated as an independent meaningful reality external from the students.

8.4 Research Approaches

A research approach is either deductive, inductive or abductive.

8.4.1 Deductive

Deductive reasoning works from the general truth or theory to logically arrive at a specific conclusion to test a hypothesis (Judd, Smith and Kidder, 1986; Saunders *et al.*, 2012). A phenomenon is explained by deduction from a universal law or theory (Mouton, 1996; Nachmias and Nachmias, 1981; Saunders *et al.*, 2012). It is used when testing hypotheses from existing theories (Bryman and Bell, 2011; Judd *et al.*, 1986; Mouton, 1996). Based on the deductive approach, a research approach can be hypothetico-deductive and would then involve a broad definition of the problem area, definition of problem statement, hypotheses development, development of variable measures, data collection, data analysis and interpretation of data (Sekaran and Bougie, 2010). A deductive approach generally involves:

1) proposing hypotheses about two or more concepts to form a theory;

2) using literature to deduce testable hypotheses;

3) examine and compare the logic of the proposed testable hypotheses with existing theories to establish if the hypotheses are sound;

4) collect appropriate data to test the hypotheses; and

5) if the results are inconsistent then the theory is false and should be rejected and the process repeated or if the results are consistent the theory is corroborated (Saunders *et al.*, 2012).

However, it suffers the drawback that researchers often collect evidence which support their ideas or their hypotheses and so sometimes leads to incorrect generalisation and researcher bias (Thakur, 1993). It also does not provide much information on the effects of the variables since it does not manipulate the variables to isolate their effects (Ibid).

8.4.2 Inductive

Inductive reasoning works from a specific observation to propose a generalisation or hypothesis or theory based on the observation (Judd *et al.*, 1986; Saunders *et al.*, 2012). In inductive reasoning, account is taken of the fact that the behaviour of people is also influenced by their interpretation of the social world rather than a mechanistic response to circumstances which is what the deductive approach does (Saunders *et al.*, 2012). The accuracy of conclusions arrived at by inductive reasoning is often questionable and requires collaboration using deductive approaches (Mouton, 1996). Also, inductive reasoning leads to the generation of hypotheses and so it cannot be used to test a hypothesis because no amount of evidence can assure that contrary evidence does not exist (Sekaran and Bougie, 2010). It is mostly used in research fields where there is little empirical work (Thakur, 1993).

8.4.3 Abductive

Abductive reasoning starts from what may be considered a 'surprising fact' which is a conclusion rather than a hypothetical proposition from which possible hypothetical propositions are made which are enough to explain the conclusion (Saunders *et al.*, 2012). If the set of hypothetical propositions are true, then the conclusion is also true (Ibid). Abductive reasoning essentially involves collecting data to identify patterns, or to identify or amend a theory which is subsequently tested through additional data collection (Ibid). This process usually moves back and forth between 'theory and data' and 'data and theory' and is therefore a mixture of both the deductive and the inductive approaches (Ibid).

The approach favoured for this study was the hypothetico-deductive approach because the research sought to test hypotheses and not to generate them. The inductive approach would not be able to test the proposed hypotheses about the antecedents to effective teaching and learning of construction studies students.

8.5 Research Design

The research design is the general plan used to answer the research questions and involves a choice of either a quantitative design, a qualitative design or a mix of both quantitative and qualitative designs (Saunders *et al.*, 2012). Qualitative design involves collecting qualitative data. Qualitative data is data that cannot be expressed as a number and includes narrative data, video data, voice data, picture data and other similar materials while quantitative data is anything which can be expressed as numbers (Ibid). The choice between qualitative design and quantitative design is based on the type or research questions being investigated with exploratory studies being best suited to qualitative design while descriptive and causal studies requiring the quantitative design (Hair *et al.*, 2007).

8.5.1 Quantitative design

The qualitative research design is associated with the positivist philosophy but may also be used within a realist or pragmatist philosophy (Saunders *et al.*, 2012). It is also associated with the deductive research approach though it can incorporate an inductive approach where the quantitative data are used to propose theory (Hair *et al.*, 2007; Saunders *et al.*, 2012). The quantitative research design is used to examine relationships among variables using statistical analyses and principles and uses either experimental or survey research strategies with questionnaires, structured interviews or structured observation (Saunders *et al.*, 2012).

8.5.2 Qualitative design

The qualitative research design is associated with the interpretivist philosophy but may also be used within the realist and pragmatist philosophies (Saunders *et al.*, 2012). It is also associated with the inductive research approach though it can also start with a deductive approach to test a theory using qualitative procedures (Hair *et al.*, 2007; Saunders *et al.*, 2012). However, most qualitative research uses abduction (Saunders *et al.*, 2012). The qualitative design examines meanings and relationships using various analytical procedures and the data collection is none standardised using, *inter alia*, action research, case study research, ethnography, grounded theory and narrative research (Hair *et al.*, 2007; Saunders *et al.*, 2012).

8.5.3 Mixed methods design

The mixed method research design is often associated with the realist and pragmatist philosophies and are likely to combine both inductive and deductive reasoning (Saunders *et al.*, 2012). Mixed method research design essentially use various combinations of research strategies and more than one data collection method (Ibid).

This study favoured the quantitative design in line with the use of a positivist philosophy following a deductive research approach to examine relationships among the study variables using statistical analyses. A qualitative design would not achieve the aim of testing hypotheses and while a mixed method deign could provide the added advantage of corroboration of findings between the quantitative and qualitative data, such an objective does not fall within the objectives of the current study because it would exceed both the cost and time budget of this study.

8.6 Research Strategies

The research strategy is an action plan to achieve the research objectives and respond to the research questions and therefore links the research philosophy with the methods for collection and analysis of the data (Saunders *et al.*, 2012). Research strategies are influenced by the general direction which a research study may follow namely exploratory or formulative, descriptive, and explanatory (Saunders *et al.*, 2012; Sekaran and Bougie, 2010; Thakur, 1993). The exploratory research design aims to gain more understanding of a phenomenon and highlight more insights into a problem by asking open questions to gain insight into a topic of interest and propose hypotheses (Saunders *et al.*, 2012; Sekaran and Bougie, 2010; Thakur, 1993). It is an inductive process which moves from a specific instance to generalisation and its' output are proposed hypotheses. The descriptive research design aims to provide an accurate description of the unit under investigation with minimum bias and maximum reliability by testing specific but non-causal hypotheses (Saunders *et al.*, 2012; Thakur, 1993). It is a deductive process which moves from generalised true principles to reach specific conclusions. Explanatory studies establish casual links between variables in order to explain the relationship between the variables and are often experimental in nature (Saunders *et al.*, 2012).

Specific strategies for conducting social science research include experiments, surveys, archival research, case studies, ethnography, action research, grounded theory and narrative inquiry. Each method is associated with either the qualitative or quantitative research design and in some instances both and can be used within either of the general research directions. Each method has its own advantages and disadvantages depending on the type of research question, control available over behavioural events or focus on either current or historical events (Saunders *et al.*, 2012; Yin, 2009). Only the experimental, survey and case study strategies are discussed below because they are "principally or exclusively linked to a quantitative design" (Saunders *et al.*, 2012: 173), which is the preferred design for this study. The case study, while principally associated with a qualitative design, can be used in a quantitative study as well (Saunders *et al.*, 2012).

8.6.1 Experiment

An experimental research involves controlling and manipulating the environment to observe and measure results in order to establish the effect of one variable on another to test causal hypotheses (Jankowicz, 2005; Murray, 2003; Neutens and Rubinson, 2002; Saunders *et al.*, 2012; Thakur, 1993). It is considered the most effective method for hypothesis testing and it has the advantages of producing valid results since the results are often based on several observations which can also be fairly easily replicated and can reliably establish cause and effect relationships (Neutens and Rubinson, 2002). However, the experimental method is costly at times and obtaining cooperation from participants can be difficult. A variant of the experimental strategy is the ex-post facto research which tests causal hypotheses for treatments to variables which has already occurred and is used in instances where it is not possible or ethical to assign elements into groups and manipulate the variable under study (Saunders *et al.*, 2012; Thakur, 1993).

8.6.2 Survey

Surveys use statistical sampling to get a representative sample of the population of study when a census of the population is not possible (Fellows and Liu, 1997; Murray, 2003). Surveys are useful for revealing the current status of a variable in an entity but they fail to highlight the unique way in which individual variables fit in the pattern within the collective averages (Jankowicz, 2005; Murray, 2003). Because they are conducted on a sample basis, they are subject to sampling error and the sample itself may not be representative of the population from which it is drawn and so generalisations may not apply to the population (Saunders *et al.*, 2012; Thakur, 1993). Surveys are one of the most widely used method and have the advantage of greater objectivity, lower cost and greater anonymity compared to other methods (Nachmias and Nachmias, 1981; Saunders *et al.*, 2012; Thakur, 1993). Survey data can be analysed using descriptive and inferential statistics and the relationships between variables can be depicted in a model of the relationships of the variables (Saunders *et al.*, 2012).

8.6.3 Case study

Case study research is preferred when "how" or "why" questions are being asked and there is little control over events and the focus is on current events in a real-life context (Yin, 2009). Case studies involve the intensive examination of a single entity but can also take a comparative form when they focus on more than a single entity (Murray, 2003; Thakur, 1993). It is used when a study focuses on a set of issues within an entity which requires an in-depth study (Jankowicz, 2005; Saunders *et al.*, 2012). While it has the advantage of revealing how a multiplicity of factors has interacted in an entity, findings cannot be reliably generalised to other entities (Fellows and Liu, 1997; Murray, 2003; Thakur, 1993)

This research used the descriptive research approach. The descriptive research approach was favoured firstly because it lends itself well to the research problem and also hypotheses needed to be tested. Secondly, while the experimental strategy has the advantage of revealing causal relationships among variables, it was not favoured, since it was not feasible to experiment on the students while the ex-post design and case study could not apply to the variables under study. The survey strategy was the favoured strategy for the research because only a representative sample was required to test the research hypotheses and so establish the current status of the research variables.

8.7 Time Horizon

There are two time horizons available for conducting research and these are cross sectional and longitudinal (Babbie, 1990; Saunders *et al.*, 2012; Sekaran and Bougie, 2010).

8.7.1 Cross sectional

A cross sectional study is also called a one-shot study. In this study, data are collected once perhaps over a period of days, weeks or months and so reports the scenario or relationships valid at the time of the data collection (Babbie, 1990; Saunders *et al.*, 2012; Sekaran, 2003; Sekaran and Bougie, 2010).

8.7.2 Longitudinal

In longitudinal studies, data are collected at least at two different times and so are able to report any changes in the variables under study over time (Babbie, 1990; Saunders *et al.*, 2012; Sekaran, 2003). Longitudinal studies are used to study phenomenon at more than just one point in time (Saunders *et al.*, 2012; Sekaran, 2003). While longitudinal studies could help identify cause-and effect relationships, they take more time and effort and are costlier than cross sectional studies (Sekaran, 2003; Sekaran and Bougie, 2010).

The cross sectional time horizon was the chosen time horizon for the research because a single time description of the research variables was enough to respond to the research questions and achieve the research objectives. While there may be value in researching the changes in the research variables with time through a longitudinal study and establishing some causal relationships, such a study would be costly and time consuming and does not fall within the objectives of the current study.

8.8 Techniques and Procedures

Research techniques and procedures refer to the details of data collection methods and procedures for choosing the research participants (Saunders *et al.*, 2012). Several options for data collection and sampling are available and these are detailed below.

8.9 Data Collection Methods

Research data can be collected in a number of ways including content analysis, questionnaires, interviews, observation surveys and projective methods. Figure 8-3 summarises the available methods of collecting data.

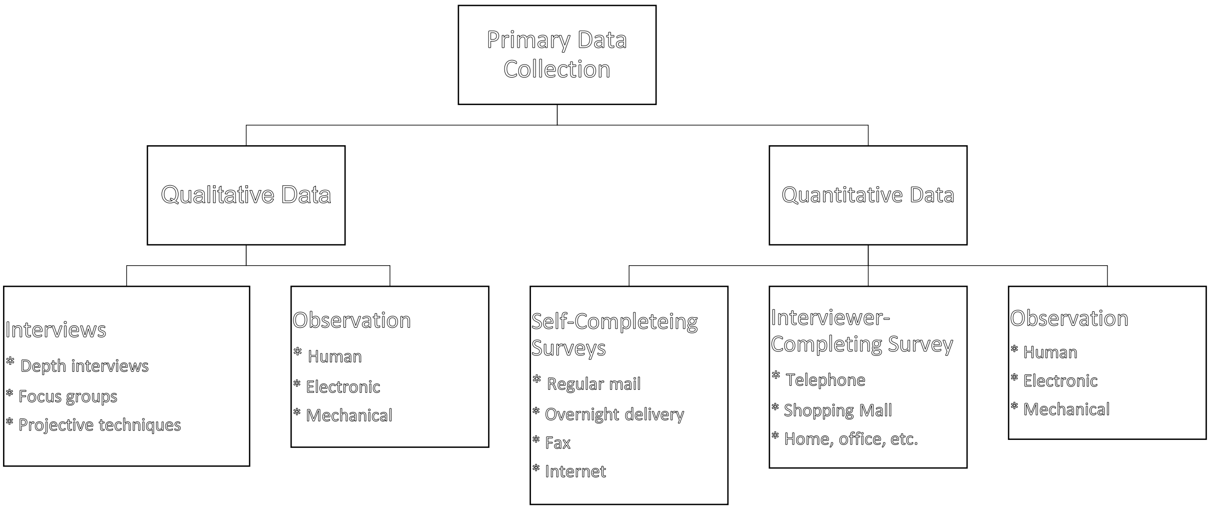


Figure 8-3: Primary data collection methods (Hair et al., 2007)

There are two broad approaches to collecting qualitative data and these are observation and interviews. Methods for collecting quantitative data fall into three broad categories namely self-completion, interviewer-completion and observation (Hair *et al.*, 2007). Observation can take the form of content analysis or ethnographies while interviews can be structured, semi-structured (which includes focus groups), unstructured, depth interviews or projective techniques. Self-completion includes self-administered questionnaires while interviewer-completion includes telephone surveys (Ibid). Some of the data collection techniques are discussed further below.

8.9.1 Content analysis

Content analysis involves systematically searching through and analysing the contents of documents (Babbie, 1990; Hair *et al.*, 2007; Murray, 2003). It is used for collecting qualitative data from written or printed documents, audio recordings, still photo-graphs, motion-picture films and video recordings among others (Murray, 2003). It is the only appropriate method for extracting data from such documents. However, it is much more time consuming and laborious in relation to the amount of data collected when compared to other methods of collecting data (Ibid).

8.9.2 Interviews

Interviews involve the researcher asking oral questions to the respondents in a purposive and systematic manner in order to obtain information pertinent to the research problem (Hair *et al.*, 2007; Murray, 2003; Thakur, 1993). This can either be in a face-to-face interaction by the researcher with the respondent or by phone or even by video conferencing (Murray, 2003; Thakur, 1993). With the advent of text messaging through computers, interviews can also be conducted in typed format with the researcher typing the questions and the respondent typing the answers (Ibid). Interviews have greater flexibility and researcher control than do questionnaires since the respondent can seek clarification for questions which are not understood and the researcher can pick up some none verbal cues from the body language of the respondent and the quality of the data is often very good (Judd *et al.*, 1986; Murray, 2003; Sekaran, 2003; Thakur, 1993). However, interviews take a lot of time since the interviewer has to meet separately with all respondents and so are generally the costliest data collection method. Also, respondents may feel uneasy about the anonymity of their responses and the rapport between the interviewer and the respondent may introduce a large interviewer bias (Judd *et al.*, 1986; Murray, 2003; Sekaran, 2003; Thakur, 1993).

8.9.3 Questionnaire

A questionnaire is an organised and ordered set of questions for gaining information from respondents related to the research problem and are preferred for data collection when the researcher knows exactly what data is required and how to measure it (Sekaran, 2003; Thakur, 1993). Questionnaires enable the researcher to collect a large amount of data in a short period of time (Murray, 2003). However, if the researcher is not available to supervise the dissemination and return of the questionnaires, respondents may not fill in the questionnaire and the respondents do not have an opportunity to seek clarification on the questions when required nor can respondents explain what has influenced their responses (Judd *et al.*, 1986; Thakur, 1993).

Questionnaires can be grouped into three types based on the responses required namely, closed responses, open responses and a mixture of both (Judd *et al.*, 1986; Saunders *et al.*, 2012; Thakur, 1993). In the closed response type, both the questions and answers are already given and can be further divided into dichotomous, multiple choice type and rank order type which is based on the available alternative answers (Judd *et al.*, 1986; Thakur, 1993). Closed response questions have the advantage of being easy to apply, score and code with no writing required from the respondents and so provides quick answers but suffer the drawback that the researcher may fail to provide all the possible alternative responses and also respondents may become disengaged in their responses (Judd *et al.*, 1986; Saunders *et al.*, 2012; Thakur, 1993). In the open-end response type questions, respondents are required to provide answers in their own words and so are not forced to respond in terms of the given choices so the respondents are less restricted in their responses and therefore may provide unanticipated and insightful responses (Ibid). However, the open-end questions are difficult to code and responses are prone to bias (Ibid).

Questions in a questionnaire may be aimed at learning what respondents know (facts), what they think, expect, feel or prefer (beliefs and attitudes) or what they have done (behaviours) (Judd *et al.*, 1986). Questions on fact are susceptible to respondent error due to memory lapses especially when events occurred far in the past and are also susceptible to pressure to provide socially acceptable answers (Hair *et al.*, 2007; Judd *et al.*, 1986; Saunders *et al.*, 2012). Questions on beliefs and attitudes are the most difficult to write because attitudes are complex and multidimensional (Ibid). Questions on behaviour should be very specific. The length of time since the behaviour occurred will influence the accuracy of the response (Ibid). A questionnaire generally includes more than one of the question categories and a single question may have more than one category (Ibid). Long complex questions are often misunderstood by respondents and so questions should be relatively short and simple (Ibid).

Questionnaires have the advantage of being the least expensive data collection method, have no interviewer bias compared to interviews, present no pressure of immediate response and give respondents a greater feeling of anonymity (Judd *et al.*, 1986). However, questionnaires are criticised for having questionable quality of data when the response rate is below 50% with rates of at least 80% being recommended as being of acceptable quality (Judd *et al.*, 1986; Saunders *et al.*, 2012). The quality of the data is also affected by the accuracy and completeness of the responses (Ibid). Further, the researcher has no control on the context in which the respondents respond to the questionnaire and in instances, respondents are influenced in their responses by people around them (Ibid). Illiterate people are not able to respond to questionnaires and often even for literate respondents, complex instructions can lead to confusion and errors or non-response (Judd *et al.*, 1986).

When the population of interest is 'captive' such as students with whom questionnaires can be mass administered at gatherings, response rates can approach 100% and some restrictions such as questionnaire length often do not apply and the approach is very low cost. However, when the 'captive' population is assembled for the sake of administering the questionnaire only, the respondents who attend may differ significantly and in unknown ways from those who choose not to attend and so even if the response rate may be very high, the sample may not be representative (Ibid).

8.9.4 Other methods of data collection

Other methods of collecting data include observation surveys and projective methods. Observation surveys involve the researcher observing the study participants in the research setting while projective methods are used to study phenomenon which cannot be easily verbalised or observed and involves trained professionals probing the respondent to reveal deep rooted ideas and thoughts (Sekaran, 2003).

There is value in using a multi-method of data collection to validate one set of data with another set because there is more confidence in data if two sets of data collected differently corroborate each other or bias in responses may be revealed when two sets of data contradict each other (Judd *et al.*, 1986; Sekaran, 2003). However, Sekaran (2003) suggested that such a study would be costlier and more time consuming. On the other hand, Judd *et al.* (1986) suggested that collecting data from one portion of the sample with questionnaires and using interviews for the remaining portion can reduce the average cost. However, such an approach would yield different responses and potentially, problems in data analysis and biases on the data (Ibid).

The choice of data collecting method was guided by the fact that the research questions required quantitative data and so qualitative methods were precluded on this basis. To collect the quantitative data, the questionnaire with close-end questions was the preferred data collection method because of the low cost associated with it, the ease of collecting large amounts of data in the format appropriate for the chosen data analysis approach. The questionnaire used questions on facts and on behaviour and attitude and so did not have any problems with questions on belief which are difficult. The questions were kept as short as possible with simple instructions. Since the questionnaire was targeted at students, there was no problem of illiterate respondents. The study took advantage of the 'captive' population of students who were the population of interest. Therefore, mass administration of the questionnaire either at the start or the end of lectures with approval and help from the lecturer in charge of the specific class session was adopted.

The disadvantage of disengaged responses, incomplete responses and low response rates was mitigated by the fact that questionnaires were administered to a captive audience of students. Since the students were not assembled for the sake of administering the questionnaire, the problem of an unrepresentative sample of students did not exist. Any disengaged or incomplete responses that materialised were identified by scrutinising the completed questionnaires and omitting and identified disengaged and incomplete questionnaires from the analysis. The modality for identifying disengaged responses is detailed under the data analysis section.

Open-end questions, interviews, observation and projective methods precluded themselves from selection for data collection because they are qualitative data collection methods and so did not lend themselves to the research problem under study and the chosen data analysis approach and a multi-method data collection approach was outside the scope, available time and budget for the study.

8.10 Sampling Methods

Sampling consists of collecting data from a portion of the population and the portion of the population selected is called a sample. The sample should be of a sufficient number of elements to be representative of the population from which it is drawn for it to be possible to generalise characteristics of the sample to the population (Judd *et al.*, 1986; Nachmias and Nachmias, 1981; Sekaran, 2003; Thakur, 1993). The alternative to sampling is collecting data from the entire population which is called a census. Sampling is preferred over a census because it collects the vital information quickly, cuts costs, and is accurate and easier (Babbie, 1990; Thakur, 1993). A good sample should be a precise and correct representation of the population from which it is drawn (Sekaran, 2003). An inappropriately selected sample may not be a precise and accurate representation of the population. Sampling techniques can be classified into two distinct groups namely probability sampling techniques and non-probability sampling techniques (Babbie, 1990; Hair *et al.*, 2007; Nachmias and Nachmias, 1981; Saunders *et al.*, 2012; Sekaran, 2003; Thakur, 1993).

8.10.1 Probability Sampling

Probability sampling allows for a known chance or probability of an element in a population of interest to be selected as a sample and so provides for a known estimate of the extent to which the sample characteristics may differ from the population of interest (Hair *et al.*, 2007; Nachmias and Nachmias, 1981; Saunders *et al.*, 2012; Thakur, 1993). For this to be possible, a list of all elements in the population of interest is required. This makes the approach costlier and time consuming (Hair *et al.*, 2007; Saunders *et al.*, 2012; Thakur, 1993). The major types of probability sampling available are simple random sampling and stratified random sampling.

In simple random sampling, every element in the population has a known and equal chance of being included in the sample (Hair *et al.*, 2007; Judd *et al.*, 1986; Saunders *et al.*, 2012; Sekaran, 2003). It has the least sampling bias and offers the most generalisability but is cumbersome, time consuming and costly (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003).

Stratified random sampling is used when the population of interest is not homogenous in the distribution of the groups. The population is therefore stratified into sub-populations of the different groups before random sampling is applied to each of the stratified sub-populations (Hair *et al.*, 2007; Saunders *et al.*, 2012; Sekaran, 2003). Two variants of stratified random sampling are possible, namely proportionately stratified sampling and disproportionately stratified sampling (Hair *et al.*, 2007).

8.10.2 Non-probability Sampling

In non-probability sampling, the probability of an element in the population of interest being included in the sample is not known *a priori* and not every element has a chance of being included in the sample (Hair *et al.*, 2007; Sekaran and Bougie, 2010). The major types of non-probability sampling techniques are, purposive sampling, convenience sampling and accidental sampling (Hair *et al.*, 2007; Nachmias and Nachmias, 1981; Thakur, 1993).

Purposive sampling involves collecting data from respondents in a specific target group who can provide the required data and it has two variants namely judgement sampling and quota sampling (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). Judgement sampling is the selection of a sample based on participants who are most advantageously placed to provide the required data while quota sampling involves assigning quotas to groups in a heterogeneous population akin to stratified random sampling but devoid of random subject assignment (Judd *et al.*, 1986; Sekaran, 2003). Convenience sampling involves sample selection based on the convenient access to the subjects (Sekaran, 2003) while accidental sampling involves picking elements of a sample based on their being available and continuing such selection until the required sample is reached (Judd *et al.*, 1986). Conveniently chosen samples usually meet the purposive sampling selection criteria that are relevant to the research aim (Saunders *et al.*, 2012).

The main advantage of non-probability sampling methods are time and economy which often outweigh the benefits of probability sampling methods (Hair *et al.*, 2007; Judd *et al.*, 1986). Based on this advantage, this study used the non-probability sampling method based on convenience to select three public universities to participate in the study. The three public universities were conveniently selected based on their proximity to the domicile of the researcher in the Durban metropolitan area of the KwaZulu-Natal province of South Africa. After the convenient sample of the public universities, all the students present in class at the time of questionnaire administration were included in the sample. The target population were undergraduate students studying construction programmes of either construction management, quantity surveying or architecture.

8.11 Data Analysis

Raw data provides very little meaning and so must be processed and analysed to turn them into information (Saunders *et al.*, 2012). Data analysis can either be univariate, bivariate, or multivariate. Univariate analysis deals with one variable at a time and usually takes the form of frequency tables, histograms, measures of central tendency and dispersion while bivariate analysis deals with establishing the relationship between two variables (Bryman and Bell, 2011). Multivariate analysis deals with the simultaneous analysis of three or more variables (Bryman and Bell, 2011; Hair *et al.*, 2007). Because the study had several research variables to consider, multivariate analysis was preferred while univariate statistics were also reported. The preferred multivariate analysis was Structural Equation Modelling (SEM). Prior to SEM, the data were also factor analysed using exploratory factor analysis (EFA) after which they were assessed for reliability and validity. Prior to SEM and EFA, the data were screened for missing data, outliers, extreme values and disengaged responses after which sample demographic statistics were computed. The data analysis process is summarised in Figure 8-4.

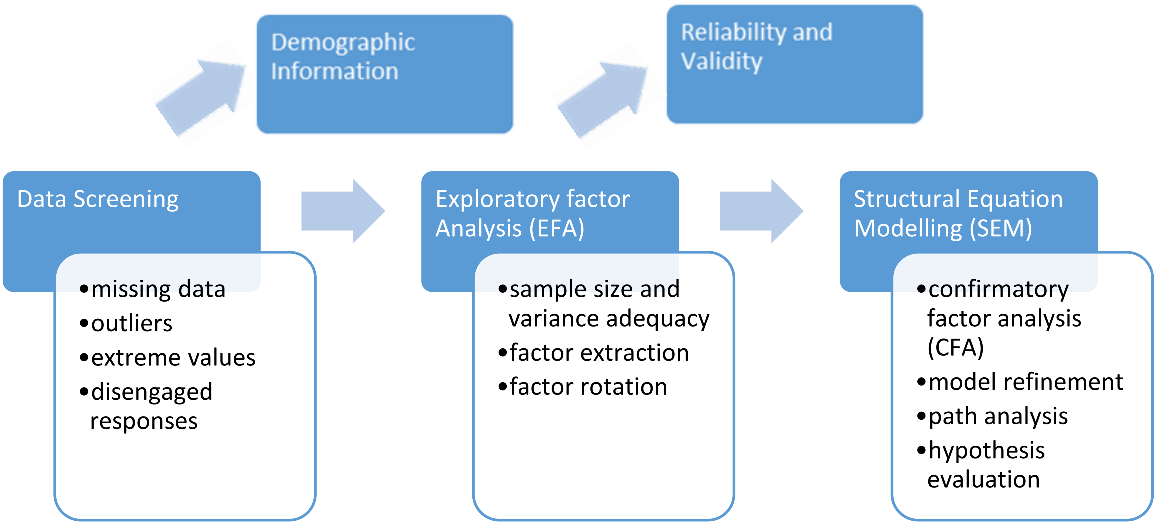


Figure 8-4: Data Analysis Process

8.11.1 Data Screening

Missing data can affect the validity of the findings (Hair *et al.*, 2007). If the proportion of missing data is greater than 10% of missing data points, it is recommended to omit the respondent from the analysis and if it is less than 10%, the missing data points may be estimated by substituting with the mean scores for each of the data points (Ibid).

Outliers, extreme values and disengaged responses can impact the validity of research findings (Ibid). Outliers are respondents with responses distinctly different from the rest of the respondents and may represent an error in data entry or may be correct entry for a respondent who is distinctly different from the rest of the respondents (Ibid). When it cannot be determined that an outlier constitutes a valid distinctly different response, it should be removed (Hair *et al.*, 2007). Extreme values were classified as those values which were at least five standard deviations from the mean. Responses which had been obviously repeated or had random patterns which were clearly not logical were flagged as disengaged responses. IBM SPSS Modeller, anomaly detection model, was used to identify unusual cases or outliers and extreme values. It is based on anomaly indices of each data point which is the ratio of the data point variance from the average group variance index for the cluster which the case belongs to. It has the advantage over other methods of anomaly detection that it does not require a training data set.

8.11.2 Exploratory Factor Analysis

Exploratory factor analysis (EFA) was used for data reduction to examine the factor structure of the measurement instrument (Byrne, 2006; Laher, 2010; Matsunaga, 2010; Worthington and Whittaker, 2006). It was used to identify coherent subsets of the data which were fairly independent of each other and could therefore be considered distinct constructs. These constructs then formed the basis of the variables for analysis. EFA was also useful for determining the construct validity of an instrument (Laher, 2010). The flow chart used to guide the EFA is shown in Figure 8-4. The EFA started with the determination of the adequacy of the sample for EFA. The KMO measure of sampling adequacy and the Bartlett's test of sphericity were used to determine whether the sample size was sufficient for a reliable EFA. This was followed by the interpretation of the communalities of the items. Then a decision was made on the number of factors to retain for the EFA by choosing either the eigen-value greater than one criteria, using a scree plot or using theory to guide the number of factors to retain. The factors retained were then rotated to achieve a better interpretation of the results. A choice was made between orthogonal and oblique rotations. The resulting factor loading were then interpreted. The specific decisions made at each point and the rationale for doing so are discussed in data analysis section.

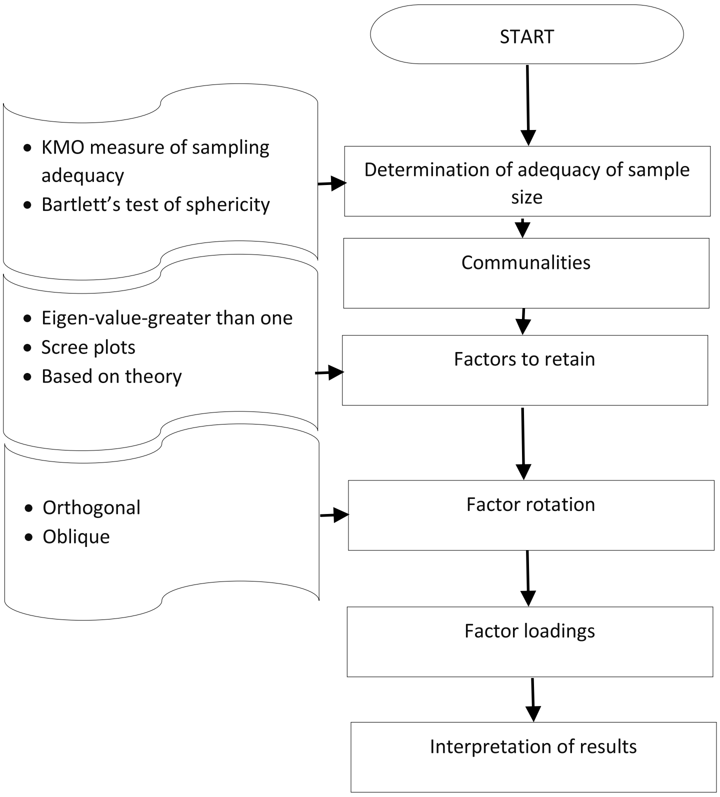


Figure 8-5: Flow Diagram for EFA

8.11.3 Structural Equation Modelling

Structural Equation Modelling (SEM) is a multivariate data analysis approach used to assess complex relationships among constructs. It graphically models hypothesised relationships among constructs with structural equations (Byrne, 2006). Subsequently, it establishes how well the theoretical model is supported by empirical data using goodness of fit indices (Byrne, 2006; Hu and Bentler, 1999). Assessment of model fitness is achieved using several model fit indices. SEM can either be covariance based (CB-SEM) or based on partial least squares (PLS-SEM). CB-SEM is used to test or confirm theory and when the error terms require covariation among other reasons (Hair *et al.*, 2014). PLS-SEM is used when identifying key predictor constructs or when the structural model is complex or when the sample is small or non-normal (ditto). While the structural model for this research was complex and the prediction of key constructs was one of the objectives (which are strong points of PLS-SEM), CB-SEM was preferred because the available software for analysis, IBM AMOS, uses a CB-SEM. Further, the sample size was very large and so suitable for CB-SEM and there was no reason to reject the assumption of normality of the data.

8.12 Reliability and Validity of Measures

The measurement instrument was checked to see that it actually measures the underlying construct and that it does so accurately (Hair *et al.*, 2007; Sekaran, 2003). The possible measures of the goodness of the measuring instrument are depicted in Figure 8.6 and they are dived into reliability and validity measures.

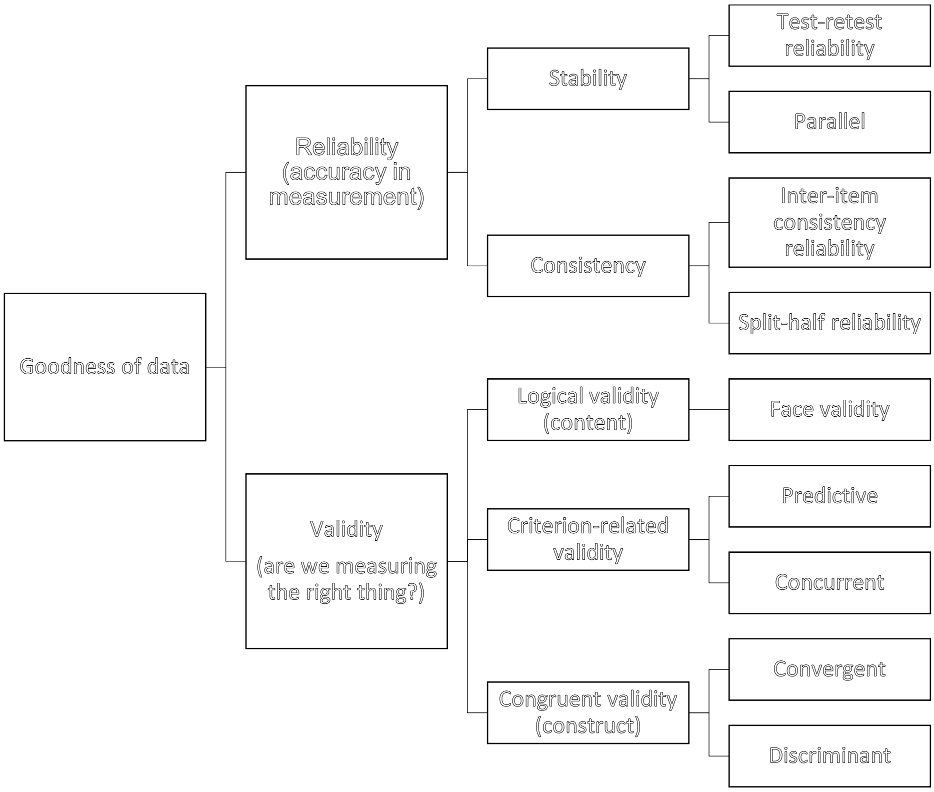


Figure 8-6: Testing Goodness of measures – Forms of Reliability and Validity (Sekaran, 2003: 204)

8.12.1 Reliability

Reliability is a measure of the consistency of the measuring instrument in measuring what it is supposed to measure (Hair *et al.*, 2007; Judd *et al.*, 1986; Saunders *et al.*, 2012; Sekaran, 2003). It relates to the degree of accuracy of the research measuring instrument exhibited by the extent to which scores of a test stay the same for the same unit of analysis over time and so independent but comparable measures of the same unit give similar results unless the unit or the situation or conditions under which the study is done change (Hair *et al.*, 2007; Nachmias and Nachmias, 1981; Sekaran, 2003; Thakur, 1993). An instrument which stays constant for the same unit of analysis is relatively error free and therefore reliable (Hair *et al.*, 2007; Nachmias and Nachmias, 1981; Thakur, 1993).

There are two types of reliability namely stability and consistency. Stability refers to the ability of a measure to stay the same for measures taken over time and can be ascertained by the test-retest reliability which is measured by the correlation of between scores of the same test taken at different time intervals (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). Stability can also be ascertained by parallel-form reliability when two comparable sets of measures for the same construct are highly correlated (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). Consistency refers to the internal correlation of the items in a construct. Items within a construct should be highly correlated if they are measuring the same thing. This can be ascertained through either the inter-item consistency reliability or the split-half reliability (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). Measures of inter-item consistency reliability include the Cronbach's alpha which is used for measures with multiple items, the Kuder-Richardson formulas which is used for dichotomous items and the split-half reliability which is the correlation of two halves of a scale (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). The split-half reliability has the drawback that the measure varies depending on how the two halves of the scale are split (Ibid).

8.12.2 Validity

Validity is a necessary measure of goodness of a measure because while reliability is necessary, it is not in itself a sufficient condition of the goodness of a measure (Hair *et al.*, 2007; Saunders *et al.*, 2012; Sekaran, 2003). The validity of a measuring instrument is the measure of how well the instrument measures what it is supposed to measure and that the instrument is not in fact measuring something else (Bryman and Bell, 2011; Hair *et al.*, 2007; Judd *et al.*, 1986; Nachmias and Nachmias, 1981; Sekaran, 2003; Thakur, 1993). There are three distinct and broad types of validity of a measuring instrument namely, content validity, criterion validity and construct validity (Bryman and Bell, 2011; Hair *et al.*, 2007; Sekaran, 2003). Content validity is the extent to which the scale items represent the construct and is ascertained by the opinion of experts on the subject matter (Bryman and Bell, 2011; Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). It can also be ascertained by face validity, which is the extent to which the items appear to measure the construct (Ibid). However, face validity is criticised by some as not being a valid component of content validity (Hair *et al.*, 2007; Sekaran, 2003). Criterion-related validity ascertains whether a measure can differentiate responses based on a criterion and it has two facets namely concurrent validity and predictive validity (Ibid). Concurrent validity is established if respondents who are known to be different can be discriminated by the measure while predictive validity discriminates respondents based on a future criterion (Ibid). Construct validity is the extent to which the results from the measure fit the theories around which the scale is deigned and therefore accurately reflects the construct of interest (Hair *et al.*, 2007; Judd *et al.*, 1986; Sekaran, 2003). It has two facets namely convergent validity and discriminant validity. Convergent validity exists when two different scales designed to measure the same construct are highly correlated while discriminate validity exists when, based on theory, two scales which are predicted to be uncorrelated are empirically found to be so (Ibid). The different aspects of validity are depicted in Table 8-1.

Table 8-1: Types of Validity

Validity	Description
Content validity	Does the measure adequately measure the concept?
Face validity	Do "experts" validate that the instrument measures what the items suggest in measures?
Criterion-related validity	Does the measure differentiate in a manner that helps to predict a criterion variable?
Concurrent validity	Does the measure differentiate in a manner that helps to predict a criterion currently?
Predictive validity	Does the measure differentiate in a manner that helps to predict a future criterion?
Construct validity	Does the instrument tap the concept as theorised?
Convergent validity	Do two instruments measuring the concept correlate highly?
Discriminant validity	Does the measure have a low correlation with a variable that is supposed to be unrelated to this variable?

Source: Sekaran (2003: 208)

Table 8-2: Research Assessment of Reliability and Validity

<table>
<tr><th colspan="2">Reliability</th><th colspan="4">Validity</th></tr>
<tr><th rowspan="2">Stability</th><th rowspan="2">Consistency</th><th rowspan="2">Face Validity (Logical Validity)</th><th rowspan="2">Content Validity</th><th colspan="2">Construct validity</th></tr>
<tr><th>Convergent Validity</th><th>Discriminant validity</th></tr>
<tr><td>• Repeated measures in pre-test
• Correlated measures among different classes from different universities</td><td>• Cronbach's alpha
• Item-to-correlations
• Composite reliability</td><td>• Literature
• Operationalisation of measures</td><td>• Literature
• Operationalisation of measures</td><td>• Inter-construct correlations
• Standardised factor loadings
• Exploratory Factor Analysis
• Confirmatory Factor Analysis</td><td>• Inter-construct correlations
• Exploratory Factor Analysis
• Confirmatory Factor Analysis
• Average variance extracted</td></tr>
</table>

Reliability and validity of the measures were assessed as depicted in Table 8-2. To ensure face validity and content validity, measures were adapted from existing instruments whose validity was reported. Where suitable measures did not exist, new measures were developed and the conceptualisation and operationalisation of these new measures was based on theory and literature to ensure both face and content validity. The conceptualisation, operationalisation and development of the research instrument is detailed in Chapter 9. Convergent validity was assessed by checking whether measures which, based on theory and literature, are expected to correlate do indeed correlate and discriminant validity was assessed by checking that measures which, based on theory and literature, are expected to have little or no correlation in fact have little or no correlation. The empirical assessments of reliability and validity are discussed in chapter 10.

8.13 External Validity of the Study

Besides the reliability and validity of the measures, external validity in the research must also be established. External validity refers to the efficacy of generalising the research findings to the population from which the sample is drawn (Neutens and Rubinson, 2002). External validity of a study is important in order to avoid the results, and therefore the implications of the research, from being doubted. External validity can be threatened by a number of factors including sample selection which may introduce sampling bias, the research design, methods and operationalisation of constructs and testing effects in experimental studies because participants often behave differently the know they are being observed.

For the current research, the choice of convenience sampling presents a threat to external validity because the conveniently selected sample may be significantly different from the general population. The research design and methods chosen for the research do not particularly introduce external validity issues. The research constructs were operationalised so as not to introduce threats to external validity. A detailed discussion of the operationalisation of the research constructs is presented in the chapter which follows.

8.14 Chapter Summary

This chapter discussed the research methodology adopted for the study. Based on the research onion by Saunders *et al.* (2012), the research methodology followed breaks down into the research philosophy used, the research approach, the research design, the research strategy adopted, the time horizon of the study, the techniques and procedures of data collection and sampling adopted, the data analysis methods adopted and also alludes to the reliability and validity of measures. The study followed a positivist epistemological philosophy and a subjective ontological philosophy, a deductive research approach, a quantitative research design, a survey research strategy, a cross sectional time horizon and techniques and procedures of questionnaire survey using non-probability convenient sampling.

The positivist philosophy was favoured because the research sought to test hypothesised relationships to which the positivist philosophy is suited while the objective ontology position was favoured because the study views students as social-actors independent from the class. A deductive approach was favoured in tandem with the philosophy of positivism and since the research sought to test hypotheses. A quantitative research design was preferred in tandem with the positivist philosophy and objective of hypothesis testing. A survey research strategy was favoured because the target population of students studying construction programmes in South Africa was too big for a census. A cross sectional time horizon was favoured because it was sufficient to meet the objectives of the research using a single time shot of survey data as opposed to a longitudinal survey which would have been costlier and time consuming. Non-probability convenient sampling was favoured because of time and resource constraints of conducting probability sampling.

CHAPTER 9

CONSTRUCT OPERATIONALISATION AND QUESTIONNAIRE DEVELOPMENT

9.1 Introduction

This chapter presents a detailed description of the development of the measurement instrument used in the study to measure the constructs detailed in the conceptual and theoretical framework. The chapter starts by describing the available measurement scale options and then argues for the choice of the selected measurement scale. A description of the measurement instruments and their conceptualisation and operationalisation including the measurement items are presented. The procedure followed to pre-test the measurement instrument is also presented with the resulting final pre-test descriptive, reliability and validity statistics.

9.2 Measurement

Measurement involves assigning numbers to characteristics of units based on pre-specified rules (Nachmias and Nachmias, 1981). Three different measurement scales are available which differ in the manner in which they try to capture the position of an individual with respect to the characteristic being measured and these are the differential scale, the summated scale and the cumulative scale (Thakur, 1993). The differential scale developed by Thurstone uses a large number of suitable brief statements which are arranged by a group of judges into statements which are either neutral, extreme unfavourable attitude or intermediate position and assigning a scale to each item and the scale is then administered to the respondents (Babbie, 1990; Judd *et al.*, 1986; Thakur, 1993). In the differential scale, the measurement items are themselves the scale and the respondents are asked to either agree or disagree with the items and their attitude score is computed as the median of the values of the items (Babbie, 1990; Judd *et al.*, 1986; Thakur, 1993). The Thurstone scale is hardly ever used in research due to the large effort required from judges to score the items and generally has lower reliability than other scales.

Rensis Likert developed a scale based on summing up individual scores from a set of brief statements (Babbie, 1990; Judd *et al.*, 1986). The summated scale by Rensis Likert measures attitude and differs from the differential scale in that rather than being rated by judges, the items in the summated scale are rated by the respondents (Babbie, 1990; Judd *et al.*, 1986; Thakur, 1993). The Likert scale is usually simpler to construct than other scales, can be used in many cases in which other scales cannot be used and is more reliable. The Rensis Likert method of scale construction assumes that the scores of the many items is a good measure of the construct under study (Babbie, 1990). However, only the items which are sufficiently correlated with the composite measure from all the items are the best indicators of the construct (Ibid). The correlation of the individual item with the composite score of the items is called the item-to-total correlation. Items measuring the same construct should be correlated with each other while a very high correlation between two items would suggest that the items are empirically the same and so one may be omitted from the construction of the scale (Babbie, 1990). The Likert scale is criticised for not indicating the latitude of acceptance (Judd *et al.*, 1986).

Other measurement scales available include the Borgardus Social Distance Scale which is a cumulative scale and the Louis Guttman Scale. Both of these scales are rarely used in practice today (Babbie, 1990; Judd *et al.*, 1986; Thakur, 1993).

Notwithstanding that the Likert scale is criticised for not indicating the latitude of acceptance like the Thurstone scale and for not giving the exact pattern of responses like the Guttman scale (Judd *et al.*, 1986), it was chosen as the preferred measurement scale. It was chosen because it offers greater advantage over all other measurement option in that the differential scale by L.L. Thurstone is time consuming and costly because of the need for several judges to rate the items, while the cumulative scales are not appropriate for the research problem and do not lend themselves to the chosen data analysis approach. The Likert scales adopted were anchored on a 5-point rating with 1=Almost Never, 2=Seldom, 3=Sometimes, 4=Often and 5=Almost Always.

The number of items in a measure is important since it has been shown that a larger number of items lead to a higher measure of reliability (Ibid). For this study, a fairly small number of items per construct were used due to the large number of constructs under study (16 constructs). Use of many items to measure each construct would have resulted in a substantially large questionnaire which would not produce reliable data due to incomplete and disengaged responses associated with large questionnaires.

9.3 Operationalisation of Concepts and Instrument Development

Operationalisation is the developing of the measuring scales to be used for collecting the research data (Mouton, 1996; Sekaran and Bougie, 2010). It is a series of procedures followed to obtain a measure of an abstract concept and consists of specifying the empirical measures that can be taken to indicate the concept under study (Babbie, 1990; Judd *et al.*, 1986; Sekaran, 2003). It starts with arriving at the operational definition of an abstract concept which renders the abstract concept measurable by looking at the behavioural dimensions, facets or properties exhibited by the concept and then reducing these into items or questions which actually capture the behavioural dimensions, facets or properties underlying the concept (Sekaran and Bougie, 2010). The items or question used should have simple and short questions rather than long ones and as a rough guide, the item or question should preferably not exceed 20 words or be more than one full line when printed (Judd *et al.*, 1986; Sekaran, 2003).

Where established measures of a concept exist, they may be used in preference to laboriously developing new measures. This is because established measures have validated psychometric properties and where more than one established measure exists, the one with better reported psychometric properties and also more frequently used by other authors should be preferred (Judd *et al.*, 1986; Sekaran, 2003; Sekaran and Bougie, 2010). Often, it is necessary to adapt a measure to suit the setting when there is a difference in the setting in which the original instrument was developed for from that in which it will be applied (Sekaran, 2003). However, Judd *et al.* (1986) recommended that when an existing measure is used, the wording should be repeated exactly because even small changes in word use may yield large differences in responses. Also, when the wording is kept exactly the same, comparison with other previous studies with similar measures produces more meaningful results (Ibid).

Hair *et al.* (2007: 248-249) suggested a 6 step approach to developing a questionnaire namely:

1. Definition the concept or concepts to be measured
2. Identification of the components of the concept
3. Specification of a sample of observable and measurable items (indicative or proxy variables that represent the components of the concept)
4. Selection of the appropriate scales to measure the items
5. Combination of the items into a composite scale, sometimes referred to as an instrument which in turn serves as a means of measuring the concept.
6. Administer the scale to a sample and assess respondent understanding
7. Confirm scale reliability and validity
8. Revise scale as needed

This approach recommended by Hair *et al.* (2007) was used to develop the questionnaire. Step 1, the definition of the concepts, was achieved in the chapter on conceptual framework. Steps 2 to 4, Identification of the components of the concept, specification of measurable items and the selection of scales, were achieved by searching for appropriate existing instruments which had already been validated. Where no appropriate instruments were found, the concept was operationally defined based on reported literature (step 2) and indicative measurable items developed (step 3) and scrutinised by an experienced researcher and subsequently revised before final items were decided (step 4). The resulting scales were then combined into the final format of the instrument (step 5) and administered to a small sample of the population of interest in a focus group to assess respondent understanding of the instrument (step 6). The instrument was adjusted based on feedback from the focus group and then pre-tested with another sample from the population of interest and the resulting data analysed for reliability and validity and the instrument further adjusted in view of the results (steps 7 and 8).

Based on the conceptual model previously presented, the concepts under study can be grouped under 1) constructivism, 2) behaviourism and 3) cognitive load theory. Approach to learning was conceptualised as deep learning and surface learning.

9.3.1 Constructivism

The sub-scales of constructivism conceptualised in this study are the zone of proximal development (ZPD), scaffolding, active learning, individual knowledge construction (individual learning), shared construction of knowledge (group learning), self-directed learning and reflective thinking. There are hardly any instruments designed to measure some of these aspects of constructivism as conceptualised in this study.

9.3.1.1 Zone of Proximal Development

No instrument was found measuring ZPD in literature. While Murray and Arroyo (2002) presented an operational definition of the ZPD there work did not focus on developing a Likert scale measure of the construct. Therefore, the ZPD sub-scale was developed by building on the operational definition by T. Murray and Arroyo (2002) and also in tandem with Christmas *et al.* (2013) and Shabani *et al.* (2010). These all operationally define ZPD as instructional material presented to students which is neither too difficult nor too easy but could be handled with some help from a more knowledgeable person. The resulting sub-scale is shown in Table 9-1.

Table 9-1: Zone of Proximal Development Scale

Zone of Proximal Development	
1	I found tests and assignments to be very challenging
2	I was given work which was beyond what I could manage to do on my own
3	I was given work which required further guidance from the lecturers in order to complete it
4	I was given work which required consulting with more knowledgeable people in order to do it well

9.3.1.2 Scaffolding

No appropriate Likert scale instrument was found measuring scaffolding even though several studies allude to it. Therefore, the scaffolding scale was developed by operationalising scaffolding as the instructional support rendered to students by lecturers when learning tasks are located in the ZPD of students (Christmas *et al.*, 2013; Murray and Arroyo, 2002; Shabani *et al.*, 2010). Therefore, the items measuring scaffolding probed the extent to which students received support from their lecturers when they needed it. The resulting scale is shown in Table 9-2.

Table 9-2: Scaffolding Scale

Scaffolding	
1	My lecturers helped me when I could not manage to do the assigned work on my own
2	My lecturers gave me sufficient knowledge, information and support to do my work
3	My lecturers gave me enough help when doing my work
4	My lecturers gave me additional information when I could not manage to do my work
5	I was guided when I could not manage to do the work on my own
6	My lecturers helped me when I asked for help with my work

9.3.1.3 Active Learning

No appropriate Likert scale was found measuring active learning and so a scale was developed. The scale was developed by operationalising active learning as the extent to which students were required to participate in class activities beyond just listening to the lecturer (Aparicio, Morales-Botello, Rubio, Hernando, Muñoz, López-Fernández, Glez-Peña, Fdez-Riverola, de la Villa, Maña, Gachet and Buenaga, 2018; Prince, 2005). The resulting scale is shown in Table 9-3.

Table 9-3: Active learning Scale

Active Learning	
1	I was required to do more than just listening in class
2	I was required to perform practical work activities in class
3	I was allowed to discuss the lecture content with fellow students during a lecture session
4	I took my own notes while listening to the lecturer
5	The lectures involved other activities besides listening to the lecturer

9.3.1.4 Individual Cognition

Individual cognition, which is the individual construction of knowledge as a concept is not measured in extant literature. Based on the seminal work by Jean Piaget (1896 – 1980) on cognitive development of children, it was established that knowledge is created by individual creation on knowledge through experience. This conception of learning is supported by many studies. Therefore, individual cognition was operationalised as the extent to which students were able to synthesise knowledge on their own from their academic experiences. The resulting scale is shown in Table 9-4.

Table 9-4: Individual Cognition Scale

Individual Cognition	
1	I connected new concepts and principles (points) in a module with what I already knew
2	I selected important points to remember from the lectures
3	I used information from class to solve assigned work problems
4	I recognised and noted useful points from the lectures
5	I tried to remember everything from the lectures

9.3.1.5 Sharing Ideas

In addition to individuals creating their own knowledge structures, Vygotsky (1978) argued that cognitive development is also influenced by the social context. Knowledge is therefore constructed and reconstructed following discourse during social interactions. The concept of sharing ideas was therefore developed and operationalised as the extent to which the module allowed students to socialise while learning. The resulting scale is shown in Table 9-5.

Table 9-5: Sharing Ideas Scale

Sharing Ideas	
1	The modules allowed for interaction with fellow students during class
2	The modules had a variety of learning activities
3	The lecturers allowed me to express myself
4	The lecturer allowed me to share my experiences

9.3.1.6 Self-directed Learning

There are several instruments which measure the concept of self-directed learning. However, they are very long instruments and therefore unsuitable for this study because several other constructs need to be measured. Also, available instruments operationalise self-directed learning as the extent to which the students engage in self-directed learning activities. For this study, self-directed learning was conceptualised and operationalised as the extent to which the learning experience offered at school engaged students in self-directed learning. Such a conception allows for the evaluation of the efficacy of attempting to direct students to engage in self-directed learning in view of its already established importance to effective learning. The resulting scale is shown in Table 9-6.

Table 9-6: Self-Directed learning Scale

Self-Directed Learning	
1	I was required to find additional knowledge and information on my own
2	I was given work which required me to learn new concepts on my own
3	I was expected to expand on what was taught in class on my own
4	I was required to learn on my own

9.3.1.7 Reflective Thinking

Several instruments measure reflective thinking of students. This study adapted the four item sub-scale of reflection from the Questionnaire for Reflective Thinking (QRT) by Kember, Leung, Jones, Loke, McKay, Sinclair, Tse, Webb, Wong, Wong and Yeung (2000). The QRT is a sixteen item instrument with four sub-scales of habitual action, understanding, reflection and critical reflection. The adapted items, after appropriate modifications to suit the current study context is shown in Table 9-7.

Table 9-7: Reflective Thinking Scale

Reflective Thinking	
1	I question the way others do something and try to think of a better way
2	I like to think over what I have been doing and consider alternative ways of doing it
3	I reflect on my actions to see whether I could have improved on what I did
4	I review my experience so I can learn from it and improve my next performance

9.3.2 Behaviourism

The concepts derived from behaviourism in this study are repetition, reinforcement and readiness based on the theory of connectionism. No instruments were found measuring any of the concepts as conceptualised in this study. Therefore, all three of the constructions developed by the authors.

9.3.2.1 Repetition, Reinforcement and Readiness

Repetition was conceptualised and operationalised as the extent to which the lectures, key points, and lessons were repeated to aid retention. Reinforcement was conceptualised and operationalisation as the extent to which students were reinforced with praise, compliments, rewards and encouragement. Readiness was conceptualised and operationalised as the extent to which students were emotionally, physically and mentally ready to learn. The resulting sub-scales are shown in Table 9-8.

Table 9-8: Behaviourism

Repetition	
1	My lecturers covered the key points of a lecture more than once
2	My lecturers repeated some lectures
3	Some topics were covered more than once
4	My lecturers emphasised the key points of a lecture by repeating themselves
5	My lecturer allowed for revision of the lecture material

Table 9-8: Behaviourism (Continued)

Reinforcement	
1	I was complimented for good conduct and doing good work
2	I was recognised for good conduct and doing good work
3	I was rewarded for good conduct and doing good work
4	I was praised for good conduct and doing good work
5	I was encouraged when my conduct and work were good
Readiness	
1	I was emotionally, physically and mentally ready to learn
2	I was well prepared for the lectures
3	I was ready to learn when I went for lectures
4	I prepared adequately for class
5	I was well rested (not tired) when going to lectures

9.3.3 Cognitive Load Theory

Based on the cognitive load theory, six concepts were derived for inclusion in the study and these are schema construction and automation, cognitive loading and types of academic problems, namely complex and ambiguous questions, authentic problems, worked examples and completion problems. None of the concepts were conceptualised and measured in a manner appropriate for this study in any previous studies found. Therefore, new measures were developed for these constructs.

9.3.3.1 Schema Construction

Schema Construction was conceptualised as the extent to which students engaged in the process of developing cognitive structures. No Likert scale instruments were found which operationalised schema construction. The scale was therefore developed by operationalising it based on the extent to which lecturers guided students to create these knowledge structures and how the students themselves built on existing schemata. The resulting scale is shown in Table 9-9.

Table 9-9: Schema Construction Scale

Schema Construction	
1	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject
2	My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew
3	I connected points that I already knew with what I was being taught in class
4	I organised, categorised or connected anything new that I learnt with what I already knew
5	My lecturers clearly highlighted the main concepts and principles

9.3.3.2 Cognitive Loading

Several scales measuring cognitive load have been developed. One of the most popular scales is a self-rating scale by Paas, Van Merriënboer and Adam (1994). It measures self-perceived mental effort expended when performing a task. It is therefore used to measure the mental effort directly after a task is performed. For this study, in order to relate cognitive loading to other factors, cognitive load was operationalised as the self-perceived mental effort expended on educational experience in the course of a semester. Based on this conception, no appropriate measure existing measure were found. Therefore, the scale was developed which was operationalised based on the extent to which students were subjected to situations which overload working memory and so induce cognitive load. The resulting scale is shown in Table 9-10.

Table 9-10: Cognitive Loading Scale

Cognitive Loading	
1	I was expected to remember too many things from each lecture
2	I was overwhelmed with the amount of information I was expected to remember
3	I was given with too much information during the lectures
4	The information I was given during lectures was confusing
5	The information I was given in class was complicated and difficult to understand
6	I was overwhelmed with the amount of work I had to do
7	I was given too many projects, assignments and tests

9.3.3.3 Academic Problems

The four types of academic problems namely complex and ambiguous questions, authentic problems, worked examples and completion problems were conceptualised as the extent to which students were presented with these types of academic problems. The concept of complex and ambiguous questions was operationalised as extent to which students were given assessment questions which were complex, ambiguous, very difficult to solve, not clearly defined and with multiple interpretations. Authentic problems were operationalised as the extent to which students were give problems of a real world nature which utilised real world situations and required real world information to solve. The concept of worked examples was operationalised as the extent to which students were given worked examples to practice on. The concept of completion problems was operationalised as the extent to which the students were presented with partially worked problems which required them to complete the remainder of the solution. The resulting sub-scales are shown in Table 9-11.

Table 9-11: Academic Problems

Complex and Ambiguous Questions	
1	I was given assignments and tests which were difficult to understand and solve
2	I was given problems which did not have enough information for me to solve them
3	I was required to solve questions which were not clear as to what I was expected to do
4	I was given questions which could be interpreted in more than one way
5	I was given problems which were not easy to understand clearly
6	I was given questions which were not expressed clearly

Table 9-11: Academic Problems (Continued)

Authentic Problems	
1	I was given problems based on actual industry real life problems
2	I was expected to use real life situations when doing my school work
3	I was required to collect some real world information to do my school work
4	I was given work which was relevant to actual current industry practice
5	I was required to come up with my own solutions to problems
Worked Examples	
1	I was given some worked examples to practice on
2	I was given examples with clearly defined steps on how to solve problems to practice on
3	I was given problems with model solutions to practice on
4	I was shown how to solve a problem before being asked to solve other problems
Completion Problems	
1	I was given partially worked examples to complete
2	I was given partly finished model solutions to problems to finalise the solution
3	I was given problems which were partly solved to practice on
4	I was given problems and part of the solution to work on
5	I was given problems which had gaps that I had to fill in

9.4 Assessment of Questionnaire Suitability - Focus Group

The resulting scales were combined into the research instrument. In tandem with the recommendations by Hair *et al.* (2007) that the instrument should be assessed for respondent understanding, the draft research instrument was administered to a sample of the population of interest. A sample of six respondents were asked to complete the questionnaire and note the amount of time they took to complete it. The respondents were also asked to note any difficulties they experienced with completing the questionnaire. A focus group discussion was held with the six respondents to review their experience with the questionnaire with a view to establish how well they understood the questionnaire and if there were any areas of concern or suggestions for improvement especially with regard to readability and layout.

Prior to the focus group discussion, the respondents were asked to complete a short questionnaire on their experience with the questionnaire. The pre-test questionnaire had a schedule of questions which the respondents were asked to respond to after filling in the questionnaire. The questions were:

1. Was the questionnaire easy to understand?
2. Are the instructions clear?
3. Do you know how to indicate responses?
4. Where there questions you did not understand?
5. Were you comfortable answering the questionnaire?
6. Are all the words in the questionnaire clear?
    a. Which words did you not understand?
7. What improvements would you make to the questionnaire?
    a. Addition or deletion of questions
    b. Clarification of instructions
    c. Improvement of format
8. Was it worth your time responding to the questionnaire?
9. How long did it take you to complete the questionnaire?

All the respondents indicated that the questionnaire was easy to understand and the instructions were clear and that they knew how to indicate responses. One respondent indicated that they did not fully understand some questions while two respondents indicated that they did not understand some words. One respondent stated that they did not understand the word "ambiguous". All the respondents stated that they were comfortable responding to the questionnaire and did not find any questions sensitive or intrusive. One respondent noted that some questions seemed repetitive and that the questionnaire item codes which were included with the draft questionnaire were confusing and distracting. The least amount of time taken to complete the questionnaire was 10 minutes while the longest time taken to complete was 24 minutes.

Based on these responses and ensuing discussion with the focus group, the draft questionnaire was revised. Some questions were revised to simplify grammar. However, the word "ambiguous" was maintained since most of the respondents felt that it was not such a difficult word. Some questions which were too closely worded and so basically meant exactly the same and were therefore repetitive were omitted. The coding which was used to identify items and would be used in subsequent analyses was removed and replaced with numbers only. The main headings for the sections were also removed and only sub-headings of the scales maintained. The time taken to complete the questionnaire was noted in the consent form to assure respondents that only between 15 to 30 minutes of their time was required to complete the questionnaire. The revised draft of the questionnaire was then subjected to pre-testing with another sample of the population of interest.

9.5 Questionnaire Pre-testing

It is important to pre-test the research instrument to avoid unforeseen errors with the instrument in terms of question wording or respondents' comprehension, question sequence, or questionnaire administration which can be dealt with prior to the actual survey (Babbie, 1990; Judd *et al.*, 1986; Saunders *et al.*, 2012). Pre-testing may also show the need for more questions to be added or some to be removed and is also a form of training for the researcher (Judd *et al.*, 1986). When the changes required to the questionnaire are major, it may be necessary to pre-test some respondents more than once but the final draft should be pre-tested among new respondents to take account of the learning process which the repeat pre-test sample may have undergone (Babbie, 1990; Judd *et al.*, 1986). It is also necessary to pre-test the data analysis including all the steps and analyses designed for the full survey to ensure that the data will lend itself well to the planned analyses (Ibid).

The revised questionnaire was pre-tested with a sample of the population of interest to assess its reliability and validity in tandem with the recommendation by Hair *et al.* (2007). The resulting data were analysed following recommendations by Babbie (1990) and (Judd *et al.*, 1986). The draft questionnaire was revised in line with results from the pre-test data analysis in line with recommendation by Hair *et al.* (2007). Subsequently two pre-test surveys were conducted.

9.5.1 Questionnaire Pre-test Survey One

The questionnaires were circulated to students at the start of lectures. Arrangements were made with lecturers responsible for different classes to allow 30 minutes at the start of their lectures to administer the questionnaires. Students were not informed that a questionnaire would be circulated and so attendance was not influenced by the questionnaire. Students were requested to complete the questionnaires after explaining to them the details of the survey and the instructions for completing the questionnaires. In keeping with responsible and ethical research conduct, the students were informed of their right to not participate in the survey if they did not wish to do so and also their right to withdraw from the study at any time and for any reason. Students were also informed that if any of them were below the age of 18, they should not fill in the questionnaire as they were minors. The students were also assured of both anonymity and confidentiality. Consent forms were circulated for signing by the students to obtain formal consent of their participation in the survey. The consent forms were circulated and collected independent of the questionnaires to ensure anonymity.

A sample of 57 students from a public university in South Africa was obtained. The sample comprised of 33% second year students and 67% third year students of which 53% were male. All the students were studying towards a bachelor's degree in Property Studies. The data were analysed using factor analysis with principle component extraction method set to a fixed number of factors based on the *a-posteriori* hypothesised factors for each group. Equamax rotation was used and factor loadings less than 0.40 were suppressed. Factor analysis was used to establish the factor structure of the measurement instrument. Separate factor analyses were done for the three main groups in the instruments namely, constructivism, behaviourism and cognitive load theory. Based on the results of the first pre-test survey, the questionnaire was revised. Items which did not load on the *a-posteriori* constructs were either dropped or revised. A second draft of the questionnaire was then produced and subjected to another pre-test.

9.5.2 Questionnaire Pre-test Survey Two

The same procedure followed for the first pre-test survey to ensure ethical and responsible research was followed for the second round of the pre-test survey except that in this case the questionnaires were circulated to students who had gathered for a talk by a professional body. The students were not informed beforehand that a questionnaire would be circulated and so attendance was not influenced by the administration of the question. Students were very keen to attend the talk and so absconding students were randomly absent. It may be concluded that the resulting sample was representative of the population of interest without bias.

A convenience sample of 74 students studying towards a bachelor's degree in a construction programme at a public university in South Africa completed the second pre-test questionnaire. The students ranged in their year of study from first to fourth year and in the second semester of the academic year. Therefore, all the students including the first years, had sufficient academic experience at a public university. The students were studying either for Construction Management (5%), Quantity Surveying (30%) or Property Studies (65%). The demographic information for each year of study and also for each programme of study and gender can be seen in Tables 9-12 and 9-13. Of the total sample, 62% were male.

Table 9-12: Crosstabulation of Year of Study and Programme of study

		Year 1	Year 2	Year 3	Year 4	Total
	Construction Management	0	0	0	4	4 (5%)
	Quantity Surveying	1	2	2	17	22 (30%)
	Property Studies	19	11	16	2	48 (65%)
Total		20 (27%)	13 (18%)	18 (24%)	23 (31%)	74 (100%)

Table 9-13: Crosstabulation of Gender and Programme of study

		Male	Female	Total
	Construction Management	2	2	4 (5%)
	Quantity Surveying	12	10	22 (30%)
	Property Studies	32	16	48 (65%)
Total		46 (62%)	28 (38%)	74 (100%)

9.6 Pre-test Data Analysis

The data obtained from the pre-test were factor analysed to establish the dimensionality of the research instruments, factorability of the data and validity and reliability of the measures. Factor analysis was performed with IBM SPSS v24. Some of the questionnaires had missing data points because students did not respond to all the items. About 22% of the questionnaires had missing data points. This was dealt with by replacing the missing data points with the item mean to avoid losing data (Hair *et al.*, 2007). Data was missing at random probably due to the length of the questionnaire rather than any problem with any individual questionnaire items. The problem of students not responding to some items was dealt with during the questionnaire administration by emphasising to the students the importance of completing the whole questionnaire to reduce the prevalence of missing data.

9.6.1 Factor Analysis

Factor analysis with principle components extraction was used for data reduction to examine construct validity. Factor analysis was preferred over principle components analysis (PCA) because it is easy and simple to use. Principle components extraction was favoured because it is simple but effective in determining factors which explain the variance in the data set (Laher, 2010). Separate factor analyses were performed for each of the three groups of constructs namely, constructivism, behaviourism and cognitive load theory to achieve better measures of sampling adequacy.

Considering the interpretability and theoretical expectation of the factor structure of the constructs under study, factors were extracted based on a fixed number of the *a-posteriori* factors. Deciding on the number of factors to be extracted based on theoretical considerations is supported by many studies (Laher, 2010;

Matsunaga, 2010). A fixed number of factors was favoured over the more common Keiser-eigenvalue-greater-than-one (K1) rule because the K1 approach often overestimates the number of factors (Laher, 2010; Ledesma and Valero-Mora, 2007).

Factor analysis produces an initial factors solution based on a single main factor which must be rotated to simplify the factor structure and also to group factors which have greater commonality (Laher, 2010). For this study, Equamax rotation with Kaiser normalisation was favoured because it provided the best interpretable factor solution.

Literature suggests factor loadings of a minimum of 0.30 as acceptable while some authors recommend higher figures (Laher, 2010; Matsunaga, 2010). Generally, the higher the factor loadings, the better the psychometric properties of the measurement scale. In order to identify any problematic items, the pre-test analyses advocated for a higher cut-off of 0.50 for factor loadings. A stringent cut-off was also used so as to retain only items with high factor loadings in the final instrument in view of the already long instrument.

9.6.1.1 Constructivism

The dimensions from constructivism had a KMO measure of sampling adequacy of 0.639 and a significant Bartlett's test of Sphericity (p=0.000) shown in Table 9-14.

Table 9-14: Constructivism Instrument Analysis

	Construct	Factor Loading	AVE	CR	Alpha	Item Correlation
	Zone of Proximal development					
1	I found tests and assignments to be very challenging	0.702				0.499
2	I was given work which was beyond what I could manage to do on my own	0.829				0.539
3	I was given work which required further guidance from the lecturers in order to complete it	0.550	0.519	0.687	0.725	0.441
4	I was given work which required consulting with more knowledgeable people in order to do it well	0.770				0.579
	Scaffolding					
1	My lecturers helped me when I could not manage to do the assigned work on my own					
2	My lecturers gave me sufficient knowledge, information and support to do my work	0.743				0.598
3	My lecturers gave me enough help when doing my work	0.787	0.563	0.746	0.858	0.738
4	My lecturers gave me additional information when I could not manage to do my work	0.736				0.658
5	I was guided when I could not manage to do the work on my own	0.756				0.704
6	My lecturers helped me when I asked for help with my work	0.727				0.680
	Active Learning					
1	I was required to do more than just listening in class					
2	I was required to perform practical work activities in class	0.549				0.405
3	I was allowed to discuss the lecture content with fellow students during a lecture session		0.506	0.665	0.576	
4	I took my own notes while listening to the lecturer					
5	The lectures involved other activities besides listening to the lecturer	0.843				0.405
	Individual Cognition					
1	I connected new concepts and principles (points) in a module with what I already knew	0.639				0.443
2	I selected important points to remember from the lectures	0.786	0.487	0.648	0.774	0.672
3	I used information from class to solve assigned work problems	0.697				0.622
4	I recognised and noted useful points from the lectures	0.660				0.594
5	I tried to remember everything from the lectures					
	Sharing Ideas					
1	The modules allowed for interaction with fellow students during class	0.748				0.488
2	The modules had a variety of learning activities	0.769	0.575	0.761	0.647	0.488
3	The lecturers allowed me to express myself					
4	The lecturer allowed me to share my experiences					

Table 9-14: Constructivism Instrument Analysis (Continued)

	Self-Directed Learning					
1	I was required to find additional knowledge and information on my own	0.798				0.641
2	I was given work which required me to learn new concepts on my own	0.742	0.506	0.609	0.801	0.668
3	I was expected to expand on what was taught in class on my own	0.604				0.573
4	I was required to learn on my own	0.688				0.584
	Reflective Thinking					
1	I question the way others do something and try to think of a better way	0.746				0.648
2	I like to think over what I have been doing and consider alternative ways of doing it	0.607				0.618
3	I reflect on my actions to see whether I could have improved on what I did	0.721	0.459	0.609	0.822	0.727
4	I review my experience so I can learn from it and improve my next performance	0.626				0.599

The sample is adequate for factors analysis based on the 0.60 KMO threshold recommended by Tabachnick and Fidell (2013) and the significant Bartlett's test. The results of the KMO measure of sampling adequacy and the Bartlett's test of Sphericity are shown in Table 9-18.

Table 9-15: Constructivism KMO and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**0.638**
Bartlett's Test of Sphericity	Approx. Chi-Square	1199.494
	df	496
	Sig.	0.000

The forced seven factor solution yielded about 65% total variance extracted. The results of the factor analysis are shown in Table 9-15. Items which did not load on the *a-posteriori* construct by at least 0.50 were omitted from the analysis. These included item 1 from the Scaffolding scale which cross loaded onto Self Directed Learning. Items 2 and 4 from the Active Learning scale had factor loadings less than 0.50 while item 3 cross loading onto Group Learning. Item 3 from Active Learning, (I was allowed to discuss the lecture content with fellow students during a lecture session) while attempting to capture the aspect of students actively taking part in class activity by discussing with fellow students in the concept of Active Learning during class is in fact at the same time an act of Group Learning and so explains why it loaded onto this construct. Item 5 under Individual Learning and items 3 and 4 under Group Learning had factor loadings less than 0.50. After this, all the scales met the minimum threshold of 0.50 for AVE and 0.60 for CR except for Individual Learning and Reflective Thinking which marginally fell below the AVE threshold. All the scales met the minimum threshold of 0.60 for Cronbach's alpha and 0.30 for item-total correlations except for Active Learning which marginally fell below the Cronbach's alpha threshold. All item-total correlations exceed the threshold of 0.30. All these statistics are shown in Table 9-15.

Notwithstanding, the three scores which fell below at least one minimum threshold, no scale had poor scores on all four criteria while four out of the seven scales had very good scores on all four criteria. Therefore, the scales under constructivism exhibit fairly good psychometric properties considering that the sample size is fairly small. Therefore, the scales they may be used for full data collection.

9.6.1.2 Behaviourism

The sample size for behaviourism was adequate for factor analysis with a KMO measure of sampling adequacy of 0.806 which is classified as meritorious by Kaiser (1974) (above 0.80) and adequate by Tabachnick and Fidell (2013). The Bartlett's test of Sphericity was also significant giving further indication of the appropriateness of the sample for factor analysis. The results of the KMO measure of sampling adequacy and the Bartlett's test of Sphericity are shown in Table 9-16.

Table 9-16: Behaviourism KMO and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.806
Bartlett's Test of Sphericity	Approx. Chi-Square	637.990
	df	105
	Sig.	0.000

The three factor solution accounted for almost 68% total variance extracted. Results of the factor analysis are shown in Table 9-17. All the items loaded on the *a-posteriori* construct when factor loadings of 0.50 were suppressed. Only item 5 from Readiness had a factor loading less than 0.50. All the scales exceeded the threshold for AVE, CR, Cronbach's alpha and item-total correlations. These statistics are shown in Table 9-17. Therefore, the behaviourism scales exhibited very good psychometric properties and may be used for full data collection.

Table 9-17: Behaviourism Instrument Analysis

	Construct	Factor Loading	AVE	CR	Alpha	Item Correlation
	Repetition					
1	My lecturers covered the key points of a lecture more than once	0.576	0.554	0.733	0.813	0.459
2	My lecturers repeated some lectures	0.806				0.639
3	Some topics were covered more than once	0.818				0.712
4	My lecturers emphasised the key points of a lecture by repeating themselves	0.789				0.702
5	My lecturer allowed for revision of the lecture material	0.704				0.563
	Reinforcement					
1	I was complimented for good conduct and doing good work	0.827	0.715	0.895	0.918	0.761
2	I was recognised for good conduct and doing good work	0.888				0.852
3	I was rewarded for good conduct and doing good work	0.865				0.824
4	I was praised for good conduct and doing good work	0.801				0.767
5	I was encouraged when my conduct and work were good	0.834				0.747
	Readiness					
1	I was emotionally, physically and mentally ready to learn	0.845	0.739	0.916	0.909	0.771
2	I was well prepared for the lectures	0.906				0.857
3	I was ready to learn when I went for lectures	0.885				0.851
4	I prepared adequately for class	0.799				0.707
5	I was well rested (not tired) when going to lectures					

9.6.1.3 Cognitive Load Theory

The KMO measure for sampling adequacy for the cognitive load theory measures was 0.738 which is classified as middling by Kaiser (1974) (above 0.70) and adequate by Tabachnick and Fidell (2013). The significant Bartlett's test of Sphericity further suggests that the sample data is appropriate for factor analysis. The results of the KMO measure of sampling adequacy and the Bartlett's test of Sphericity are shown in Table 9-18.

Table 9-18: Cognitive Load Theory KMO and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.738
Bartlett's Test of Sphericity	Approx. Chi-Square	1393.694
	df	496
	Sig.	0.000

The six factor solution accounted for almost 67% total variance extracted. The results of the factor analysis are shown in Table 9-19. The majority of the items loaded on the *a-posteriori* constructs when factor loadings less than 0.50 were suppressed. Item 5 from Schema Construction cross loaded onto Worked Examples and item 4 from Cognitive Loading cross loaded onto Completion Problems. Item 4 from Worked Examples also cross loaded onto Completion Problems. This can be attributed to the similarity between Worked examples and completion problems since completion problems are in fact partly worked examples or examples with incomplete solutions. These items were omitted from the analysis. After these adjustments, most constructs met the minimum thresholds for AVE, CR, Cronbach's alpha and item-total correlation. Cognitive Loading, Complex and Ambiguous Questions and Worked examples marginally fell below the threshold of 0.50 for AVE while Schema Construction marginally fell below the threshold of 0.60 for CR. All constructs had Cronbach's alpha greater than 0.70 and all item-total correlation exceeded 0.30. Therefore, the constructs have acceptable psychometric properties to proceed to full data collection.

Table 9-19: Cognitive Load Theory Instrument Analysis

	Construct	Factor Loading	AVE	CR	Alpha	Item Correlation
	Schema Construction					
1	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject	0.565				0.464
2	My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew	0.711				0.594
3	I connected points that I already knew with what I was being taught in class	0.789	0.730	0.553	0.786	0.652
4	I organised, categorised or connected anything new that I learnt with what I already knew	0.875				0.670
5	My lecturers clearly highlighted the main concepts and principles					
	Cognitive Loading					
1	I was expected to remember too many things from each lecture	0.733				0.473
2	I was overwhelmed with the amount of information I was expected to remember	0.686				0.624
3	I was given with too much information during the lectures	0.693				0.683
4	The information I was given during lectures was confusing		0.455	0.604	0.856	0.535
5	The information I was given in class was complicated and difficult to understand	0.553				0.732
6	I was overwhelmed with the amount of work I had to do	0.723				0.724
7	I was given too many projects, assignments and tests	0.645				0.604
	Complex and Ambiguous Questions					
1	I was given assignments and tests which were difficult to understand and solve	0.522				0.550
2	I was given problems which did not have enough information for me to solve them	0.760				0.734
3	I was required to solve questions which were not clear as to what I was expected to do	0.785	0.484	0.640	0.848	0.805
4	I was given questions which could be interpreted in more than one way	0.575				0.501
5	I was given problems which were not easy to understand clearly	0.744				0.613
6	I was given questions which were not expressed clearly	0.742				0.598
	Authentic Problems					
1	I was given problems based on actual industry real life problems	0.675				0.591
2	I was expected to use real life situations when doing my school work	0.842				0.782
3	I was required to collect some real world information to do my school work	0.842	0.602	0.791	0.855	0.761
4	I was given work which was relevant to actual current industry practice	0.764				0.607
5	I was required to come up with my own solutions to problems	0.744				0.613
	Worked Examples					
1	I was given some worked examples to practice on	0.725				0.595
2	I was given examples with clearly defined steps on how to solve problems to practice on	0.702	0.488	0.650	0.825	0.780
3	I was given problems with model solutions to practice on	0.667				0.685
4	I was shown how to solve a problem before being asked to solve other problems					

Table 9-19: Cognitive Load Theory Instrument Analysis (Continued)

	Construct	Factor Loading	AVE	CR	Alpha	Item Correlation
	Completion Problems					
1	I was given partially worked examples to complete	0.812	0.654	0.844	0.925	0.800
2	I was given partly finished model solutions to problems to finalise the solution	0.830				0.841
3	I was given problems which were partly solved to practice on	0.890				0.878
4	I was given problems and part of the solution to work on	0.740				0.781
5	I was given problems which had gaps that I had to fill in	0.762				0.728

A summary of the resulting 16 scales and their descriptive statistics can be seen in Table 9-20. The mean scores ranged between 2.880 and 4.007.

Table 9-20: Research Scales Descriptive Results

	Concept		Mean	Std. Deviation
1	Zone of Proximal Development	ZPD	3.2674	0.74034
2	Scaffolding	SCAFF	3.5857	0.73766
3	Active Learning	ACTLN	3.7192	0.86597
4	Individual Cognition	INDCOG	4.0068	0.61657
5	Shared Cognition	SHRDCOG	3.6689	0.78198
6	Self-Directed Learning	SDL	3.9452	0.72797
7	Reflective Thinking	REFTHK	3.8176	0.75772
8	Repetition	REP	3.6028	0.71514
9	Reinforcement	REINF	3.1397	0.97735
10	Readiness	READ	3.4028	0.93537
11	Schema Construction	SCHEMCON	3.7635	0.64225
12	Cognitive Loading	COGLD	3.3373	0.68755
13	Complex and Ambiguous Questions	COMPQUE	3.1944	0.75940
14	Authentic Problem	AUTHPR	3.7942	0.70040
15	Worked Examples	WRKDEX	3.3744	0.89226
16	Completion Problems	COMPPR	2.8795	1.06340

The scale for Completion Problems had the lowest average score of less than 3 indicating that completion problems were mostly either seldom or almost never used. The scale for Individual Cognition had the highest mean score just slightly above 4 indicating that mostly, students either often or almost always engaged in individual activities of synthesising knowledge on their own.

The resulting scales were assessed for discriminant validity. For discriminant validity to exist, the square root of the AVE should be less than the inter-construct correlation (Fornell and Larcker, 1981). Evidence of discriminant validity can be seen in Table 9-21 which shows inter-construct correlations and the square root of the AVE in bold in the diagonal. All the inter-construct correlations are less than the square root of the AVE. In fact, all the inter-construct correlations are less that the smallest square root of AVE of 0.616 indicative of good discriminant validity. Having established that the measurement instrument is adequate with acceptable reliability and validity based on the factor analysis, measures of AVE, CR, Cronbach's alpha, item-total correlations and exhibits good discriminant validity, the instrument was circulated to a sample of the target population. The complete instrument can be seen in the appendices.

Table 9-21: Inter-construct Correlations

	Construct	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	HIORDLN	**0.616**	2																			
2	INTLN	0.473**	**0.730**	3																		
3	REFLNA	0.446**	0.392**	**0.782**	4																	
4	REFLNB	0.280*	0.514**	0.305**	**0.809**	5																
5	MEMLN	0.270*	0.223	0.247*	0.210	**0.911**	6															
6	ZPD	0.244*	-0.019	0.048	-0.118	0.239*	**0.829**	7														
7	SCAFF	0.311**	0.472**	0.289*	0.338**	0.041	-0.098	**0.864**	8													
8	ACTLN	0.122	0.277*	0.261*	0.313**	0.236*	-0.036	0.265*	**0.815**	9												
9	INDCOG	0.395**	0.405**	0.468**	0.181	0.149	0.054	0.189	0.322**	**0.805**	10											
10	SHRDCOG	0.399**	0.234*	0.439**	0.337**	0.367**	0.139	0.420**	0.303**	0.198	**0.872**	11										
11	SDL	0.360**	0.449**	0.303*	0.295*	0.245*	0.209	0.145	0.491**	0.367**	0.257*	**0.780**	12									
12	REFTHK	0.285*	0.447**	0.451**	0.339**	0.192	0.034	0.314**	0.425**	0.555**	0.374**	0.404**	**0.780**	13								
13	REP	0.221	0.423**	0.336**	0.458**	0.299*	0.082	0.278*	0.441**	0.234	0.339**	0.441**	0.337**	**0.856**	14							
14	REINF	0.132	0.331**	0.116	0.312**	0.154	-0.118	0.411**	0.354**	0.193	0.295*	0.247*	0.299*	0.259*	**0.946**	15						
15	READ	0.436**	0.447**	0.211	0.312**	-0.013	0.066	0.347**	0.192	0.390**	0.318**	0.184	0.455**	0.278*	0.434**	**0.957**	16					
16	SCHEMCON	0.210	0.425**	0.200	0.316**	0.143	-0.071	0.312**	0.469**	0.448**	0.275*	0.428**	0.492**	0.307**	0.318**	0.461**	**0.744**	17				
17	COGLOD	0.158	0.140	0.161	0.099	0.304*	0.432**	-0.016	0.200	0.066	0.250*	0.186	0.027	0.221	0.138	0.077	0.117	**0.777**	18			
18	COMPQUE	0.147	0.170	0.088	0.140	0.135	0.246*	-0.035	0.036	0.030	0.029	0.123	-0.030	0.092	0.167	0.080	-0.088	0.665**	**0.800**	19		
19	AUTHPRB	0.291*	0.422**	0.181	0.176	0.160	0.165	0.334**	0.351**	0.180	0.221	0.421**	0.227	0.389**	0.252*	0.339**	0.255*	0.169	0.059	**0.889**	20	
20	WRKDEX	0.272*	0.323**	0.192	0.098	0.104	0.203	0.271*	0.227	0.195	0.307**	0.110	0.288*	0.308**	0.366**	0.228	0.324**	0.319**	0.246*	0.247*	**0.806**	21
21	COMPPRB	0.125	0.225	0.122	0.129	0.118	0.132	0.282*	0.169	-0.013	0.421**	0.090	0.185	0.302*	0.311**	0.202	0.248*	0.399**	0.271*	0.163	0.592**	**0.919**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

9.7 Chapter Summary

This chapter presented a detailed description of the development of the research instrument and the pre-testing procedure followed. The research instrument used a Likert scale anchored on a 5-point rating with 1=Almost Never, 2=Seldom, 3=Sometimes, 4=Often and 5=Almost Always. While the Likert scale is criticised for not indicating the latitude of acceptance and for not giving the exact pattern of responses like alternative scales such as the Thurstone and the Guttman scales, it was favoured because these other scales are either not appropriate for the data analysis method adopted or costlier and more time consuming to prepare.

Where appropriate scales were available in literature, these were adapted to the current study. Otherwise, new measures were developed. The development of new measures consisted of firstly arriving at the operational definition of the abstract concepts to render the concept measurable. The operational definition looked at the behavioural dimensions, facets or properties exhibited by the concept and then reduced these into items which actually capture the behavioural dimensions, facets or properties underlying the concept. The resulting scales were integrated into a questionnaire and administered to sample of the population of interest to assess respondent understanding. The results of this initial assessment were obtained through a focus group discussion. Appropriate modifications were made to the questionnaire based on the feedback from the respondents and the questionnaire was administered to another sample of the population to assess its reliability and validity. The results were analysed for reliability and validity and the questionnaire was subsequently modified based on the reliability and validity results and subsequently administered yet again to another sample of the population. The reliability and validity of the instruments was again assessed. The reliability and validity were deemed adequate after the third pre-test session and the questionnaire was administered to a large sample of the population of interest.

CHAPTER 10

RESULTS AND ANALYSIS

10.1 Introduction

This chapter presents the findings, analysis and discussion of the findings from the research. The research aimed to establish the best way to teach undergraduate construction programmes in South Africa by identifying important antecedents to effective teaching and learning emanating from different contemporary theories of learning and modelling these into a curriculum. A quantitative research design with a positivist philosophy and a deductive research approach were in a descriptive research type. Therefore, the hypotheses tested are non-causal. The data were collected using a questionnaire in a cross sectional survey. Prior to the data analysis, the response rate from the survey is discussed. The data are then prepared for data analysis by dealing with missing data points, outliers, extreme values and disengaged responses. This step is done to ensure that the data are free from bias and therefore appropriate for the analysis. The descriptive statistics for the demographic information are then presented and discussed. The data were analysed in two phases, firstly with Exploratory Factor Analysis (EFA) and secondly with Structural Equation Modelling (SEM). EFA was used to examine the factor structure of the measurement instrument and to identify coherent subsets of the data which can therefore be considered distinct constructs for further analysis. SEM was used to estimate the regression parameters among the study constructs because it is good for assessing complex relationships. Prior to the assessment of structural relationships, the study constructs were assessed for reliability and validity.

Results show that learning individually combined with learning in groups and scaffolding students learning activities and students being able to engage in reflective thinking are the most important factors for effective teaching and learning. Repetition, reinforcement, readiness, self-directed learning and providing worked examples are also important for effective learning. Results also show that cognitive loading should be an important consideration in curriculum design. Complex questions induce high levels of cognitive loading but also encourage self-directed learning.

10.2 Response Rate

Babbie (1990) suggested that while there are many reported acceptable response rates, a response rate of 50% is generally acceptable, 60% is good and 70% or more is very good. These recommendations are however rough guides with no statistical basis (Ibid). However, Judd *et al.* (1986) recommend a response rate of at least 80% as being free of bias from causes of non-response. The target population for this study survey was 1,429 which is the total number of students who were eligible to attend the lectures which were used for data collection. A total number of 543 questionnaires were circulated and received back. The distribution of the responses for each of the three universities divided by year of study is shown in Table 10-1.

Table 10-1: Response Rate

University	Population Size	Sample Size	Sample/Population Percentage
University One			
1st Year Architecture	30	23	77%
2nd Year Architecture	47	37	79%
1st Year Property Development	57	20	35%
2nd Year Property Development	37	13	35%
3rd Year Property Development	38	21	55%
4th Year Honours (Quantity Surveying)	28	17	61%
4th Year Honours (Construction Management)	11	6	55%
Total	***248***	***137***	***55%***
University Two			
1st Year	130	53	41%
2nd Year	109	14	13%
1st Year Architecture	44	27	61%

2nd Year Architecture	30	20	67%
3rd Year	86	49	57%
4th Year Bachelor of Technology	259	102	39%
Total	***658***	***238***	***36%***
University Three			
1st Year Construction Management and Quantity Surveying	214	89	42%
2nd Year Construction Management and Quantity Surveying	133	42	32%
3rd Year Construction Management and Quantity Surveying	176	37	21%
Total	***523***	***168***	***32%***

10.3 Data Preparation

After the data were collected, they were assessed for suitability for data analysis in a data preparation exercise. The data preparation exercise consisted of screening the data set for missing data points, disengaged responses and outliers.

10.3.1 Missing Data

Data points were missing from 127 cases representing just over 22% of the sample. Consistently, about 22% of cases also had some missing data points in the pre-test survey. The initiative to emphasise to the respondents the need to complete the entire questionnaire did not yield the desired results since the percentage of cases with missing data remained large. According to Tabachnick and Fidell (2013), if less than 5% of the data points are missing, the anomaly can be ignored and the missing data can either be replaced with mean or analysed with robust data analyses which accommodate missing data. Teo, Tsai and Yang (2013) cite literature suggesting that even up to 10% of missing data is not a problem with multivariate analyses such as Structural Equation Modelling. Otherwise it is appropriate to delete the cases with missing data.

All questionnaires which were circulated were received back because they were circulated to a captive audience of students who had assembled to attend lectures. Therefore, when the response rate is considered in relation to the number of questionnaires circulated, the response rate is nearly 100%. This is often the case when the population of interest is captive (Judd *et al.,* 1986). While the target population was 1,429, only 543 students were sampled because these are the students who were present in class at the time of administering questionnaires. For university one, questionnaires to 1st, 2nd, 3rd and 4th year students were administered to the students while they were attending a talk organised by a professional association. Therefore, not all students registered for the respective classes were present and so the lower ratio between the total population for those classes against the sample. For university two, the classes are divided into two separate classes due to the large class sizes. Access was available to only one of the classes for 1st, 2nd and 3rd year classes. Second year students were attending work placement and so were not required to attend. Only a few students, who had outstanding modules to complete, were attending classes and so the relatively small proportion of the sample size against the population of the second year students. The third university also divided the large classes into two separate classes and only one of the classes for each year of study were sampled. Also, for all the university, the sample was affected by absenteeism. However, the number of absent students was not affected by the data collection exercise because the students were not informed beforehand about the exercise. Besides, questionnaire administration has not been found to cause students to abscond class. Therefore, the number of students sampled is fair proportion of the population of interest.

Table 10-2: Missing Data

Missing Data Points	% Missing	Frequency	Percentage
1	1.0%	56	44.1%
2	2.0%	22	17.3%
3	2.9%	5	3.9%
4	3.9%	8	6.3%
5	4.9%	13	10.2%
6	5.9%	2	1.6%
7	6.9%	1	0.8%
8	7.8%	1	0.8%
9	8.8%	2	1.6%
>10	>10%	11	8.7%

IBM SPSS Modeller software was used to identify missing data points. The Anomaly Detection Mode in the software identifies missing data. The number of missing data points for each case identified are shown in Table10-2.

The research instrument had 102 items requiring data entry from the respondents. Therefore, the percentage of missing data was computed as the percentage of the number of missing data points divided by 102. Cases which had more than 10% of the responses missing were classified as incomplete since a substantial amount of data was missing in tandem with recommendations by Teo *et al.* (2013). These cases were subsequently removed from the sample. A total of 11 cases missing 10 or more responses were found representing 1.93% of the initial sample or 8.7% of the total number of missing data points.

Data was classified as missing completely at random (MCAR) when no visible pattern was apparent to the order of the missing data (Ibid). Cases which are MCAR do not present problems in data analysis (Tabachnick and Fidell, 2013; Teo *et al.*, 2013). Missing data were checked to establish if any pattern existed in the manner in which the data were missing. Patterns checked for included continuous strings of missing data within a case or repeatedly missing data point across cases. Therefore, cases with a single missing data were classified as MCAR after it was established that there was no pattern even across cases. Cases with more than one data point missing but the missing data was not a continuous string were equally classified as MCAR when there was not pattern even across cases. When a pattern exists in the manner in which the data is missing, then the missing data can be classified as not missing at random (NMAR) (Teo *et al.*, 2013). Listwise deletion, in which the deletion of the entire case with data which NMAR was the preferred treatment for the NMAR data as highlighted.

Cases with only one data point missing had the missing data point replaced with the mode of the other scores from the measurement scale were the data point was missing. This was done because the items in each scale were measuring the same concept and are very closely related. Using the available data points to estimate the missing data point is therefore the best option in such a scenario. Similarly, when several data points were missing but missing from different scales, the missing data point was replaced with the mode of the available data points within the scale.

Cases with multiple missing data points in strings but less than 10% were analysed on a case by case basis to establish if the missing data showed any pattern. Were a continuous string of missing data left no data points from which the missing data could be reliably estimated, the case was deleted. Otherwise, where sufficient data were available in the scale to reliably estimate the missing data, the mode of the available data points was used to fill in the missing data.

10.3.2 Outliers, Extreme Values and Disengaged Responses

Outliers were classified as those values which were at least three standard deviations from the mean. There were 61 cases which satisfied this condition. Extreme values were classified as those values which were at least five standard deviations from the mean. There were only five cases with items which satisfied this condition.

IBM SPSS Modeller, anomaly detection models, was used to identify unusual cases or outliers and extreme values. It is based on anomaly indices of each data point which is the ratio of the data point variance from the average group variance index for the cluster which the case belongs to. It has the advantage over other methods of anomaly detection that it does not require a training data set. It was decided to keep the cases which had some outlying values when these were verified as not being disengaged responses. Cases with extreme values, on the other hand, were discarded.

Disengaged responses were identified on visual inspection. Responses which had been obviously repeated or had random patterns which were clearly not logical were flagged as disengaged responses and scrutinised further. All cases identified as disengaged responses were subsequently discarded.

10.4 Demographic Descriptive Statistics

Table 10-3 shows the gender profile of the respondents. There were more male students (60.30%) than female students in the sample. This is consistent with the general gender distribution of students in the population of study. The gender distribution is therefore representative of the population of interest.

Table 10-3: Gender Distribution

Gender	Frequency	Percent
Male	314	60.30%
Female	207	39.70%
Total	521	100.00%

Table 10-4: Year of Study

Year	Frequency	Percent
Year 1	188	36.10%
Year 2	116	22.30%
Year 3	99	19.00%
Year 4	118	22.60%
Total	521	100.00%

The distribution of the sample by year of study is shown in Table 10-4. First year students had the highest frequency of 36.10% closely followed by 4th year students at 22.60% and 2nd year students at 22.30% and lastly 3rd year students at 19.00%. There were more 1st year students because at South African universities 1st year classes are generally larger than subsequent classes. This is because some students repeat the 1st year while progression to subsequent years of study is rarely 100% since some students fail or drop out and do not proceed to subsequent years of study. Fourth year students accounted for the second largest frequency not withstanding that only two out of the three sampled universities had fourth year students. This is because the 4th year of study was made up of students studying towards Honours or Bachelor of Technology (B-Tech) degrees. These degrees are offered to students who completed their bachelor's degrees from different universities and even those who completed the bachelor's degrees several years prior. Second and third years of study, on the other hand, draw from the students who progress from the lower levels of study.

The distribution of the sample by programme of study is shown in Table 10-5. Property studies accounted for the least number of students (8.30%) because only one out of the three universities offered such a programme. The property studies degree is, however, quite very similar in all aspects with the degrees of construction management or quantity surveying in the other universities. Construction Management accounted for the highest frequency of students in the sample because all three sampled universities offered construction management while only two offered Architecture and Quantity Surveying. Architecture had the second lowest frequency because only two of the three universities offered it and also, generally, Architecture classes had much smaller numbers of students. This is typical of Architecture programmes owing to their reliance on the studio approach to learning which is suited to smaller class sizes. Therefore, notwithstanding that distribution of the sample appears heterogeneous in terms of the programmes of study, it is representative of the proportions of distribution of the population of interest.

Table 10-5: Programme of Study

Programme	Frequency	Percent
Architecture	102	19.60%
Construction Management	232	44.50%
Quantity Surveying	144	27.60%
Property Studies	43	8.30%
Total	521	100.00%

Table 10-6: Crosstabulation of Year of Study and Gender

Year of Study			Gender		Total
			Male	Female	
Year	Year 1	Count	110	78	188
		% within Year	58.5%	41.5%	100.0%
		% within Gender	35.0%	37.7%	36.1%
	Year 2	Count	76	40	116
		% within Year	65.5%	34.5%	100.0%
		% within Gender	24.2%	19.3%	22.3%
	Year 3	Count	58	41	99
		% within Year	58.6%	41.4%	100.0%
		% within Gender	18.5%	19.8%	19.0%
	Year 4	Count	70	48	118
		% within Year	59.3%	40.7%	100.0%
		% within Gender	22.3%	23.2%	22.6%
Total		Count	314	207	521
		% within Year	60.3%	39.7%	100.0%
		% within Gender	100.0%	100.0%	100.0%

The demographic information was cross-tabulated to establish the distributions of the various demographics. Table 10-6 shows the crosstabulation of year of study with gender. Male students accounted for between 58% and 66% of each year of study. Of the male students, 35% were in the 1st year, 24.20% were in the 2nd year while only 18.5% were in the 3rd year and 22.30% were in the 4th year. Female students were quite similarly distributed across the years of study. Generally, the gender distribution across the different years of study was even relative to the ratio of the male to female students in the sample which was 60.30% to 39.70% male to female. The higher proportion of male students compared to female students is consistent with the general nature of the field of construction which is traditionally gender biased towards the male gender. The sample is therefore fairly representative of the population of interest in terms of the gender distribution across years of study.

Table 10-7: Crosstabulation of Programme of Study and Gender

			Gender		Total
			Male	Female	
Programme	Architecture	Count	63	39	102
		% within Programme	61.8%	38.2%	100.0%
		% within Gender	20.1%	18.8%	19.6%
	Construction Management	Count	140	92	232
		% within Programme	60.3%	39.7%	100.0%
		% within Gender	44.6%	44.4%	44.5%
	Quantity Surveying	Count	83	61	144
		% within Programme	57.6%	42.4%	100.0%
		% within Gender	26.4%	29.5%	27.6%
	Property Studies	Count	28	15	43
		% within Programme	65.1%	34.9%	100.0%
		% within Gender	8.9%	7.2%	8.3%
Total		Count	314	207	521
		% within Programme	60.3%	39.7%	100.0%
		% within Gender	100.0%	100.0%	100.0%

Table 10-7 shows the crosstabulation of the programme of study with gender. Male students accounted for between 58% and 66% just like the distribution of gender across year of study and consistent with the expected proportion of male to female students in public universities in South Africa. As a proportion of each gender total, the distribution was consistent with both genders being very close to each other. For example, in the 1st year, the percentage of male students within the gender is 35.00% while that for female students is 37.70%. A similar trend can be seen across all years of study. This is indicative of the fair distribution of the genders across the different programmes of study and subsequently a sample representative of the population of interest in terms of gender distribution across programmes of study.

Table 10-8 shows the crosstabulation of programme of study with year of study. The sample had only 1st and 2nd year Architecture students, 1st to 3rd year Property Studies students and 1st to 4th year Construction Management and Quantity Surveying students. Architecture was offered at only two of the three sampled universities. Only one of the two universities offered an honours degree in Architecture and so a 4th year of study while the other one only offered a three-year Architecture programme. However, during the data collection period, 3rd year and 4th year Architecture students were not available to participate in the study. Therefore, only 1st and 2nd year students were included in the sample. Given that the data collection was done towards the end of the academic year, it is expected that 1st and 2nd year students had sufficient academic experience to provide a fair reflection of the academic experience of a typical Architecture student. Therefore, the absence of 3rd and 4th year Architecture students from the sample is not expected to create any bias in the analysis. The Property Studies programme is a general degree which leads to specialisation in either Construction Management or Quantity Surveying at the sampled university or any other construction related specialisation elsewhere. Therefore, the programme does not have a 4th year of study as this becomes either a Construction Management or Quantity Surveying degree in the 4th year. Construction Management and Quantity Surveying are represented in all years of study.

Table 10-8: Crosstabulation of Programme of Study and Year of Study

			Year				Total
			Year 1	**Year 2**	**Year 3**	**Year 4**	
Programme	Architecture	Count	47	55	0	0	102
		% within Programme	46.1%	53.9%	0.0%	0.0%	100.0%
		% within Year	25.0%	47.0%	0.0%	0.0%	19.6%
	Construction Management	Count	89	32	70	43	234
		% within Programme	38.0%	13.7%	29.9%	18.4%	100.0%
		% within Year	47.3%	27.3%	70.7%	36.8%	44.9%
	Quantity Surveying	Count	37	19	14	74	144
		% within Programme	25.7%	13.2%	9.7%	51.4%	100.0%
		% within Year	19.7%	16.2%	14.1%	63.2%	21.8%
	Property Studies	Count	15	11	15		41
		% within Programme	36.6%	26.8%	36.6%	0.0%	100.0%
		% within Year	8.0%	9.4%	15.2%	0.0%	7.9%
Total		Count	188	117	99	117	521
		% within Programme	36.1%	22.3%	19.0%	22.6%	100.0%
		% within Year	100.0%	100.0%	100.0%	100.0%	100.0%

The distribution of Architecture between the 1st and 2nd year is fairly well balanced (46.1% to 53.9% respectively). The distribution for Property Studies is also fairly well balanced across the three years of study (36.6%, 26.8% and 36.6%). Construction Management has fewer 2nd and 4th year students (13.7% and 18.4% respectively) compared to 1st and 3rd year students (39% and 29.9% respectively). The relatively smaller number of 4th year students can be attributed to fact that out of the three universities, only two offered the 4th year of study. The number of second year students is relatively small because at the university with the most construction management students, the second year students were engaged the in industrial experience part of the programme and so were not available for inclusion in the sample. Quantity Surveying significantly more 4th year students (51.4%) compared to other years of study with 3rd year contributing a relatively small number (9.7%). The high incidence of 4th year students can be attributed to the fact that two of the three universities do not have Quantity Surveying as a programme at levels lower than 4th year. With only one of the three universities contributing Quantity Surveying students to the 1st, 2nd and 3rd year sample, the numbers for these years of study are small relative to the number of 4th year students who come from two out of the three universities. Coupled with the fact that the 4th year of study (Honours degree and B-Tech) is popular and draws students who are completed their degrees at various points previously as highlighted earlier. Considering that this study sought to establish the perception of students undertaking construction related programmes in respect of their academic experience, the distribution of the students across programme and year of study as presented does not affect or influence the perception of the experiences of the students. Therefore, the sample fairly and adequately represents the population of interest.

10.5 Exploratory Factor Analysis

Exploratory factor analysis (EFA) was used for data reduction to examine the factor structure of the measurement instrument (Byrne, 2006; Laher, 2010; Matsunaga, 2010; Worthington and Whittaker, 2006). It is used to identify coherent subsets of the data which are fairly independent of each other and can therefore be considered distinct constructs. These constructs will then form the basis of the variables for analysis. EFA is also useful for determining the construct validity of an instrument (Laher, 2010).

Exploratory factors analysis is carried out in steps starting with the selection and measurement of a set of observed variables. The selection of the measurement variables was done during the design of the questionnaire and measurement was the collection of the data. This is followed by the determination of the adequacy of the resulting sample for EFA. The next stage is factor extraction and determination of number of factors to retain, rotation of the factors and then the interpretation of the resulting factors.

10.5.1 Adequacy of Sample Size and Variance

EFA is sensitive to sample size. When conducted with an insufficient sample size, its results are not reliable. Matsunaga (2010) citing research evidence suggests that a sample size less than 200 is poor, 200 is fair, 300 is good and 500 is very good while 1000 is excellent. Alternatively, the number of responses per instrument item should be 10 (Matsunaga, 2010). Field (2018) concluded that a sample of 300 or more is fairly good. However, several factors need to be considered to determine the appropriate sample size. There is no consensus on the appropriate sample size for EFA since the factors which need to be considered are varied (Teo *et al.*, 2013). However, there is general consensus that the larger the sample size the better (Ibid).

A measure to assess the adequacy of the sample size for EFA called the Kaiser-Meyer-Olkin Measure of Sampling Adequacy is commonly used for EFA. It measures the amount of variance shared among the items compared to their error variance (Kaiser, 1974; Tabachnick and Fidell, 2013). A Kaiser-Meyer-Olkin Measure of Sampling Adequacy greater than 0.60 is considered evidence of an adequate sample size for EFA (Tabachnick and Fidell, 2013). Kaiser (1974) classified a Kaiser-Meyer-Olkin Measure of Sampling Adequacy of less than 0.49 as unacceptable, between 0.50 and 0.59 as miserable, between 0.60 and 0.69 and mediocre, between 0.70 and 0.79 as middling, between 0.80 and 0.89 as meritorious and above 0.90 as marvellous. For this study, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.878 shown in Table 10-9 suggests that the sample size is very adequate for EFA. The Bartlett's test of Sphericity needs to be significant for the sample to be deemed to have sufficient variance for EFA. Based on the results in Table 10-9, the sample meets the size and variance requirements for EFA. Field (2018) notes that when the sample size is large, as it usually is in EFA, the Bartlett's test will nearly always be significant. Therefore, it is not a very useful test.

Table 10-9: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**0.883**
Bartlett's Test of Sphericity	Approx. Chi-Square	21239.878
	Df	3081
	Sig.	0.000

10.5.2 Factor Extraction

There are several options for factor extraction in EFA. These include Principal Factors (FA), Principal Components (PCA), Image Factor Extraction, Maximum Likelihood Factor Extraction, Unweighted Least Squares Factoring, Generalized Least Squares Factoring and Alpha Factoring. PCA is a data driven extraction method in that it gives an empirical summary of the data. FA is a theory driven extraction method and is used when there is a known underlying theory behind the measurement variables.

PCA was the preferred factor extraction method because the instrument used was designed by the author and so no prior assessment of the factor structure of the primary data existed. Consequently, no underlying theory about the factor structure was available which precluded FA. PCA is usually the preferred method of factor extraction because it is simple and yet effective in determining factors including the error variance (Laher, 2010; Matsunaga, 2010).

Factor extraction is performed in collaboration with the number of factors to retain. There are several criteria which can be used to determine the number of factors to retain. The eigenvalue-greater-than-one criteria by Kaiser (1974) also known as the K-1 criteria is perhaps the most widely used criteria. It retains all factors which have eigenvalues greater than 1. Laher (2010) and Ledesma and Valero-Mora (2007) cite several research evidence that the K-1 criterion has several deficiencies including that it was designed for Principle Components Analysis (PCA) and EFA. Also, the cut off of eigenvalues greater than 1 is arbitrary and the criteria also tends to overestimate the number of factors (Matsunaga, 2010). Other criterion for determining the number of factors to retain include the Cartell's scree test, Velicer's MAP test and Horn's Parallel Analysis (Laher, 2010; Ledesma and Valero-Mora, 2007; Matsunaga, 2010). Cartell's scree test has been criticised for being subjective, Velicer's MAP test was found to consistently underestimate the number of major components when there were few items per factor (Laher, 2010; Ledesma and Valero-Mora, 2007; Matsunaga, 2010). The subjectivity in using the scree plot can be seen in Figure 10-1 where in it is not clear where the curve can be said to start. Horns' Parallel Analysis was hailed as the best alternative for determining the number of factors to retain (Laher, 2010; Ledesma and Valero-Mora, 2007; Matsunaga, 2010). Notwithstanding the criticisms and recommendations for the choice of criteria for retaining factors, the most important criterion in determining the number of factors to retain is the interpretability of the resulting factors. Laher (2010) suggests that besides empirical analyses, it is important to make theoretical considerations based on the instrument design and model being studied when deciding on how many factors to retain.

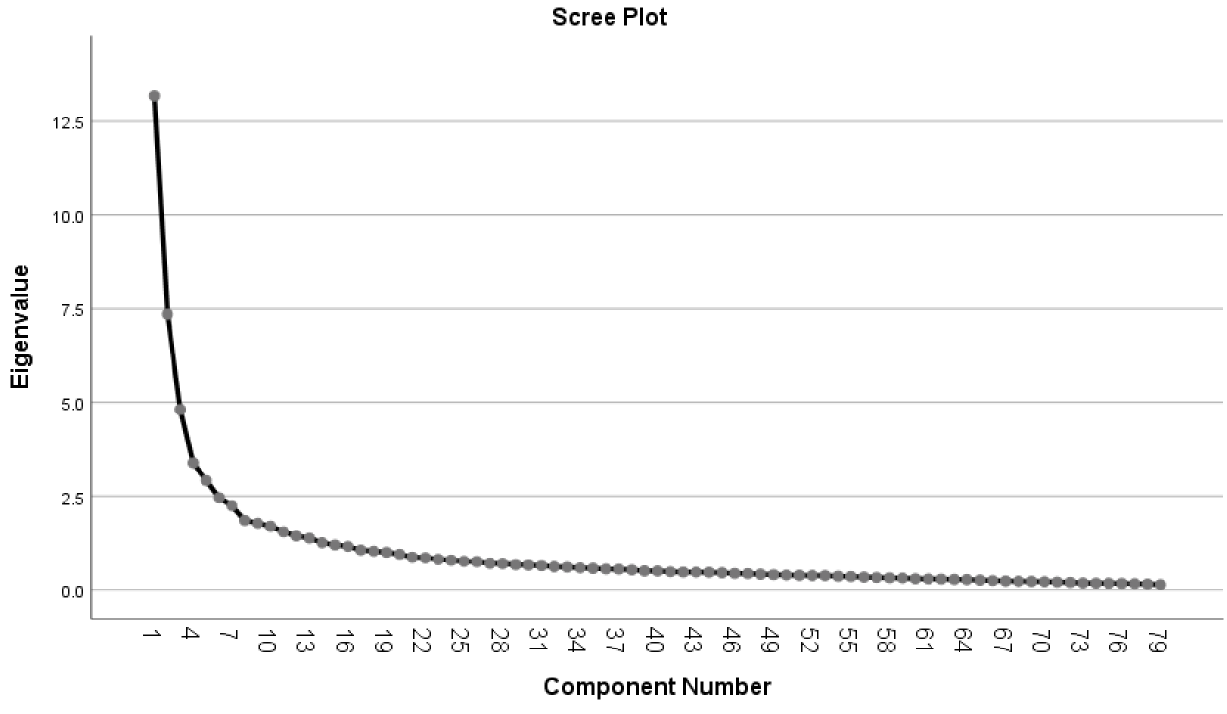


Figure 10-1: Factor Exraction Scree Plot

IBM SPSS only has two options for deciding on the number of factors to retain and these are using an eigen-value cut off or dictating the number of factors to retain (Matsunaga, 2010). Using the K-1 criterion yielded 19 factors which explained 66.752% of the variance explained. However, some factors had no theoretical interpretation since the instrument was designed to measure 16 concepts. Therefore, after theoretical considerations, 16 factors were retained. The theoretical consideration made suggested fewer factors than the K-1 criterion consistent with observations by others (Laher, 2010; Ledesma and Valero-Mora, 2007; Matsunaga, 2010).

10.5.3 Factor Rotation

After deciding on the number of factors to retain, the factors need to be rotated. Rotation is required because initial factor extraction produces factor solutions with one general factor followed by bipolar factors (Laher, 2010). Therefore, the initial factor structure needs to be simplified for better interpretation which can be achieved by factor rotation (Field, 2018; Laher, 2010).

Table 10-10: Total Variance Explained

	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
Factor	**Total**	**% of Variance**	**Cumulative %**	**Total**
1	13.173	16.675	16.675	6.243
2	7.357	9.313	25.987	5.880
3	4.811	6.090	32.077	5.306
4	3.386	4.287	36.364	6.225
5	2.919	3.695	40.059	5.459
6	2.457	3.110	43.169	5.991
7	2.244	2.840	46.009	7.399
8	1.852	2.345	48.354	7.954
9	1.776	2.248	50.602	5.029
10	1.696	2.146	52.748	5.713
11	1.545	1.956	54.704	5.425
12	1.439	1.822	56.526	5.197
13	1.380	1.747	58.273	5.610
14	1.255	1.589	59.862	5.204
15	1.198	1.516	61.378	3.786
16	1.157	1.465	62.843	5.139

Extraction Method: Principal Component Analysis.
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Table 10-11: Factor Structure

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ZPD1	0.680															
ZPD2	0.738															
ZPD3	0.717															
ZPD4	0.643															
SCAF1		0.767														
SCAF2		0.533														
SCAF3		0.802														
SCAF4		0.735														
SCAF5		0.754														
SCAF6		0.710														
ACTLN1																
ACTLN2			0.711													
ACTLN3			0.744													
ACTLN4																
ACTLN5			0.704													
INDLN1																
INDLN2				0.750												
INDLN3				0.645												
INDLN4				0.666												
INDLN5				0.539												
GRPLN1																
GRPLN2																
GRPLN3					0.862											
GRPLN4					0.867											

There are two types of factor rotation methods namely orthogonal and oblique rotation. Orthogonal rotation treats the factors as being uncorrelated while oblique rotation treats them as correlated (Matsunaga, 2010). Therefore, orthogonal rotation is appropriate for factors which are not correlated. While oblique rotation is appropriate for factors which are correlated, it still produces reliable factors even if the factors are in fact not correlated. Orthogonal rotation includes Varimax, Quartimax and Equamax while oblique rotation includes Direct Oblim, Direct Quartimax and Promax rotation.

Table 10-11: Factor Structure (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SDL1						0.719										
SDL2						0.799										
SDL3						0.805										
SDL4						0.758										
REFTHK1							0.605									
REFTHK2							0.747									
REFTHK3							0.801									
REFTHK4							0.650									
REP1								0.662								
REP2								0.849								
REP3								0.849								
REP4								0.816								
REP5								0.524								
REINF1									0.807							
REINF2									0.884							
REINF3									0.825							
REINF4									0.846							
REINF5									0.771							
READ1										0.520						
READ2										0.793						
READ3										0.804						
READ4										0.771						
READ5										0.616						
SCMCON1											0.696					
SCMCON2											0.834					
SCMCON3											0.844					
SCMCON4											0.804					
SCMCON5											0.560					
COGLD1												0.818				
COGLD2												0.879				
COGLD3												0.858				
COGLD4												0.530				
COGLD5												0.501				
COGLD6																
COGLD7																
COMPQ1													0.672			
COMPQ2													0.807			
COMPQ3													0.877			
COMPQ4													0.866			
COMPQ5													0.862			
COMPQ6													0.766			
AUTHPB1														0.798		
AUTHPB2														0.899		
AUTHPB3														0.823		
AUTHPB4														0.720		
AUTHPB5														0.565		
WOKEXP1															0.789	
WOKEXP2															0.812	
WOKEXP3															0.795	
WOKEXP4															0.661	
COMPPB1																0.698
COMPPB2																0.788
COMPPB3																0.790
COMPPB4																0.833
COMPPB5																0.734

For this study, Promax with Kaiser normalization was the preferred factor rotation method with a Kappa value of 4 as recommended by Matsunaga (2010). Promax was preferred firstly because it is an oblique rotation method and so is suited to factors which are correlated and still works perfectly well if the factors are not correlated (Ibid). Given the large number of factors in this study, it is normal and expected that some factors will be correlated while others may not. Therefore, an oblique rotation is best suited. Secondly, from the available oblique rotation options, Promax produced the best interpretable solution with no cross-loadings when factor loadings less than 0.50 were suppressed. For a clear pattern of the factor structure, it is necessary to suppress small factor loadings. The decision on the appropriate cut-off for factor loadings is a matter of opinion and based on rules of thumb (Laher, 2010). Laher (2010) and Matsunaga (2010) citing research evidence suggested that factor loadings should be greater than 0.30 but loadings greater than 0.40 are preferable.

Anderson and Gerbing (1988) recommends a more stringent cut-off of 0.50 for factor loadings. This more stringent cut-off was preferred for this study since it produced a factor structure which was interpretable and consistent with the underlying theory of the study with no cross loading among the extracted factors. The resulting factor structure can be seen in Table 10-11. The 20 factors retained accounted for almost 63% of the total variance captured by the instrument as shown in Table 10-10.

10.5.4 Factor Loadings

All the items loaded on the *a posteriori* constructs when factors loadings less than 0.50 were suppressed as recommended by Anderson and Gerbing (1988). Therefore, the reported factor loadings range between 0.501 and 0.899. A total of 7 items fell below the 0.50 threshold and so did not load onto any constructs. These items were subsequently dropped and omitted from further analysis. The items can be seen in Table 10-10. In summary, 2 items were dropped from ACTLN, 1 from INDLN, 2 from GRPLN and 2 from COGLD. The reliability and validity of the remaining items was assessed.

10.6 Reliability and Validity

The validity of a measuring instrument is the extent to which the instrument measures what it is intended to measure (Field, 2018; Hair *et al.*, 2007; Saunders *et al.*, 2012). Instrument validity falls into three broad groups namely, logical validity, criterion-related validity and congruent or construct validity. These were extensively discussed in the Research Methodology chapter. Logical validity (face validity) was assessed by several rounds of instrument scrutiny by an expert and subsequent reviews by different authors. The two facets of construct validity namely convergent and discriminant validity were assessed by a number of criteria. Convergent validity was assessed based on the factorial clustering of items supported by theory (Chin, 1998; Chinomona and Omoruyi, 2015). Communality, which is the extent to which a measurement item correlates with all other variables, is also a measure of the convergent validity of a research instrument since it measures the extent to which the items cluster together. Discriminant validity was assessed using Average Variance Extracted (AVE) and the comparison of the square root of the highest shared variance. Discriminant validity is also considered to exist when the inter-correlations between constructs is less than 0.60 (Hulland, 1999).

Convergent validity is considered to exist when the items load onto their constructs without significant cross-loading at factors of 0.50 after factor analysis (Chin, 1998; Chinomona and Omoruyi, 2015). Communalities of at least 0.30 also suggest good convergent validity. It is widely accepted that convergent validity also exists when the AVE values exceed 0.50 (Fornell and Larcker, 1981; Worthington and Whittaker, 2006). However, Chin (1998) and Chinomona and Omoruyi (2015) suggest that AVE values exceeding 0.40 are equally fairly acceptable. Discriminant validity exists when the square root of the AVE is less than the shared variance (inter correlation) between the two constructs or when the square root of the highest shared variance between two constructs is less than the highest AVE (Fornell and Larcker, 1981).

All the statistics for the assessment of construct validity can be seen in Table 10-12. Since items which failed to load on their hypothesised constructs by at least 0.50 were not considered in scale development, the resulting items therefore exhibit good convergent validity based on the criteria of factor loading cited by

Chinomona and Omoruyi (2015) and recommended by Chin (1998). Further, all the communalities exceeded the threshold of 0.30 further suggesting good convergent validity. AVE was calculated using the formula:

$$VE = \frac{\sum_{i=1}^{n} \lambda_i^2}{n}$$

Equation 10-1: Average Variance Extracted

Where:
n= number of items in scale
λ= standardised factor loading

The resulting scores for AVE ranged between 0.428 and 0.747 and can be seen in Table 10-12. Based on the widely accepted minimum threshold of 0.50 by Fornell and Larcker (1981), two constructs fell below the thresholds. The affected constructs are ZPD and INDLN which had scores of 0.484 and 0.428 respectively. While 0.50 is the widely accepted threshold for AVE, 0.40 is also considered marginally acceptable especially when other measures of validity are adequately met (Chin, 1998; Chinomona and Omoruyi, 2015). Based on this threshold of 0.40, all constructs have acceptable AVE.

Reliability refers to the extent to which a measurement instrument remains consistent in its measures (Hair *et al.*, 2007; Saunders *et al.*, 2012). There are two broad categories of reliability namely stability and consistency and these were discussed in the Research Methodology chapter. The research instrument was assessed for reliability with three measures namely, item-total correlation, Cronbach's alpha (Alpha) and Composite Reliability (CR) all of which measure the internal consistency of the instrument.

Item-total correlations ranged between 0.428 to 0.826 and so exceeded the minimum threshold of 0.30 recommended by Brzoska and Razum (2010) and Hair *et al.* (2007). Nunnally (1978) and Anderson and Gerbing (1988) recommended a more stringent cut-off of 0.50 for item-total correlation. However, the more recent recommendation of 0.30 was followed. Therefore, no items were excluded from further analysis based on low item-total correlation since they all exceeded the 0.30 minimum. The values for the item-total correlations can be seen in Table 10-12.

The items which factored with sufficient loadings were assessed for internal consistency using Cronbach's alpha. Items which failed to load onto their respective constructs at the adopted cut-off value of 0.50 were omitted from the calculation of the Cronbach's alpha. The scores for Cronbach's alpha ranged between 0.657 and 0.90 as shown in Table 10-12. Several studies recommend a cut-off of 0.70 for an acceptable Cronbach's alpha (Byrne, 2006; Cronbach and Meehl, 1955; Nunnally, 1978). Nunnally (1978) further qualified the threshold of 0.70 as being appropriate for basic research. It was recommended that for applied research, a Cronbach's alpha of 0.80 may not be high enough. Generally, it was recommended that when important decisions which would affect the fate of individuals were going to be made, a Cronbach's alpha of at least 0.90 or better still 0.95 was preferable. Therefore, the appropriate cut-off for an acceptable Cronbach's alpha is related to the use and decisions which will be made with the resulting scales. Basing on the 0.70 threshold, two scales fell below the acceptable limit. The affected scales are ZPD and ACTLN. Considering the recommendation of basing the cut-off value on the use of the resulting scales and the potential impact of results, several studies have adopted cut-offs lower than the commonly accepted 0.70 (for example, Chinomona and Omoruyi, 2015). Based on this, the two scales which fell below the 0.70 Cronbach's alpha threshold were retained for further scrutiny.

Table 10-12: Scale Reliability and Validity Statistics

	Construct	Mean	Std. Dev.	Skewness	Kurtosis	Communalities	Item Correlation	Factor Loading	AVE	CR	Alpha
	Zone of Proximal Development										
1	ZPD1	3.452	1.000	0.023	-0.547	0.532	0.428	0.680			
2	ZPD2	2.687	1.169	0.323	-0.687	0.628	0.486	0.738	0.484	0.644	0.693
3	ZPD3	3.198	1.115	-0.179	-0.612	0.583	0.536	0.717			
4	ZPD4	3.596	1.060	-0.395	-0.475	0.538	0.460	0.643			
	Scaffolding										
1	SCAF1	2.889	1.207	-0.075	-0.879	0.586	0.541	0.767			
2	SCAF2	3.585	1.040	-0.507	-0.226	0.491	0.524	0.533			
3	SCAF3	3.388	1.045	-0.299	-0.412	0.707	0.715	0.802	0.521	0.692	0.831
4	SCAF4	3.238	1.117	-0.263	-0.600	0.618	0.613	0.735			
5	SCAF5	3.063	1.146	-0.109	-0.750	0.638	0.648	0.754			
6	SCAF6	3.772	1.079	-0.641	-0.179	0.558	0.587	0.710			
	Active Learning										
1	ACTLN1	3.971	0.989	-0.709	-0.020	0.477					
2	ACTLN2	3.501	1.180	-0.499	-0.507	0.517	0.476	0.711			
3	ACTLN3	3.255	1.273	-0.274	-0.918	0.594	0.484	0.744	0.518	0.691	0.657
4	ACTLN4	4.081	1.087	-10.125	0.603	0.487					
5	ACTLN5	3.499	1.174	-0.503	-0.524	0.517	0.443	0.704			
	Individual Learning										
1	INDLN1	3.597	0.892	-0.245	-0.074	0.379					
2	INDLN2	4.092	0.789	-0.589	0.031	0.608	0.574	0.750			
3	INDLN3	4.086	0.833	-0.684	0.224	0.523	0.595	0.645	0.428	0.564	0.754
4	INDLN4	4.098	0.862	-0.787	0.297	0.575	0.619	0.666			
5	INDLN5	3.825	0.958	-0.554	-0.131	0.424	0.434	0.539			
	Group Learning										
1	GRPLN1	3.655	1.047	-0.444	-0.264	0.537					
2	GRPLN2	3.706	0.965	-0.480	-0.161	0.537			0.747	0.921	0.824
3	GRPLN3	3.666	1.118	-0.566	-0.422	0.768	0.700	0.862			
4	GRPLN4	3.597	1.140	-0.557	-0.444	0.730	0.700	0.867			
	Self-Directed Learning										
1	SDL1	3.960	0.992	-0.725	-0.096	0.650	0.644	0.719			
2	SDL2	3.841	0.976	-0.610	0.000	0.695	0.672	0.799	0.594	0.783	0.803
3	SDL3	3.910	0.968	-0.765	0.237	0.684	0.676	0.805			
4	SDL4	3.810	1.123	-0.781	-0.085	0.558	0.499	0.758			
	Reflective Thinking										
1	REFTHK1	3.645	1.026	-0.416	-0.249	0.507	0.502	0.605			
2	REFTHK2	3.883	0.881	-0.565	0.182	0.624	0.601	0.747	0.500	0.660	0.774
3	REFTHK3	3.977	0.860	-0.394	-0.668	0.708	0.678	0.801			
4	REFTHK4	4.127	0.879	-0.830	0.162	0.628	0.546	0.650			
	Repetition										
1	REP1	3.703	1.055	-0.586	-0.178	0.583	0.581	0.662			
2	REP2	2.954	1.291	0.032	-10.052	0.711	0.681	0.849			
3	REP3	3.033	1.214	-0.017	-0.882	0.764	0.719	0.849	0.564	0.742	0.837
4	REP4	3.511	1.078	-0.430	-0.347	0.691	0.698	0.816			
5	REP5	3.561	1.111	-0.461	-0.459	0.504	0.531	0.524			
	Reinforcement										
1	REINF1	3.145	1.181	-0.190	-0.699	0.722	0.753	0.807			
2	REINF2	3.006	1.153	-0.117	-0.641	0.807	0.826	0.884			
3	REINF3	2.493	1.212	0.357	-0.818	0.702	0.711	0.825	0.685	0.873	0.900
4	REINF4	2.660	1.231	0.185	-0.974	0.738	0.769	0.846			
5	REINF5	3.177	1.206	-0.283	-0.756	0.671	0.698	0.771			
	Readiness										
1	READ1	3.612	1.076	-0.530	-0.170	0.552	0.549	0.520			
2	READ2	3.641	1.006	-0.430	-0.171	0.721	0.719	0.793			
3	READ3	3.802	0.979	-0.508	-0.196	0.735	0.697	0.804	0.504	0.666	0.812
4	READ4	3.520	1.056	-0.373	-0.356	0.660	0.625	0.771			
5	READ5	3.098	1.260	-0.075	-0.937	0.505	0.464	0.616			

Table 10-12: Scale Reliability and Validity Statistics (Continued)

	Construct	Mean	Std. Dev.	Skewness	Kurtosis	Communalities	Item Correlation	Factor Loading	AVE	CR	Alpha
	Schema Construction										
1	SCMCON1	3.779	0.950	-0.640	0.297	0.614	0.665	0.696			
2	SCMCON2	3.733	0.911	-0.488	-0.091	0.671	0.701	0.834			
3	SCMCON3	3.791	0.877	-0.438	-0.032	0.678	0.650	0.844	0.570	0.752	0.848
4	SCMCON4	3.695	0.916	-0.428	0.010	0.695	0.658	0.804			
5	SCMCON5	3.944	0.936	-0.666	0.000	0.613	0.611	0.560			
	Cognitive Loading										
1	COGLD1	3.497	1.056	-0.233	-0.649	0.632	0.585	0.818			
2	COGLD2	3.461	1.037	-0.294	-0.443	0.673	0.605	0.879			
3	COGLD3	3.298	1.020	-0.065	-0.533	0.698	0.659	0.858			
4	COGLD4	2.789	1.087	0.121	-0.528	0.592	0.617	0.530	0.542	0.710	0.822
5	COGLD5	2.785	1.085	0.154	-0.538	0.608	0.608	0.501			
6	COGLD6	3.332	1.104	-0.125	-0.583	0.544					
7	COGLD7	3.267	1.201	-0.157	-0.837	0.509					
	Complex Questions										
1	COMPQ1	2.829	1.076	0.130	-0.431	0.594	0.638	0.672			
2	COMPQ2	2.693	1.119	0.304	-0.501	0.706	0.756	0.807			
3	COMPQ3	2.837	1.119	0.151	-0.640	0.725	0.767	0.877	0.659	0.849	0.885
4	COMPQ4	3.108	1.063	-0.042	-0.515	0.592	0.579	0.866			
5	COMPQ5	2.875	1.098	0.091	-0.566	0.690	0.744	0.862			
6	COMPQ6	2.772	1.163	0.137	-0.725	0.647	0.704	0.766			
	Authentic Problems										
1	AUTHPB1	3.616	1.089	-0.573	-0.129	0.616	0.590	0.798			
2	AUTHPB2	3.716	1.067	-0.654	-0.069	0.745	0.742	0.899			
3	AUTHPB3	3.854	0.989	-0.769	0.447	0.699	0.710	0.823	0.592	0.777	0.838
4	AUTHPB4	3.914	0.989	-0.735	0.057	0.621	0.643	0.720			
5	AUTHPB5	3.787	1.020	-0.643	0.054	0.546	0.528	0.565			
	Worked Examples										
1	WOKEXP1	3.463	1.109	-0.360	-0.558	0.661	0.630	0.789			
2	WOKEXP2	3.417	1.055	-0.322	-0.351	0.765	0.760	0.812	0.588	0.775	0.848
3	WOKEXP3	3.280	1.114	-0.301	-0.564	0.746	0.733	0.795			
4	WOKEXP4	3.459	1.105	-0.363	-0.451	0.630	0.628	0.661			
	Completion Problems										
1	COMPPB1	2.871	1.159	0.074	-0.718	0.684	0.702	0.698			
2	COMPPB2	2.722	1.129	0.185	-0.683	0.719	0.760	0.788			
3	COMPPB3	2.733	1.116	0.058	-0.800	0.731	0.772	0.790	0.593	0.781	0.879
4	COMPPB4	2.866	1.187	-0.016	-0.846	0.731	0.753	0.833			
5	COMPPB5	2.651	1.195	0.177	-0.814	0.597	0.580	0.734			

A further assessment of the internal consistency of the scales using CR was conducted. CR is computed

$$\mathrm{CR} = \frac{\left(\sum_{i=1}^{n} \lambda_i\right)^2}{\left(\sum_{i=1}^{n} \lambda_i\right)^2 + \left(\sum_{i=1}^{n} \delta_i\right)}$$

from the factor loadings of the scale items using the formula:

Equation 10-2: Composite Reliability

Where:
n= number of items in scale
λ= standardised factor loading
δ= $(1 - \lambda)^2$

The scores for CR are shown in Table 10-12 and these ranged from 0.564 to 0.921. Hair *et al.* (2007) and Hulland (1999) suggested a threshold of CR of between 0.60 and 0.70 as acceptable. INDLN fell below the

0.60 lower limit of the threshold. While 0.60 is often used as a lower cut-off limit, 0.50 is considered marginally acceptable. Therefore, some studies have adopted scales with CR values less than 0.60.

In summary, reliability was assessed with item-total correlations, Cronbach's alpha and Composite Reliability. All items met the minimum threshold of 0.30 for item-total correlation recommended by (Brzoska and Razum, 2010; Hair *et al.*, 2007). ZPD and ACTLN fell below the 0.70 minimum threshold recommended of Cronbach's by alpha (Byrne, 2006; Cronbach and Meehl, 1955; Nunnally, 1978). However, they had marginally acceptable Cronbach's alpha of 0.693 and 0.657 respectively. INDLN fell below the minimum CR threshold of 0.60 recommended by Hair *et al.* (2007) and Hulland (1999). Validity was assessed with factor loadings, communalities, AVE, square root of smallest AVE against the highest inter-construct correlation and construct inter-correlations. All items met the requirements for factor loadings since they factored without cross-loadings when factor loadings of 0.50 were suppressed. All items had communalities greater than 0.30 suggested by (Chin, 1998; Chinomona and Omoruyi, 2015). ZPD and INDLN fell below the minimum threshold of 0.50 for AVE recommended by (Fornell and Larcker, 1981; Worthington and Whittaker, 2006). All inter-construct correlations were less than 0.60 suggesting good discriminant validity as suggested by Hulland (1999) as can be seen in Table 10-14 with the highest inter-construct correlations being 0.517.

Table 10-13: Descriptive Statistics of Study Constructs

	Concept		Mean	Std. Deviation	Skewness	Kurtosis
Constructivism						
1	Zone of Proximal Development	ZPD	3.233	0.784	0.173	-0.388
2	Scaffolding	SCAF	3.323	0.815	-0.303	-0.025
3	Active Learning	ACTLN	3.418	0.932	-0.246	-0.517
4	Individual Cognition	INDLN	4.025	0.654	-0.688	0.701
5	Group Learning	GRPLN	3.632	1.041	-0.583	-0.293
6	Self-Directed Learning	SDL	3.880	0.806	-0.648	0.226
7	Reflective Thinking	REFTHK	3.908	0.705	-0.462	0.100
Behaviourism (Connectionism)						
8	Repetition	REP	3.352	0.898	-0.156	-0.519
9	Reinforcement	REINF	2.896	1.010	-0.089	-0.567
10	Readiness	READ	3.535	0.816	-0.212	-0.152
Cognitive Science (Cognitive Load Theory)						
11	Schema Construction	SCMCON	3.789	0.724	-0.478	0.265
12	Cognitive Loading	COGLD	3.418	0.875	-0.220	-0.339
13	Complex and Ambiguous Questions	COMPQ	2.852	0.882	0.170	-0.196
14	Authentic Problem	AUTHPB	3.775	0.846	-0.523	0.090
15	Worked Examples	WOKEXP	3.405	0.908	-0.293	-0.263
16	Completion Problems	COMPPB	2.769	0.950	-0.004	-0.509

The lowest AVE from the remaining constructs is 0.428 for INDLN. The square root of this smallest AVE, which is 0.654, is greater than the highest inter-construct correlation, which is 0.517 between SCMCON and INDLN. Therefore, the constructs exhibited good general discriminant validity. The univariate statistics of all the constructs are shown in Table 10-13. Having established that the constructs are reliable and valid, the relationships among the construct were evaluated. Because the study needed to assess the relationships among several research variables, multivariate data analysis was the data analysis approach of choice. Multivariate analysis deals with the simultaneous analysis of three or more variables (Bryman and Bell, 2011; Hair *et al.,* 2007). The preferred multivariate analysis was Structural Equation Modelling (SEM).

Table 10-14: Inter-construct Correlations

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	ZPD	1														
2	SCAF	0.029	1													
3	ACTLN	0.099*	0.310**	1												
4	INDLN	0.041	0.210**	0.282**	1											
5	GRPLN	0.006	0.353**	0.421**	0.251**	1										
6	SDL	0.297**	0.140**	0.312**	0.332**	0.241**	1									
7	REFTHK	0.103*	0.189**	0.325**	0.488**	0.216**	0.406**	1								
8	REP	0.058	0.389**	0.253**	0.333**	0.240**	0.181**	0.249**	1							
9	REINF	0.024	0.343**	0.220**	0.150**	0.295**	0.139**	0.187**	0.361**	1						
10	READ	0.022	0.199**	0.243**	0.469**	0.232**	0.221**	0.403**	0.281**	0.323**	1					
11	SCMCON	-0.023	0.429**	0.309**	0.517**	0.369**	0.255**	0.412**	0.413**	0.320**	0.426**	1				
12	COGLD	0.302**	-0.033	0.018	0.063	0.051	0.245**	0.147**	0.119**	-0.006	0.013	0.078	1			
13	COMPQ	0.347**	-0.132**	-0.040	-0.147**	-0.094*	0.212**	0.036	-0.034	0.062	-0.115**	-0.207**	0.347**	1		
14	AUTHPB	0.215**	0.187**	0.245**	0.224**	0.191**	0.367**	0.233**	0.187**	0.113**	0.202**	0.272**	0.173**	0.036	1	
15	WOKEXP	0.053	0.311**	0.189**	0.293**	0.197**	0.067	0.184**	0.345**	0.252**	0.305**	0.349**	0.096*	-0.097*	0.264**	1
16	COMPPB	0.157**	0.205**	0.111*	0.153**	0.092*	0.081	0.149**	0.255**	0.242**	0.248**	0.195**	0.254**	0.185**	0.058	0.512**

10.7 Structural Equation Modelling

Structural Equation Modelling (SEM) is a multivariate data analysis approach used to assess complex relationships among constructs. It graphically models hypothesised relationships among constructs with structural equations (Byrne, 2006). Subsequently, it establishes how well the theoretical model is supported by empirical data using goodness of fit indices (Hu and Bentler, 1999). Consequently, the assessment of model fitness against empirical data and the estimation of the regression parameters is the primary goal of SEM (Byrne, 2006; Hu and Bentler, 1999). Assessment of model fitness is achieved using several model fit indices. The fit indices are grouped into three distinct groups namely, absolute, incremental and parsimonious fit indices.

Absolute fit indices assess the fundamental fit between the data and the model without comparison to any baseline model. The indices included in this category are the Chi-Squared test, Relative Normed Chi-Square value (λ/df), Root Mean Square Error of Approximation (RMSEA), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit index (AGFI), the Root Mean Square Residual (RMR), the Standardised Root Mean Square Residual (SRMR) and Hoelter's critical N. The chi-square assesses the discrepancy between the sample and the covariance matrix with a good model being insignificant at a 0.05 alpha level (Hooper, Coughlan and Mullen, 2008; Hu and Bentler, 1999). The chi-square is very sensitive to violations of multivariate normality and is almost always insignificant for large samples. The Relative Normed Chi-square reduces the effect of the sample size on the chi-square statistics and so is a better measure of fitness than the chi-square when large samples are used (Hooper *et al.*, 2008). A statistic of less than 2.0 is considered appropriate for the Relative Normed Chi-square (Tabachnick and Fidell, 2013). GIF assesses the variance accounted for by the estimated population covariance of the model (Ibid). It has a downward bias when there is a large degree of freedom in relation to sample size (Hooper *et al.*, 2008). The AGFI adjusts for the degrees of freedom to improve on the index (Ibid). While both the GFI and AGFI are widely reported, they are both criticized for being strongly influenced by sample size and are insufficiently and inconsistently sensitive to model misspecification (Byrne, 2006; Hu and Bentler, 1999). For these reasons, Hu and Bentler (1999) and Hooper *et al.* (2008) among several others recommended against reporting the them. The RMR is based on the square root of the residuals of the sample covariance matrix (Hooper *et al.*, 2008). It is difficult to interpret when the scales in the sample are different (Ibid). The SRMR corrects this and becomes easier to interpret when the scales are different (Ibid). Accepted thresholds for both RMR and SRMR are 0.08 or less (Ibid). RMSEA is said to be one of the most informative fit indices and favours models with fewer parameters (parsimonious) (Byrne, 2006; Hooper *et al.*, 2008). RMSEA statistics of less than 0.05 are considered indicative of a good model fit (Hu and Bentler, 1999). Hoelter's critical N is a useful criterion for determining the adequacy of the sample size (Teo *et al.*, 2013). It reports the largest sample size with which the model cannot be rejected. A Hoelter's critical N of 200 at a significance level of either 0.05 or 0.01 indicates that the sample size is sufficient for the model.

Incremental fit indices are also known as comparative fit indices or relative fit indices. Generally, they compare the chi-square value of the model to a baseline or null model (Hooper et al., 2008). A null model is a model with all variables uncorrelated. The indices included in this category are the Incremental Fit Index (IFI), Normed Fit Index (NFI), Comparative Fit Index (CFI), Tucker Lewis Index (TLI) and the Relative Fit Index (RFI). The IFI, RFI and NFI compare the model chi-square to the chi-square of the null model with recommended acceptable statistics being either greater than 0.90 (Hooper *et al.*, 2008) or a more stringent greater than 0.95 (Hu and Bentler, 1999). They are sensitive to sample size and so tends to underestimate statistics for samples less than 200. The Non-Normed Fit Index (NNFI) also known as the TLI is a good alternative for samples less than 200 but becomes problematic with very small samples (Tabachnick and Fidell, 2013). CFI is a revised form of NFI and takes into account sample size and so performs well even with small samples (Byrne, 2006; Hooper *et al.*, 2008; Tabachnick and Fidell, 2013). A cut-off of greater than 0.90 is considered acceptable while 0.95 is more preferable (Hu and Bentler, 1999). Incremental fit indices do not penalise for less parsimonious models (Hooper et al., 2008).

Parsimonious fit indices were developed to penalise for model complexity because complex, nearly saturated models are dependent on the sample during estimation (Ibid). Non-parsimonious or complex models are models which contain few paths. Complex models create a less rigorous theoretical model that produces better fit indices (Ibid). Parsimonious indices include the Parsimony Goodness-of-Fit (PGFI), the Parsimony Adjusted Normed Fit Index (PNFI) and the Parsimony Adjusted Comparative Fit Index (PCFI). They are all based on adjusting their parent fit indices for loss of degrees of freedom and the seriously penalise for model complexity (Ibid). This therefore results in model fit indices much lower than the other indices. There are no widely accepted minimum thresholds of acceptance. Often values of 0.50 are obtainable even when other indices exceed the 0.90 threshold. Therefore, it is recommended to report them in tandem with other indices (Ibid).

Anderson and Gerbing (1988) suggested a two-step approach to SEM. The first step is Confirmatory Factor Analysis (CFA) while the second step is the assessment of the structural relationships among the constructs. SEM (both CFA and path modelling) was conducted using IBM SPSS AMOS v25. While other software for performing SEM are available, the IBM SPSS AMOS software was preferred because it was the available software at the time of the research. Within the AMOS software, several estimation methods are available including Maximum likelihood, Generalised least squares, Unweighted least squares, Scale-free least squares and asymptomatically distribution-free estimation methods. For this research, the preferred estimation method was Maximum likelihood estimation. It was preferred because it is considered to be a robust estimation method.

10.7.1 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is an important and necessary follow up step to EFA (Yale, Jensen, Carcioppolo, Sun and Liu, 2015). It consists of a theoretical model which links a set of observed variables to their respective latent variables. CFA allows for the testing and refining of research constructs in relation to a theoretical framework (Yale, Jensen, Carcioppolo, Sun and Liu, 2015). It is a theoretically driven process as opposed to EFA which is data driven (Byrne, 2006). CFA assesses how well a theorised factor structure is consistent with empirical data (Ibid). CFA is conducted using a graphical model called the measurement model. The initial hypothesised measurement model is shown in Figure 10-1.

10.7.2 CFA Reliability and Validity

After the confirmatory factor analysis, the constructs were again assessed for reliability and validity. CFA differs from EFA in that it is theory driven while EFA is data driven. EFA is based on reasoning which is *a posteriori* in that it data driven while CFA is based on reasoning which is *a priori* in that it is based on theoretical consideration. Therefore, further assessing reliability and validity is a further check on how well the measurement items fit the theory *a priori*. The reliability and validity statistics are based on the factor loadings from the CFA and are shown in Table 10-15.

Table 10-15: Reliability and Validity

	Construct	Item Correlation	Factor Loading	AVE	CR	Alpha
	Zone of Proximal Development					
1	ZPD1	0.428	0.491	0.386	0.503	0.693
2	ZPD2	0.486	0.640			
3	ZPD3	0.536	0.666			
4	ZPD4	0.460	0.671			
	Scaffolding					
1	SCAF1	0.541	0.577	0.479	0.637	0.831
2	SCAF2	0.524	0.706			
3	SCAF3	0.715	0.773			
4	SCAF4	0.613	0.712			
5	SCAF5	0.648	0.707			
6	SCAF6	0.587	0.663			
	Active Learning					
1	ACTLN2	0.476	0.591	0.383	0.500	0.657
2	ACTLN3	0.484	0.695			
3	ACTLN5	0.443	0.563			

Table 10-15 - Reliability and Validity (Continued)

	Construct	Item Correlation	Factor Loading	AVE	CR	Alpha
	Individual Learning					
1	INDLN2	0.574	0.699	0.456	0.603	0.754
2	INDLN3	0.595	0.703			
3	INDLN4	0.619	0.749			
4	INDLN5	0.434	0.529			
	Individual Learning					
1	GRPLN3	0.700	0.857	0.701	0.887	0.824
2	GRPLN4	0.700	0.817			
	Self-Directed Learning					
1	SDL1	0.644	0.796	0.518	0.685	0.803
2	SDL2	0.672	0.786			
3	SDL3	0.676	0.738			
4	SDL4	0.499	0.525			
	Reflective Thinking					
1	REFTHK1	0.502	0.523	0.471	0.621	0.774
2	REFTHK2	0.601	0.626			
3	REFTHK3	0.678	0.822			
4	REFTHK4	0.546	0.738			
	Repetition					
1	REP1	0.581	0.653	0.549	0.726	0.837
2	REP2	0.681	0.843			
3	REP3	0.719	0.794			
4	REP4	0.698	0.796			
5	REP5	0.531	0.585			
	Reinforcement					
1	REINF1	0.753	0.866	0.617	0.805	0.900
2	REINF2	0.826	0.927			
3	REINF3	0.711	0.665			
4	REINF4	0.769	0.718			
5	REINF5	0.698	0.720			
	Readiness					
1	READ1	0.549	0.663	0.502	0.663	0.812
2	READ2	0.719	0.810			
3	READ3	0.697	0.810			
4	READ4	0.625	0.712			
5	READ5	0.464	0.501			
	Schema Construction					
1	SCMCON1	0.665	0.616	0.495	0.657	0.848
2	SCMCON2	0.701	0.682			
3	SCMCON3	0.650	0.778			
4	SCMCON4	0.658	0.799			
5	SCMCON5	0.611	0.622			
	Cognitive Loading					
1	COGLD1	0.585	0.463	0.346	0.429	0.822
2	COGLD2	0.605	0.444			
3	COGLD3	0.659	0.530			
4	COGLD4	0.617	0.832			
5	COGLD5	0.608	0.842			
	Complex Questions					
1	COMPQ1	0.638	0.730	0.564	0.746	0.885
2	COMPQ2	0.756	0.833			
3	COMPQ3	0.767	0.822			
4	COMPQ4	0.579	0.601			
5	COMPQ5	0.744	0.759			
6	COMPQ6	0.704	0.739			

Table 10-15: Reliability and Validity (Continued)

	Construct	Item Correlation	Factor Loading	AVE	CR	Alpha
	Authentic Problems					
1	AUTHPB1	0.590	0.701	0.531	0.706	0.838
2	AUTHPB2	0.742	0.813			
3	AUTHPB3	0.710	0.779			
4	AUTHPB4	0.643	0.719			
5	AUTHPB5	0.528	0.617			
	Worked Examples					
1	WOKEXP1	0.630	0.696	0.595	0.783	0.848
2	WOKEXP2	0.760	0.849			
3	WOKEXP3	0.733	0.825			
4	WOKEXP4	0.628	0.703			
	Completion Problems					
1	COMPPB1	0.702	0.797	0.606	0.795	0.879
2	COMPPB2	0.760	0.778			
3	COMPPB3	0.772	0.837			
4	COMPPB4	0.753	0.837			
5	COMPPB5	0.580	0.625			

The factor loadings ranged from 0.444 to 0.927. A total of three items fell below the adopted threshold of 0.50 suggested by Anderson and Gerbing (1988) and these are item 5 from INDLN and items 1 and 2 from COGLD. Also, AVE, CR and Cronbach's alpha scores for ZPD and ACTLN (0.386, 0.503, 0.693 and 0.383, 0.500, 0.657 respectively) fell below the acceptable thresholds of 0.50, 0.60 and 0.70 suggested by Fornell and Larcker (1981) and Hair *et al.,* (2007) among others. COGLD had AVE and CR scores (0.346 and 0.429 respectively) which fell below the accepted thresholds while SCAFF, INDLN, REFTHK and SCMCON had AVE values (0.479, 0.456, 0.471 and 0.495 respectively) less than the recommended 0.50 threshold. Therefore, it was necessary to refine the measurement model considering the above.

10.7.3 Model Refinement

The model was refined by omitting problematic constructs and items as suggested by Hooper et al. (2008). Subsequently, the two constructs of ZPD and ACTLN were dropped from the model owing to their poor reliability and validity scores which could not be improved upon. Based on the EFA, ZPD exhibited marginally poor reliability and validity but was initially accepted because it had marginally acceptable AVE (0.473) and Cronbach's alpha (0.693) and acceptable CR (0.628). ACTLN also exhibited marginally poor initial reliability and validity but was accepted because it exhibited marginally acceptable Cronbach's alpha (0.657) and acceptable AVE (0.500) and CR (0.662).

Further, some items from SCAFF, INDLN, REFTHK, SCMCON and COGLD, which had marginally acceptable AVE and acceptable CR and Cronbach's alpha, were dropped in order to improve the AVE scores of these constructs. Some factor loadings for INDLN, REFTHK and COGLD in fact fell the adopted acceptable threshold of 0.50. Therefore, the respective items which had factor loadings were removed from the model and these are item 5 from INDLN and items 1 and 2 from COGLD. Subsequently, the AVE, CR and Cronbach's alpha scores for these two items changed (from 0.456, 0.603 and 0.754 to 0.515, 0.686 and 0.768 for INDLN and from 0.346, 0.429 and 0.822 to 0.561, 0.737 and 0.781 for COGLD).

Further, item 1 was dropped from REFTHK, item 1 from SCMCON and item 1 from SCAFF in order to improve their AVE scores. Subsequently, the AVE, CR and Cronbach's alpha scores for the respective constructs changed (from 0.471, 0.621 and 0.774 to 0.537, 0.713 and 0.767 for REFTHK, from 0.495, 0.657 and 0.848 to 0.524, 0.696 and 0.815 for SCMCON and from 0.479, 0.637 and 0.831 to 0.508, 0.677 and 0.818 for SCAFF). Subsequent to this refinement, all 16 constructs exhibited acceptable reliability and validity based on AVE, CR and Cronbach's alpha. The refined and accepted measurement model with ACTLN and ZPD and the other respective items omitted from the model is shown in Figure 10-2.

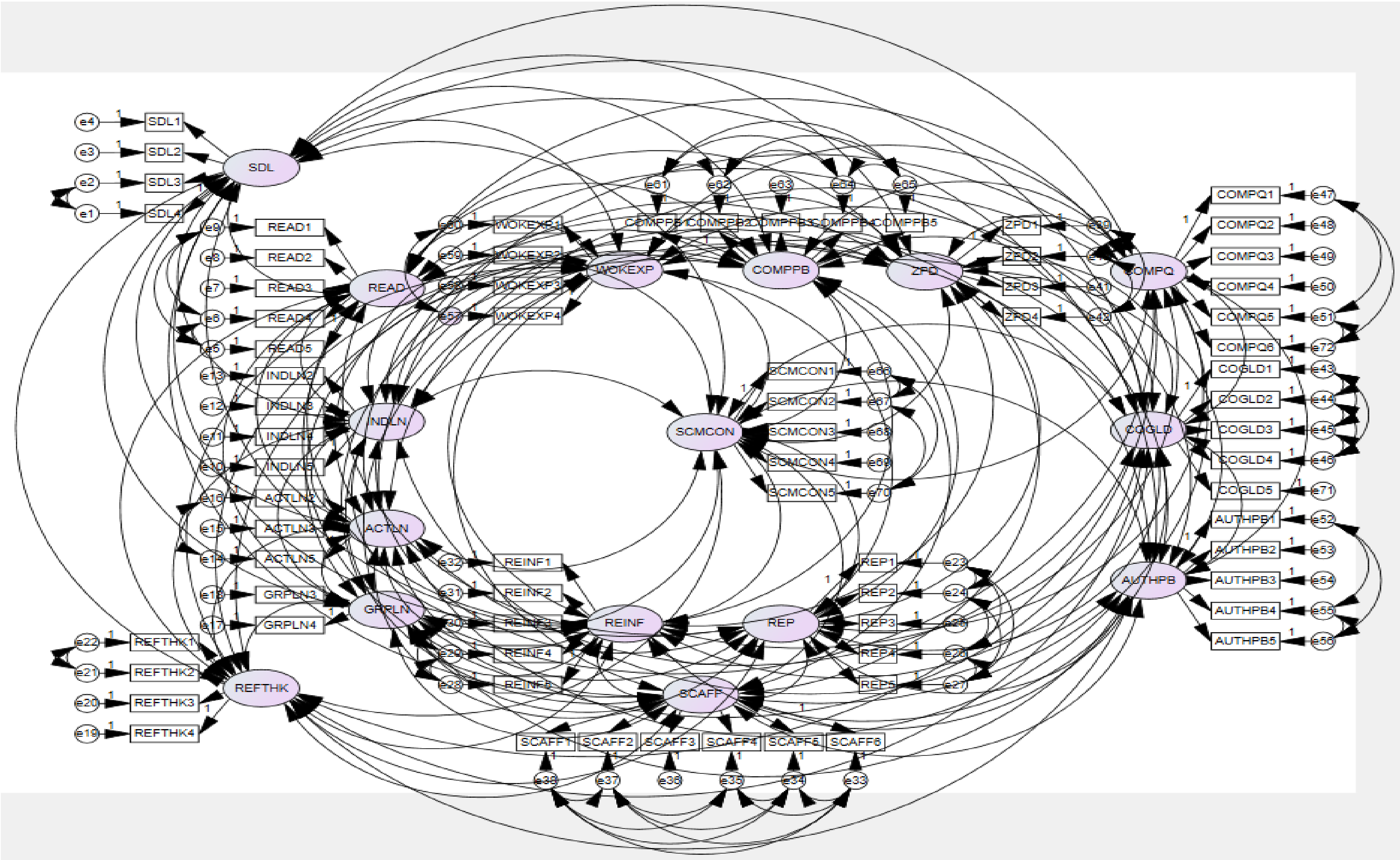


Figure 10-2: Initial Measurement Model

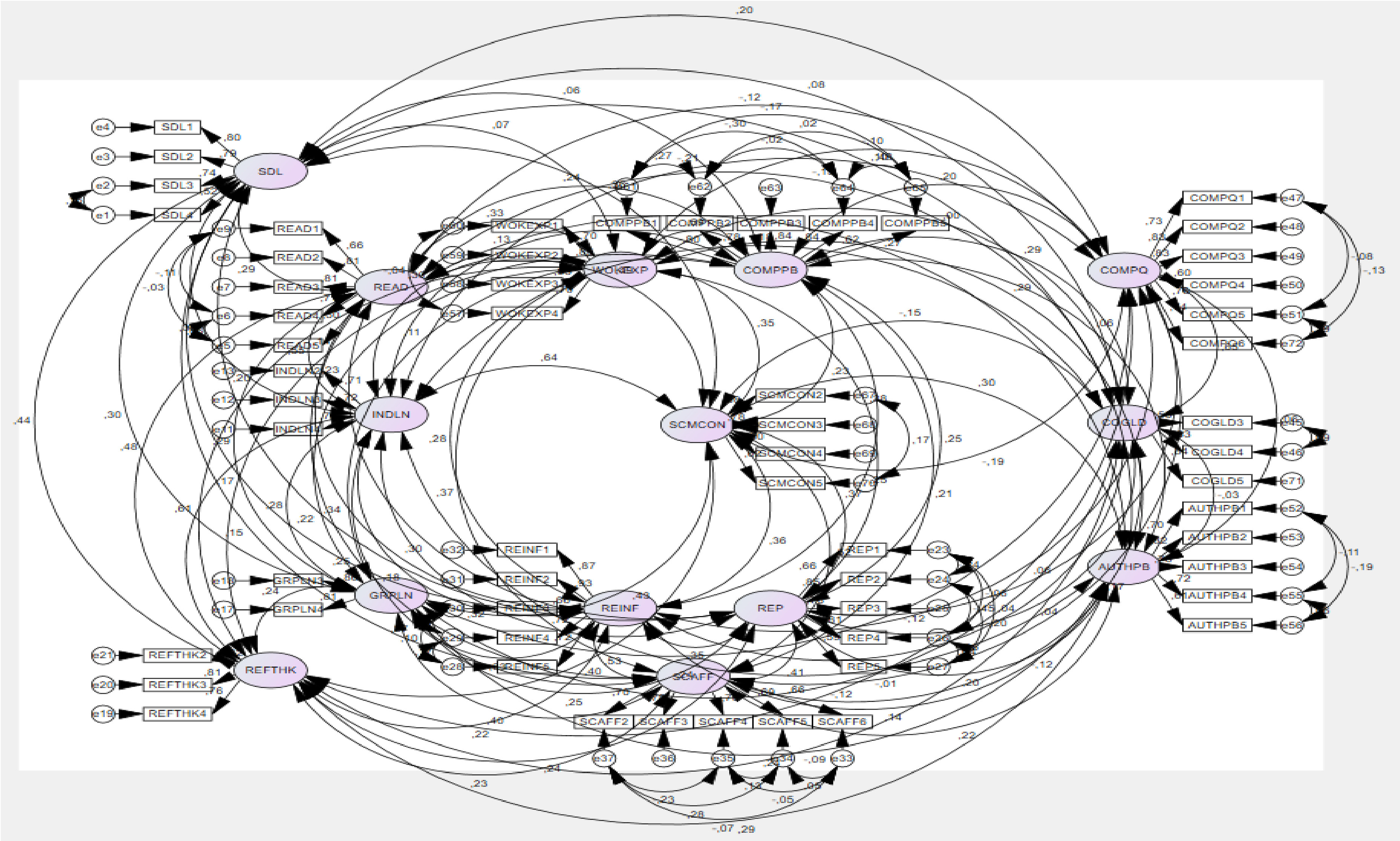


Figure 10-3: Refined Measurement Model

10.7.4 Measurement Model Fitness

The model fit indices for the refined model are shown in Table 10-16. Absolute fit was assessed using the Chi-square, the Relative Normed Chi-square (λ/df), the RMSEA, RMR, GFI, AGFI and Hoelter's critical N. The Chi-square was significant (p=0.000) indicating a poor fit (Hooper et al., 2008; Hu and Bentler, 1999). However, the Chi-square is almost always insignificant for large samples (Hooper *et al.*, 2008). The Relative Normed Chi-square (λ/df), which reduces the effect of sample size, met recommended threshold of being less than 2.00 (Tabachnick and Fidell, 2013). The RMSEA met the minimum threshold of being less than 0.05 (Hu and Bentler, 1999).

Table 10-16: Measurement Model Indices

Model Fit Index	Acceptable Threshold	Study Threshold	Met/Not Met
Absolute Fit Indices			
Chi-Square Significance	P>0.05	P=0.000	Not Met
Relative Normed Chi-Square value (λ/df)	<2	1.639	Met
Random Measures of Sample Error Approximation (RMSEA)	<0.080	0.035	Met
Root Mean Square Residual (RMR)	<0.080	0.057	Met
Goodness-of-Fit Index (GFI)	>0.900	0.860	Not Met
Adjusted Goodness-of-Fit Index (AGFI)	>0.900	0.838	Not Met
Hoelter's CN (p=0.01)	>200	345	Met
Incremental Fit Indices			
Incremental Fit Index (IFI)	>0.900	0.936	Met
Normed Fit Index (NFI)	>0.900	0.851	Not Met
Comparative Fit Index (CFI)	>0.900	0.935	Met
Tucker Lewis Index (TLI)	>0.900	0.928	Met
Relative Fit Index (RFI)	>0.900	0.833	Not Met
Parsimonious Fit Indices			
Parsimony Adjusted Normed Fit Index (PNFI)	>0.900	0.759	Not Met
Parsimony Adjusted Comparative Fit Index (PCFI)	>0.900	0.835	Not Met

The RMR met the recommended acceptable threshold while GFI and AGFI fell below their respective acceptable thresholds. However, the GFI and AGFI are strongly criticised for being strongly influenced by sample size and being insufficiently and inconsistently sensitive to model misspecification (Byrne, 2006; Hooper *et al.*, 2008; Hu and Bentler, 1999). It is therefore not surprising that the GFI and AGFI fell below the normally accepted threshold. The Hoelter's critical N was greater than 200 at a significance level of 0.01 indicating that the sample size was sufficient for the analysis. Therefore, notwithstanding that the Chi-square was significant, which is expected for large samples, and also two other indices (GFI and AGFI), which are severely criticised, fell below acceptable thresholds, four out of the seven absolute fit indices met the minimum thresholds of acceptance. Therefore, the measurement model exhibits acceptable absolute fitness.

Incremental indices assessed were the IFI, NFI, CFI, TLI and the RFI. The IFI, CFI and TLI all met the minimum thresholds suggested by Hooper *et al.* (2008) and Hu and Bentler (1999). However, the NFI and RFI fell below the 0.90 threshold. It is worth noting that the CFI is sensitive to sample size (Hooper *et al.*, 2008). Notwithstanding that two of the five incremental fit indices assessed fell below the acceptable threshold, the remaining indices provide support for acceptable model fitness. Therefore, the model has acceptable incremental fit. Parsimony was assessed using PNFI and PCFI. The indices exceeded the threshold of 0.50 suggested by Hooper *et al.* (2008). However, it may be argued that the general cut-off index of 0.90 which is widely accepted for all other indices might be more appropriate. Considering the complexity of the model being assessed and the fact that parsimony indices severely punish for model complexity (Ibid), it was expected that these indices would be much lower than the other indices. Therefore, as expected, the model presented is not so parsimonious.

10.7.5 Structural Model Fitness

The second step in SEM is the path modelling which consists of linking the latent variables with a series of recursive and non-recursive relationships. Structural modelling allows for the estimation of the structural or regression relationships among the constructs. The structural model is shown in Figure 10-3.

Consistent with the measurement model, the structural model exhibited acceptable absolute fit. The respective fit indices can be seen in Table 10-18. However, the Chi-square was significant (p=0.000) indicating a poor fit (Hooper et al., 2008; Hu and Bentler, 1999). As stated earlier, this is expected in view of the large sample size which often leads to significant Chi-square values (Hooper *et al.*, 2008). The Relative Normed Chi-square (λ/df), which compensates for the drawback of the Chi-square met the threshold of less than 2.00 recommended by (Tabachnick and Fidell, 2013). The RMSEA met the minimum threshold of less than 0.05 Hu and Bentler (1999). Therefore, notwithstanding the less than favourable Chi-square statistics, which was expected, the structural model exhibits acceptable absolute fitness. The NFI and the RFI fell below the threshold of acceptance like in the measurement model. In contrast, the IFI, CFI and TLI met the minimum threshold of 0.90 recommended by Hooper *et al.* (2008) and Hu and Bentler (1999). Therefore, the incremental fit is acceptable.

The parsimony fit indices assessed were less than 0.90. It may be argued that there are no widely accepted thresholds for parsimony fit indices notwithstanding that Hooper *et al.* (2008) suggested that a cut-off of 0.50 may be acceptable. Considering that parsimony indices are designed to severely penalise complex models, simply accepting a much less stringent cut-off would be merely denying the fact that a model is not as parsimonious as could be. Therefore, notwithstanding that the parsimony indices met the threshold suggested by Hooper *et al.* (2008), the structural model is not so parsimonious.

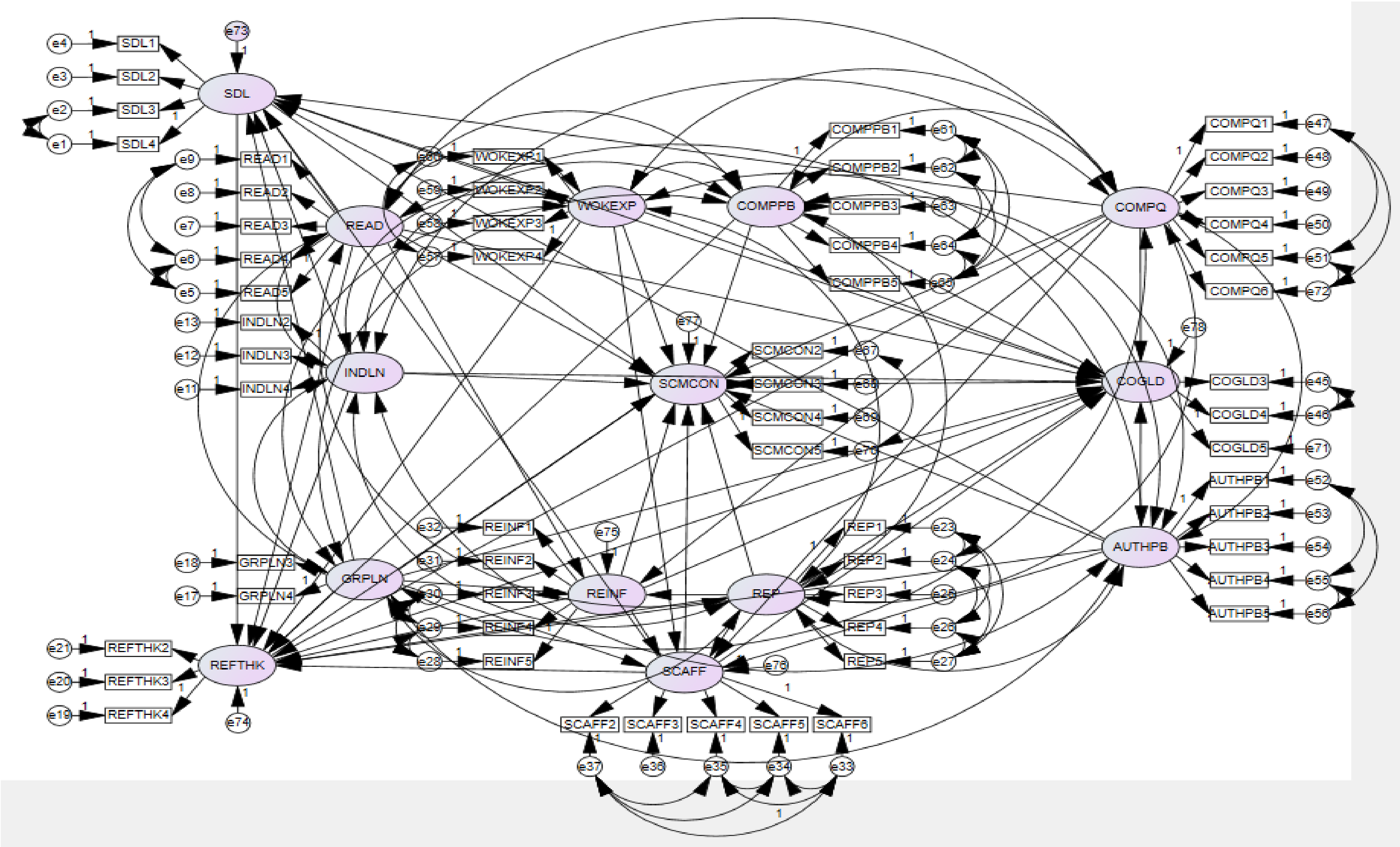


Figure 10-4: Structural Model

Table 10-17: Structural Model Indices

Model Fit Index	Acceptable Threshold	Study Threshold	Met/Not Met
Absolute Fit Indices			
Chi-Square Significance	P>0.05	P=0.000	Not Met
Relative Normed Chi-Square value (λ/df)	<2	1.778	Met
Random Measures of Sample Error Approximation (RMSEA)	<0.080	0.039	Met
Root Mean Square Residual (RMR)	<0.080	0.070	Met
Goodness-of-Fit Index (GFI)	>0.900	0.852	Not Met
Adjusted Goodness-of-Fit Index (AGFI)	>0.900	0.830	Not Met
Hoelter's CN (p=0.01)	>200	318	Met
Incremental Fit Indices			
Incremental Fit Index (IFI)	>0.900	0.922	Met
Normed Fit Index (NFI)	>0.900	0.837	Not Met
Comparative Fit Index (CFI)	>0.900	0.921	Met
Tucker Lewis Index (TLI)	>0.900	0.912	Met
Relative Fit Index (RFI)	>0.900	0.819	Not Met
Parsimonious Fit Indices			
Parsimony Adjusted Normed Fit Index (PNFI)	>0.900	0.752	Not Met
Parsimony Adjusted Comparative Fit Index (PCFI)	>0.900	0.828	Not Met

10.7.6 Results of Structural Modelling

The relationships among the constructs were estimated from the structural relationships in the structural model. The relationships were hypothesised as follows:

SCMCON and Constructivism

59. H_1: *SCMCON has a positive significant relationship with SCAFF*
60. H_2: *SCMCON has a positive significant relationship with GRPLN*
61. H_3: *SCMCON has a positive significant relationship with SDL*
62. H_4: *SCMCON has a positive significant relationship with REFTHK*
63. H_5: *SCMCON has a positive significant relationship with INDLN*

SCMCON and Behaviourism (Connectionism)

64. H_8: *SCMCON has a positive significant relationship with REP*
65. H_9: *SCMCON has a positive significant relationship with REINF*
66. H_{10}: *SCMCON has a positive significant relationship with READ*

SCMCON and Cognitive Science (Cognitive Load Theory)

67. H_{11}: *SCMCON has a negative significant relationship with COGLD*
68. H_{12}: *SCMCON has a negative significant relationship with COMPQ*
69. H_{13}: *SCMCON has a negative significant relationship with AUTHPB*
70. H_{14}: *SCMCON has a positive significant relationship with WOKEXP*
71. H_{15}: *SCMCON has a positive significant relationship with COMPPB*

REFTHK and Constructivism

72. H_{16}: *REFTHK has a positive significant relationship with SCAFF*
73. H_{17}: *REFTHK has a non-significant relationship with GRPLN*
74. H_{18}: *REFTHK has a positive significant relationship with SDL*
75. H_{19}: *REFTHK has a positive significant relationship with INDLN*

REFTHK and Behaviourism (Connectionism)

76. H_{22}: *REFTHK has a non-significant relationship with REP*
77. H_{23}: *REFTHK has a non-significant relationship with REINF*
78. H_{24}: *REFTHK has a non-significant relationship with READ*

REFTHK and Cognitive Science (Cognitive Load Theory)

79. H_{25}: *REFTHK has a non-significant relationship with COMPQ*
80. H_{26}: *REFTHK has a non-significant relationship with AUTHPB*

81. H_{27}: *REFTHK has a non-significant relationship with WOKEXP*
82. H_{28}: *REFTHK has a non-significant relationship with COMPPB*

COGLD and Constructivism

83. H_{29}: *COGLD has a negative significant relationship with SCAFF*
84. H_{30}: *COGLD has a non-significant relationship with GRPLN*
85. H_{31}: *COGLD has a non-significant relationship with SDL*
86. H_{32}: *COGLD has a non-significant relationship with REFTHK*
87. H_{33}: *COGLD has a positive significant relationship with INDLN*

COGLD and Behaviourism (Connectionism)

88. H_{36}: *COGLD has a non-significant relationship with REP*
89. H_{37}: *COGLD has a non-significant relationship with REINF*
90. H_{38}: *COGLD has a non-significant relationship with READ*

COGLD and Cognitive Science (Cognitive Load Theory)

91. H_{39}: *COGLD has a positive significant relationship with COMPQ*
92. H_{40}: *COGLD has a positive significant relationship with AUTHPB*
93. H_{41}: *COGLD has a non-significant relationship with WOKEXP*
94. H_{42}: *COGLD has a non-significant relationship with COMPPB*

SDL

95. *SDL has a non-significant relationship with SCAFF*
96. *SDL has a positive significant relationship with GRPLN*
97. *SDL has a positive significant relationship with INDLN*
98. *SDL has a positive significant relationship with READ*
99. *SDL has a non-significant relationship with COMPQ*
100. *SDL has a non-significant relationship with AUTHPB*
101. *SDL has a non-significant relationship with WOKEXP*

SCAFF

102. *SCAFF has a positive significant relationship with GRPLN*
103. *SCAFF has a positive significant relationship with REP*
104. *SCAFF has a positive significant relationship with REINF*
105. *SCAFF has a non-significant relationship with COMPQ*
106. *SCAFF has a non-significant relationship with AUTHPB*
107. *SCAFF has a positive significant relationship with WOKEXP*

REINF

108. *REINF has a positive significant relationship with GRPLN*
109. *REINF has a positive significant relationship with REP*
110. *REINF has a non-significant relationship with COMPQ*

The resulting standardised regression relationships from the structural model are shown in Table 10-18. The results are reported by discussing the hypotheses with each endogenous variable in the model.

Table 10-18: Structural Model Statistics

	Proposed Hypothesis					Regression Estimate	P Level	Rejected/Supported
	SCMCOM and Constructivism							
1	SCMCON	<---	SCAFF	H_1	Positive Significant	0.264	***	Supported
2	SCMCON	<---	GRPLN	H_2	Positive Significant	0.103	0.036	Supported
3	SCMCON	<---	SDL	H_3	Positive Significant	0.063	0.289	Not Supported
4	SCMCON	<---	REFTHK	H_4	Positive Significant	0.129	0.043	Supported
5	SCMCON	<---	INDLN	H_5	Positive Significant	0.359	***	Supported
	SCMCON and Behaviourism (Connectionism)							
6	SCMCON	<---	REP	H_6	Positive Significant	-0.003	0.951	Not Supported
7	SCMCON	<---	REINF	H_7	Positive Significant	0.084	0.075	Not Supported
8	SCMCON	<---	READ	H_8	Positive Significant	0.056	0.313	Not Supported

Table 10-18: Structural Model Statistics (Continued)

	Proposed Hypothesis					Regression Estimate	P Level	Rejected/Supported
	SCMCOM and Cognitive Science (Cognitive Load Theory)							
9	SCMCON	<---	COGLD	H_{9}	Negative Significant	0.035	0.569	Not Supported
10	SCMCON	<---	COMPQ	H_{10}	Negative Significant	-0.121	0.059	Not Supported
11	SCMCON	<---	AUTHPB	H_{11}	Negative Significant	0.041	0.422	Not Supported
12	SCMCON	<---	WOKEXP	H_{12}	Positive Significant	-0.040	0.529	Not Supported
13	SCMCON	<---	COMPPB	H_{13}	Positive Significant	0.109	0.064	Not Supported
	REFTHK and Constructivism							
14	REFTHK	<---	SCAFF	H_{14}	Positive Significant	0.070	0.264	Not Supported
15	REFTHK	<---	GRPLN	H_{15}	Non-significant	-0.010	0.862	Supported
16	REFTHK	<---	SDL	H_{16}	Positive Significant	0.161	0.017	Supported
17	REFTHK	<---	INDLN	H_{17}	Positive Significant	0.458	***	Supported
	REFTHK and Behaviourism (Connectionism)							
18	REFTHK	<---	REP	H_{18}	Non-significant	-0.029	0.583	Supported
19	REFTHK	<---	REINF	H_{19}	Non-significant	0.019	0.707	Supported
20	REFTHK	<---	READ	H_{20}	Non-significant	0.172	0.007	Not Supported
	REFTHK and Cognitive Science (Cognitive Load Theory)							
21	REFTHK	<---	COMPQ	H_{21}	Non-significant	0.072	0.187	Supported
22	REFTHK	<---	AUTHPB	H_{22}	Non-significant	0.055	0.348	Supported
23	REFTHK	<---	WOKEXP	H_{23}	Non-significant	-0.047	0.508	Supported
24	REFTHK	<---	COMPPB	H_{24}	Non-significant	0.027	0.667	Supported
	COGLD and Constructivism							
25	COGLD	<---	SCAFF	H_{25}	Negative Significant	-0.033	0.581	Not Supported
26	COGLD	<---	GRPLN	H_{26}	Non-significant	0.004	0.934	Supported
27	COGLD	<---	SDL	H_{27}	Non-significant	0.017	0.780	Supported
28	COGLD	<---	REFTHK	H_{28}	Non-significant	-0.070	0.292	Supported
29	COGLD	<---	INDLN	H_{29}	Positive Significant	-0.003	0.972	Not Supported
	COGLD and Behaviourism (Connectionism)							
30	COGLD	<---	REP	H_{30}	Non-significant	0.113	0.024	Not Supported
31	COGLD	<---	REINF	H_{31}	Non-significant	-0.131	0.008	Not Supported
32	COGLD	<---	READ	H_{32}	Non-significant	-0.061	0.292	Supported
	COGLD and Cognitive Science (Cognitive Load Theory)							
33	COGLD	<---	COMPQ	H_{33}	Positive Significant	0.599	***	Supported
34	COGLD	<---	AUTHPB	H_{34}	Positive Significant	-0.038	0.482	Not Supported
35	COGLD	<---	WOKEXP	H_{35}	Non-significant	-0.024	0.721	Supported
36	COGLD	<---	COMPPB	H_{36}	Non-significant	0.218	***	Not Supported
	SDL							
37	SDL	<---	SCAFF	H_{37}	Non-significant	-0.011	0.852	Supported
38	SDL	<---	GRPLN	H_{38}	Positive Significant	0.171	0.002	Supported
39	SDL	<---	INDLN	H_{39}	Positive Significant	0.339	***	Supported
40	SDL	<---	READ	H_{40}	Positive Significant	0.044	0.462	Not Supported
41	SDL	<---	COMPQ	H_{41}	Non-significant	0.258	***	Not Supported
42	SDL	<---	AUTHPB	H_{42}	Non-significant	0.385	***	Not Supported
43	SDL	<---	WOKEXP	H_{43}	Positive significant	-0.162	0.002	Not Supported
	SCAFF							
44	SCAFF	<---	GRPLN	H_{44}	Positive Significant	0.209	***	Supported
45	SCAFF	<---	REP	H_{45}	Positive Significant	0.224	***	Supported
46	SCAFF	<---	REINF	H_{46}	Positive Significant	0.219	***	Supported
47	SCAFF	<---	COMPQ	H_{47}	Non-significant	-0.149	0.003	Not Supported
48	SCAFF	<---	AUTHPB	H_{48}	Non-significant	0.097	0.060	Supported
49	SCAFF	<---	WOKEXP	H_{49}	Positive Significant	0.121	0.028	Supported
	REINF							
50	REINF	<---	GRPLN	H_{50}	Positive Significant	0.219	***	Supported
51	REINF	<---	REP	H_{51}	Positive Significant	0.235	***	Supported
52	REINF	<---	COMPQ	H_{52}	Non-significant	0.120	0.007	Not Supported

10.7.6.1 Hypotheses with SCMCON

All the five constructs from constructivism were hypothesised to have a positive significant relationship with SCMCON. Four out of the 5 hypotheses supported and these are SCAFF (R^2=0.264; p=0.000), GRPLN (R^2=0.103; p=0.036), REFTHK (R^2=0.129; P=0.043) and INDLN (R^2=0.359; p=0.000). SDL had a non-significant relationship (R^2=0.063; p=0.289) contrary to the hypothesis. All the three constructs from behaviourism were hypothesised to have positive significant relationships with SCMCON. However, all three hypotheses were not significant at 95% confidence interval (REP (R^2=-0.003; p=0.951), REINF (R^2=0.084; p=0.075) and READ (R^2=0.056; p=0.313)). Three out of the five constructs from cognitive science were hypothesised to have negative significant relationships with SCMCON while the remaining two were hypothesised to have positive significant relationships. All five hypotheses were not supported. The constructs hypothesised to have negative significant relationships were COGLD (R^2=0.035; p=0.569), COMPQ (R^2=-0.121; p=0.059) and AUTHPB (R^2=0.041; p=0.422). The constructs hypothesised to have positive significant relationships were WOKEXP (R^2=-0.040; p=0.529) and COMPPB (R^2=0.0.109, p=0.064).

10.7.6.2 Hypotheses with REFTHK

From constructivism, SCAFF, SDL and INDL were hypothesised to have positive significant relationships with REFTHK while GRPLN was hypothesised to have a non-significant relationship. Two out of the three hypotheses expected to have positive significant relationships were supported and these are SDL (R^2=0.161; p=0.017) and INDLN (R^2=0.458; p=0.000) while SCAFF did not significantly associate with REFTHK at 95% CI ((R^2=0.070; p=0.264). In tandem with the hypothesis, GRPLN had a non-significant relationship with REFTHK (R^2=-0.010; p=0.862). All three constructs from behaviourism were hypothesised to have non-significant relationships with REFTHK and two of the hypotheses were supported and these are REP (R^2=-0.029; p=0.583) and REINF (R^2=0.019; p=0.707). Contrary to expectation, READ had a significant relation with REFTHK (R^2=0.172; p=0.007). All the four constructs from cognitive science were also hypothesised to have non-significant relationships with REFTHK and all the hypotheses were supported (COMPQ (R^2=0.0.072; p=0.187), AUTHPB (R^2=0.055; p=0.348), WOKEXP (R^2=-0.047; p=0.508) and COMPPB (R^2=0.0.027; p=0.667)).

10.7.6.3 Hypotheses with COGLD

SCAFF was hypothesised to have a negative significant relationship with COGLD. While the relationship was negative, it was not significant (R^2=-0.033; p=0.581). GRPLN, SDL and REFTHK were hypothesised to have non-significant relationships with COGLD and both hypotheses were supported (R^2=0.004; p=0.934, R^2=0.0.017; p=0.780 and R^2=-0.070; p=0.292 respectively). INDLN was hypothesised to have a positive significant relationship with COGLD and the hypotheses was not supported (R^2=-0.003; p=0.972). All three constructs from behaviourism were hypothesised to have non-significant relationships with COGLD and two of the hypotheses were not supported. Contrary to expectation, REP and REINF were significantly associated with COGLD (R^2=0.113; p=0.024 and R^2=-0.131; p=0.008). The non-significant hypotheses with READ was supported (R^2=-0.061; p=0.292). From cognitive science, COMPQ and AUTHPB were hypothesised to have positive significant relationships with COGLD while WOKEXP and COMPPB were hypothesised to have non-significant relationships. COMPQ was positively significantly associated with COGLD (R^2=0.599; p=0.000) in tandem with the hypothesis while AUTHPB had a non-significant association (R^2=-0.038; p=0.482) which is against the hypothesis. WOKEXP had a non-significant relationship with COGLD (R^2=-0.024; p=0.721) as hypothesised while COMPPB had a significant relationship (R^2=0.218; p=0.000) contrary to expectation.

10.7.6.4 Hypotheses with SDL

SCAFF was hypothesised to have a non-significant relationship with SDL and the hypothesis was supported (R^2=-0.011; p=0.852). GRPLN was hypothesised to have a positive significant relationship with SDL and the hypothesis was supported (R^2=0.171; p=0.002). INDLN was hypothesised to have a positive significant relationship with SDL and the hypothesis was supported (R^2=0.339; p=0.000). READ was hypothesised to have a positive significant relationship with SDL and the hypothesis was not supported. Contrary to expectation, READ had a non-significant relationship with SDL (R^2=0.044; p=0.462). COMPQ and AUTHPB were hypothesised to have non-significant relationships with SDL and both the hypotheses were not supported (R^2=0.258; p=0.000, R^2=0.385; p=0.000). WOKEXP was hypothesised to have a positive significant relationship with SDL and the hypothesis was also not supported. Contrary to the hypotheses WOKEXP had a negative significant relationship with SDL (R^2=-0.162; p=0.002).

10.7.6.5 Hypotheses with SCAFF

GRPLN, REP and REINF were hypothesised to have positive significant relationships with SCAFF and all three hypotheses were supported (R^2=0.209; =0.000, R^2=0.224; p=0.000 and R^2=0.219; p=0.000 respectively). COMPQ and AUTHPB were hypothesised to have non-significant relationships with SCAFF. Contrary to expectation, COMPQ had a negative significant relationship (R^2=-0.149; p=0.003) with SCAFF while the hypothesis with AUTHPB was supported (R^2=0.097; p=0.060). WOKEXP was hypothesised to have a positive significant relationship with SCAFF and the hypothesis was supported (R^2=0.121; p=0.028).

10.7.6.6 Hypotheses with REINF

GRPLN and REP were hypothesised to have positive significant relationships with REINF and both hypotheses were supported (R^2=0.219; p=0.000 and R^2=0.235; p=0.000 respectively). COMPQ was hypothesised to have a non-significant relationship with REINF. Instead, the relationship was significant (R^2=0.120; p=0.007).

10.7.6.7 Indirect Relationships

While four constructs had direct relationships with SCMCON, namely INDLN, SCAFF, REFTHK and GRPLN, some constructs which did not directly influence schema construction indirectly contributed to SCMCON. REP, REINF, COMPQ and WOKEXP had indirect relationships with SCMCON through SCAFF while READ and SDL had indirect relationships through REFTHK. AUTHPB, COMPQ, GRPLN and WOREXP had indirect relationships with REFTHK through SDL.

10.8 Summary of Key Findings

The significant findings from the research with non-significant relationships omitted are shown in Table 10-19 and in Figure 10-4. Some significant relationships which have minor impact on variables have also been omitted. Also, some significant indirect relationships which have constructs which already have direct significant relationships have been omitted.

Table 10-19: Summary of Key Findings

Construct	Regression Estimate in Percentage				Relationship
SCMCON					
• INDLN	36%				Direct influence on SCMCON
• SCAFF	26%				Direct influence on SCMCON
o REP		22%			Indirect influence on SCMCON
▪ COGLD			11%		Indirect influence on SCAFF
o REINF		22%			Indirect influence on SCMCON
▪ COGLD			-13%		Indirect influence on SCAFF
o GRPLN		21%			Indirect influence on SCMCON
o COMPQ		-15%			Indirect influence on SCAFF
▪ COGLD				60%	Indirect influence on SCAFF
o WOKEXP		12%			Indirect influence on SCMCON
• REFTHK	13%				Direct influence on SCMCON
o INDLN		46%			Indirect influence on SCMCON
o READ		17%			Indirect influence on SCMCON
o SDL		16%			Indirect influence on SCMCON
▪ AUTHPB			39%		Indirect influence on REFTHK
▪ COMPQ			26%		Indirect influence on REFTHK
➢ COGLD				-60%	Indirect influence on SDL
▪ WOKEXP			-16%		Indirect influence on REFTHK
• GRPLN	10%				Direct influence on SCMCON

The selected relationships have been omitted in order to highlight only the very important antecedents to effective teaching and learning emanating from the research and how they are related. Table 10-19 show important direct and indirect relationships including negative relationships while Figure 10-4 does not show negative relationships except for the constructs which lead to high cognitive loading. Figure 10-4 and Table

10-19 highlights that INDLN, SCAFF, REFTHK and GRPLN directly influence SCMCON in that order of importance. REP, REINF, COMPQ, WOREXP, READ and SDL indirectly influence SCMCON through a mediator while COGLD, COMPQ and AUTHPB indirectly influence SCNCOM through two mediators.

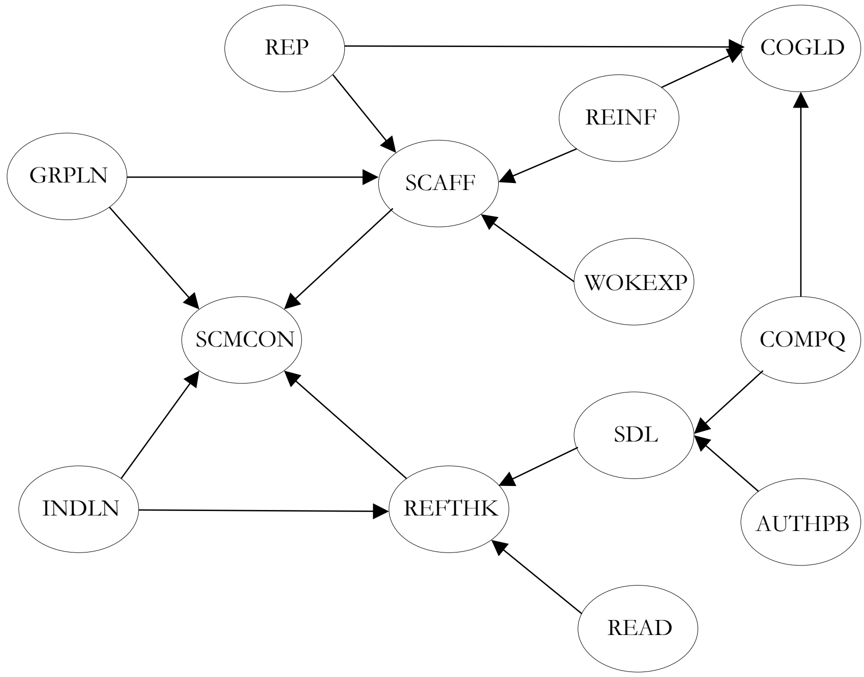


Figure 10-5: Conceptual Model of Key Findings

10.9 Discussion of Results

The discussion of the results is done considering each endogenous variable in the conceptual model with its associated hypotheses. A summary of the discussion under each endogenous is provided before a detailed discussion of each hypothesis. Indirect relationships are discussed after all direct relationships. Indirect relationships are discussed because constructs which are initially highlighted as having not direct influence on the target variables may still have an influence on another variable indirectly.

10.9.1 Schema Construction

Of the thirteen concepts hypothesised to have direct positive significant relationships with schema construction, only four were supported. The four concepts are scaffolding, group learning, individual learning and reflective thinking. All the four constructs are from the theory of constructivism. None of the constructs from behaviourism and cognitive science were found to have positive significant relationships with schema construction. This can be attributed to the fact that schema construction is a metacognitive activity (Chater and Vitányi, 2003). Therefore, activities which do not directly lead students to engage in metacognition do not directly lead to schema construction while those which are more direct metacognitive activities do. Scaffolding, reflective thinking, group learning and individual learning are all implicitly metacognitive concepts in nature. They directly involve students in reflecting on what they are working on or with. Consequently, students think critically about what they are studying and think reflectively about the new knowledge and how it connects and relates with what they already know. Therefore, while reflective thinking ranks second among the four constructs which directly predict schema construction very important and cardinal and is perhaps the most significant ingredient in achieving schema construction.

This does not automatically mean that the other concepts from behaviourism and cognitive science are not relevant to schema construction and learning. While they may not have direct relationships with schema construction, they may have indirect relationships which underscore their importance and relevance to schema construction and these will be discussed later.

10.9.1.1 Schema Construction and Constructivism

Based on the theory of constructivism and previous research findings, it was expected that scaffolding, group learning, reflective thinking and individual learning would directly contribute to schema construction such as, for example, Hmelo-Silver *et al.* (2007), Kori *et al.* (2014), Lazonder and Harmsen (2016), Mäeots and Pedaste, (2014), Pedaste and Sarapuu (2006), Scanlon *et al.* (2011) and Spronken-Smith *et al.* (2008). From the four constructs, individual learning has the largest effect on schema construction followed by scaffolding, reflective thinking and then group learning. Because schema construction is concerned with the individual creation of own knowledge (Lyens *et al.,* 2009; Baviskar *et al.,* 2009; Richardson, 2003; Marin *et al.,* 2000, Kivunja, 2014), it is not surprising that individual learning has the largest effect on schema construction. When students work individually, they have the opportunity to make meaningful connections between any knew knowledge and what they already know and so create lasting schemata. Scaffolding has the second largest effect on schema construction after learning. This is in tandem with several other studies which show that learning outcomes are improved when learning activities are scaffolded (for example, Lazonder and Harmsen, 2016). Reflective thinking also makes a fairly large direct contribution to schema construction and several studies have shown that it is very important to academic performance and learning generally (for example, Kember *et al.*, 2000; Sánchez-Martí *et al.*, 2018). It directly contributes to reflective thinking because reflecting on any new knowledge in relation to existing knowledge is required to make sense of the new knowledge and subsequently connect it with existing schemata (Kori *et al.*, 2014; Sánchez-Martí *et al.*, 2018). Group learning contributes to schema construction because working in groups allows students to compare their understanding and learn from peers and therefore create lasting associations of the new knowledge (Cheng *et al.*, 2014; de Hei *et al.*, 2016; Wong, 2018). This is based on the theory of social constructivism which suggests that know is also socially constructed.

It is surprising that self-directed learning does not have a direct influence on schema construction especially since several studies have highlighted the importance of self-directed learning to academic achievement. However, considering that schema construction is concerned with creating knowledge structures stored in long-term memory, it is understandable that self-directed learning would not in itself lead to schema construction. Simply because a student directs their own learning does not guarantee that they will create lasting and meaningful knowledge structures. Self-directed learning coupled with critical reflection on the study material would lead to schema construction. Therefore, it is very likely that the influence self-directed learning on schema construction is indirect through reflective thinking. That is to say that only when students engage in reflective thinking while engaging in self-directed learning would they achieve schema construction.

10.9.1.2 Schema Construction and Behaviourism (Connectionism)

While the theory of connectionism posits that repetition, reinforcement and readiness are important for learning, they do not directly contribute to schema construction. The results suggest that merely repeating lessons or key points to students, reinforcing students learning activities or when students are emotionally, physically and mentally ready to learn do not directly lead to the creation of schemata. While previous studies found that repetition is an important antecedent to learning (for example, Axelsson and Horst, 2014) these studies were based on a sample of very young children (for example, Szmalec *et al.*, 2012). Therefore, it is likely that repetition directly contributes to learning or schema construction in young children learning fairly simple things. The results suggest that in more advanced learners, repetition does lead directly to schema construction. This could be because the body of knowledge the students have to learn is always quite very large and the limited amount of repetition allowed for does not significantly help with creating lasting associations between any new and existing knowledge. Reinforcement also does not directly contribute to schema construction even though the theory of connectionism suggests that it is an important antecedent to learning. While students will be encouraged to continue with a particular course of action or change to a more desirable one depending on the reinforcement feedback they receive, the reinforcement in itself will not lead directly to making connections between any new and existing knowledge. The same argument suffices for readiness. Being mentally, physically and emotionally ready to learn does not in itself lead directly to students being able to connect new and existing knowledge. Considering that behaviourism is not a science of the mind even though it acknowledges the role of cognition on behaviour (Kohlenberg and Tsai, 2000), it is therefore understandable that none of the constructs from behaviourism have a direct influence on schema construction, which is a cognitive activity.

10.9.1.3 Schema Construction and Cognitive Science (Cognitive Load Theory)

Based on the cognitive load theory and research evidence (for example, Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke *et al.*, 2009; Sweller, 2006), it was expected that cognitive loading would have a negative significant relationship with schema construction. Complex questions and authentic questions were also expected to have negative significant relationships with schema construction because, based on the cognitive load theory and research evidence, they are expected to lead to high levels of cognitive loading. However, the relationships, save for with complex questions, were positive and were all not significant at 95% confidence interval. The results suggest that cognitive loading does not directly impede schema construction and consequently, complex questions and authentic problems also do not directly impede schema construction. This is surprising and further suggests that the process of linking any new information in working memory with knowledge already stored in long term memory is not significantly impeded when the working memory of students is overloaded. Perhaps this is because cognitive loading does not persist but is localised and limited to the time period when the students are exposed to too much information at once. Schema construction on the other hand is not necessarily instantaneous and limited to the time period when students are exposed to new information. It is a process which requires reflecting on the new information in relation to already existing knowledge and realising the connections which exist between the new information and knowledge already possessed. It is therefore plausible that cognitive loading in fact impedes learning but during the periods when the students are experiencing high level of cognitive loading. The process of schema construction on the other hand is not limited to the time period when students are exposed to new information. This argument is in tandem with the way the concepts of cognitive loading and schema construction were conceptualised in this research which was as the extent to which the students felt they were cognitively overloaded and the extent to which they were able to and were encouraged to engage in schema construction during the semester. Research which found that cognitive loading impeded learning were based on the observation of cognitive loading during periods of time when students were exposed to specific learning tasks (for example, Hsieh, Hsu and Huang, 2016). Therefore, the finding in this research suggests that the effect of cognitive loading on learning is limited to the time period when the students experience high levels of cognitive loading and that the negative effect of cognitive loading on learning wears off with time. This then also explains why complex questions and authentic questions also did not significantly impede schema construction. These questions would create high levels of cognitive loading during specific periods of time and the levels of the consequent cognitive loading would recede with time as students became familiar with the questions. However, while the relationship between schema construction and schema construction was not significant at 95% confidence interval, it was mildly negative and significant at say 90% confidence interval. Because question complexity was subjectively measured as the extent to which the students felt that questions given to them were complex, the resulting variability as self-perceived measures of complexity and the genuine variety in the different levels of question complexity may reduce the resulting confidence interval with which the results may be expected. Therefore, it is plausible that complex questions in fact, to an extent, impede schema construction while authentic problems do not.

Worked examples and completion problems were expected to have positive significant relationships with schema construction. This hypothesis was based on the cognitive load theory and research evidence which reported improved academic performance attributed to worked examples and completion problems (for example, Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke *et al.*, 2009; Sweller, 2006). However, this research found no significant relationship between schema construction and the use of worked examples and completion problems. These findings can be attributed to the differences in the way the concepts were conceptualised. Previous studies were experimental in nature and investigated the phenomenon for brief period of time (for example, McLaren, van Gog, Ganoe and Yaron, 2016b) while this research was based on the perception of students in relation to an entire semester. Considering that schema construction and so learning is a cognitive development process, it is likely that the use of worked examples and completion problems could lead to some level of linking of any new information with existing knowledge. Therefore, the finding that worked examples and completion problems do not lead to schema construction may be as a result of the manner in which the concepts of worked examples and completion problems were conceptualised and operationalised.

10.9.2 Reflective Thinking

Of the three constructs hypothesised to have direct positive significant relationships with reflective thinking, two were supported. Eight constructs were hypothesised to have non-significant relationships with reflective thinking and seven were supported. Being a cognitive process, reflective thinking was expected to be associated with constructs which directly influence cognitive processes. The two constructs which directly predicted reflective thinking were self-directed learning and individual learning because they allow students the opportunity to engage with study material and think reflectively about it. The remaining constructs do not directly influence the cognitive process of reflective thinking because they are not themselves cognitive in nature. However, this does not suggest that these concepts which do not directly influence reflective thinking are not relevant to learning. While they may not have direct relationships with reflective thinking, they may have indirect relationships which influence learning. Indirect relationships will be discussed later.

10.9.2.1 Reflective Thinking and Constructivism

Based on the theory of constructivism and research evidence, it was expected that scaffolding, individual learning and self-directed learning would have positive significant relationships with reflective thinking while group learning was expected to have a non-significant relationship. The hypotheses with group learning, individual learning and self-directed learning were supported while the relationship with scaffolding was not. The findings suggest that scaffolding does not lead to better reflective thinking. While it was expected that providing additional support when students struggle with a learning task would lead to a breakthrough in the learning task in such a way that they would be able to make connections with knowledge they already possess. It appears that it is not guaranteed that this would happen. Group learning does not lead to reflective thinking because, during group exercises, there is little opportunity for students to reflect on what they are working on due to the group dynamics. Self-directed learning and individual learning lead to reflective thinking because when students engage with the learning material at an individual level, they have the opportunity to interrogate the learning material and make connections between any new information they encounter and what they already know and understand.

10.9.2.2 Reflective Thinking and Behaviourism (Connectionism)

Repetition, reinforcement and readiness were expected to have non-significant relationships with reflective thinking. This is because they are concerned with behaviour rather than cognitive processes. The findings support the hypotheses with repetition and reinforcement while readiness unexpectedly had a significant relationship with reflective thinking. Therefore, merely repeating aspects of a lesson is not likely to help students to think reflectively. Likewise, reinforcing students learning activities by acknowledging, encouraging and applauding desirable actions does not cause them to think reflectively. This is because repetition and reinforcement do not affect the cognitive process of reflective in a way that could be contributory. The same was expected of readiness. Merely being prepared emotionally, physically and mentally to learn was not expected to have a fundamental effect on the cognitive process of reflective thinking. It is more likely that readiness has a spurious relationship with reflective whereby students who, by other factors, engage in reflective thinking, are also the ones who exhibit readiness to learn.

10.9.2.3 Reflective Thinking and Cognitive Science (Cognitive Load Theory)

Types of questions administered to students were not expected to be associated with reflective thinking. Regardless of the level of question complexity, it was expected the questions themselves would not have any fundamental effect on whether students would engage in reflective thinking or not. The findings support this postulation. Therefore, whether students are subjected to complex questions, authentic question, worked examples or completion problems will not have an influence on their ability or practice of reflective thinking. This is because the type of question administered to students, on its own, is not likely to influence the cognitive function of reflective thinking.

10.9.3 Cognitive Loading

Contrary to expectation, completion problems were found to induce cognitive loading while reinforcement was found to reduce it. Complex questions increase cognitive loading which is consistent with other findings such as, for example, Hadie and Yusoff (2016), while authentic problems do not consistently increase cognitive loading. Therefore, when complex questions are administered, appropriate reinforcement should be used to help reduce the levels of cognitive loading. Otherwise, problems based on authentic real world problems should be preferred in order to avoid high levels of cognitive loading.

10.9.3.1 Cognitive Loading and Constructivism

Based on the cognitive load theory and research evidence, it was expected that group learning, self-directed learning and reflective thinking would have non-significant relationships with cognitive loading. Scaffolding was expected to have a negative significant relationship with cognitive loading while individual learning was expected to have a positive significant relationship. Consistent with theory, group learning, self-directed learning and reflective thinking had non-significant relationships with cognitive loading. This means that learning in groups, engaging in self-directed learning and thinking reflectively do not induce significant levels of cognitive loading. This is because none of the three concepts relies on committing extensive amounts of information in working memory which is what induces cognitive loading. Learning in groups does not rely on holding large chunks of information in working memory but rather interacting with peers and comparing ones understanding with others. Self-directed learning allows the student to moderate how much information to engage with at a time and to avoid overloading their cognitive capacity. When thinking reflectively, students assess and evaluate any information relative to what they already know and understand. This ensures against overloading working memory since any new information is quickly linked with information in long-term memory. Contrary to expectation, the hypothesis with scaffolding was not supported by the results. While the association was negative, it was not significant. This means that scaffolding does not consistently reduce cognitive loading as expected. Based on theoretical considerations, it was expected that giving students educational support with aspects of a learning task which they were struggling with would help free up some working memory and so reduce cognitive loading. However, results suggest that this may not always be the case. Also contrary to expectation, the hypothesis with individual learning was not significant. It was expected that engaging in individual learning would lead to increased cognitive loading because it would require use of some memory capacity. The findings suggest that engaging in individual learning does not increase the levels of cognitive loading. This may be because individual learning would have some aspects of self-directed learning and so students would be able to moderate the extent of the individual learning. Such moderation of learning at an individual level could be the reason why engaging in individual learning does not lead to increased cognitive loading.

10.9.3.2 Cognitive Loading and Behaviourism (Connectionism)

Repetition, reinforcement and readiness were expected to have non-significant relationships with cognitive loading. The hypothesis with readiness was supported. Therefore, as expected, being emotionally, physically and mentally ready to learn is not associated with the extent of cognitive loading which a student will experience. It was expected that repetition would not increase cognitive loading because it would work to constantly remind students of important aspects of the topic and so create a more lasting impression in long-term memory. Contrary to expectation, repetition had a significant relationship with cognitive loading. This means that repeating aspects of a lesson is likely to lead to higher levels of cognitive loading. The results suggest that repetition would in fact increase the burden on working memory and lead to higher levels of cognitive loading. It is worth noting, however, that the increase in cognitive loading, while significant, is quite very small (about 2% increase per unit increase in repetition). Reinforcing students learning activities was not expected to lead to cognitive loading because acknowledging, encouraging and applauding desirable actions should not burden working memory. However, contrary to expectation, reinforcement had a negative significant relationship with cognitive loading. This means that reinforcing student learning activities, in fact, reduces the extent of cognitive loading. This could be a result of students being validated by the reinforcement when they are doing the right thing.

10.9.3.3 Cognitive Loading and Cognitive Science (Cognitive Load Theory)

Based on the cognitive load theory and research evidence, complex questions and authentic problems were expected to have positive significant relationships with cognitive loading while worked examples and completion problems were not. The hypothesis with complex questions was significant while that with authentic problems was not. Consistent with theory and with research evidence, complex questions lead to higher levels of cognitive loading such as, for example, Hadie and Yusoff (2016). Contrary to expectation, authentic problems do not consistently lead to higher levels of cognitive loading. It was expected that due to the complex nature of problems based on real world scenarios and their interdisciplinary nature, they would lead to higher levels of cognitive loading. However, findings suggest that students are not unduly cognitively burdened by problems based on real world scenarios. As expected, worked examples do not induce significant amounts of cognitive loading. This is consistent with theory and research evidence such as, for example, Paas and van Gog (2006); Rourke and Sweller (2009); Schwonke *et al.*, (2009); Sweller (2006). However, contrary to expectation, findings suggest that completion problems lead to higher levels of cognitive loading. Because in completion problems, part of the solution is already worked out for the students so that they may only compete the remaining part, based on the cognitive load theory, it is argued that the consequent cognitive loading is reduced (Mihalca *et al.*, 2015). The findings here are contrary to other research findings. This could be attributed to the fact that completion problems were rarely used with the research sample. The average summated score for the construct measuring the use of completion problems was the lowest of all the constructs at 2.769 with a standard deviation of 0.950 meaning that the research respondents indicated that the completion problems were administered to them on average either sometimes or seldom. Based on this, it cannot be stated with virtual certainty that completion problems actually lead to higher levels of cognitive loading.

10.9.4 Self-directed Learning

Group learning, individual learning, readiness and worked examples were expected to have positive significant relationships with self-directed learning while scaffolding, complex questions and authentic problems were expected to have non-significant relationships. The hypotheses with group learning, individual learning and worked examples were supported by the results. This means that group learning, individual learning and worked examples encourage students to engage in self-directed learning. Learning in groups allows students to engage with and learn from peers and to compare their understanding. The group interaction would expose students to learning material they do not know or understand but which they will perceive as being relevant. Realising that some peers know or have a different, more or better understanding is likely to motivate students to engage in self-directed learning so as to catch up with the peers. This could take place either within the group setting or subsequent to the group interaction. Learning individually allows the students to engage more deeply with study material and discover other and deeper aspects to the topic beyond what they were initially exposed to. Subsequently, students engage in self-directed learning to explore the topic further. Giving students worked examples encourages them to engage in self-directed learning because the students will perceive the examples as being vital and relevant to their learning. Subsequently, the students will go through the examples at their convenience when they choose to engage in self-directed learning. Also, worked examples are fairly easy to understand and so students will be encouraged to study them and so engage in self-directed learning. It is likely that the underlying reason why group learning, individual learning and worked examples lead to self-directed learning is that they reveal learning material which students perceive as being relevant to their course or module.

The expectation that readiness does would lead to students engaging in self-directed learning was based on the argument that students who are mentally, emotionally and physically prepared to learn would extend their learning readiness beyond the class and engage in self-study more than those who are less ready for learning. The results contradict this expectation and suggest that learning readiness does not translate to a larger aptitude for extra learning in the form of self-directed learning. This could be because, regardless of the aptitude for learning readiness, students will only engage in self-directed learning when they identify learning material which they perceive as being relevant to the course or module. In this case, the aptitude for learning readiness is not related to any kind of learning material which students may perceive as being relevant.

The hypothesis that scaffolding would have a non-significant relationship with self-directed learning was based on the argument that merely giving students educational support with aspects of a learning task which they are struggling with would not necessary lead them to engage in self-directed learning outside of the classroom environment. The results support this argument. Therefore, scaffolding does not encourage students to engage in self-directed learning. The hypotheses that complex questions and authentic problems would not lead to self-directed learning were based on the argument that because of the inherent level of difficulty associated with such types of problems, students would not engage with them. However, both hypotheses with complex questions and completion problems with self-directed learning were significant. This means that both complex questions and authentic problems lead students to engage in self-directed learning. This can be attributed to that fact that students do not have a choice about whether or not to respond to assessment questions. Therefore, regardless of the level of complexity of the question, they are obliged to attend to the question. And when the question is provided without sufficient information to complete the task without further reading, the students are obliged to engage in self-directed learning to fill in the missing information and complete the task. Therefore, complex questions and authentic problems being associated with self-directed learning is most likely a consequence of the fact that students need to complete the tasks and not because of the question complexity. This argument resonates with the finding that worked examples also lead to self-directed learning. It may well be that the students engaged in self-directed learning not so much because of the type of questions presented to them but rather because they had to complete the tasks administered to them but were provided insufficient information to do so without engaging in some self-directed learning. Basing on this argument, it is also possible that all the constructs which were found to be associated with self-directed learning, namely group learning, individual learning, complex questions, authentic questions and worked examples, were associated with self-directed learning because students did not have sufficient information to compete which ever tasks they were engaging in without having to engage in some self-directed learning.

10.9.5 Scaffolding

Group learning, repetition, reinforcement and worked examples were expected to have positive significant relationships with scaffolding. All four hypotheses were supported. This means that group learning, repetition, reinforcement and worked examples work to scaffold student learning experience. This is because when students work in groups they help each other with tasks which may be problematic for some students and this acts as a scaffold for students who struggling. This finding is supported by other studies which have underscored the importance of group learning such as, for example, Cheng *et al.*, (2014); de Hei *et al.*, (2016); Wong (2018). Repeating key lessons also works to help students to focus on the key issues of a lesson and so works to provide educational support especially to students who are struggling by limiting their area of focus. Reinforcement works to scaffold students by reassuring them when they are doing the right and alerting them when they are not. Because of their tendency to coach students to solve similar problems, worked examples are an educational support for students struggling with a learning task and so they provide scaffolding.

Complex questions and authentic problems were expected to have non-significant relationships with scaffolding. The hypothesis with authentic problems was supported while the one with complex questions was not. Therefore, authentic problems do not act as educational scaffolds for students. Contrary to expectation, complex questions had a negative significant relationship with scaffolding. This means that complex questions actually interfere with scaffolding. Based on the negative association, this finding also shows that when students were administered with questions which they perceived as being complex, they also felt that they were not provided with appropriate additional support to cope with the questions. Therefore, when complex questions are administered, students need to be provided with scaffolding to cope.

10.9.6 Reinforcement

Group learning and repetition were expected to have positive significant relationships with reinforcement while complex questions were expected to have a non-significant relationship. The hypotheses with group learning and repetition were supported. This means that group learning and repetition work to reinforce the learning activities of students. This is because when working in groups, students encourage each other and this works as a form of reinforcement. Repeating key points or lessons also works to reinforce the understanding of students.

10.9.7 Indirect Relationships

Only four constructs directly predicted schema construction and these are individual learning, scaffolding, reflective thinking and group learning. Some constructs which did not directly predict schema construction had an indirect relationship with schema construction. The indirect relationships mean that even when these constructs did not have a direct effect on schema construction, they still affect schema construction through their influence of the variables which directly influences schema construction. Repetition, reinforcement, complex questions and worked examples had indirect relationships with schema construction through scaffolding. This means that each of the five constructs has an influence in schema construction, albeit through scaffolding. By influencing scaffolding, repetition, reinforcement, complex questions and worked examples influence schema construction because schema construction is influenced by scaffolding. Because the construct of complex questions has a negative relationship with repetition, it indirectly adversely affects schema construction by negatively affecting scaffolding while repetition, reinforcement, group learning and worked examples positively indirectly influence schema construction. Readiness and self-directed learning had indirect relationships with schema construction through reflective thinking. Therefore, while repetition, reinforcement, readiness, self-directed learning, complex questions and worked examples did not have direct effects on schema construction, they have and influence on it albeit indirectly. Therefore, these constructs are also fairly important in determining schema construction.

Other indirect relationships affected predictors of schema construction rather than schema construction itself. Authentic problems, complex questions, group learning and worked examples had indirect relationships with reflective thinking through self-directed learning. This means that while these four constructs did not directly affect reflective thinking, by influencing self-directed learning, which directly influenced reflective thinking, they indirectly contributed to reflective thinking. Considering that worked examples had a negative influence on self-directed learning, it therefore has a negative indirect effect on reflective thinking.

10.9.8 Chapter Summary

This chapter presented the results, the analysis of the results and the discussion of the findings of the research. prior to the analysis of the results, the data were screened to identify and deal with responses with missing data, outliers, extreme values and disengaged responses. Subsequently, the demographic information was presented and showed that the sample, notwithstanding being conveniently selected, was fairly representative of the population of interest. Exploratory factor analysis was then performed to determine the factorial structure of the research constructs and subsequently evaluate reliability and validity of the research scales. Scales which failed to factor as hypothesised *a posteriori* and subsequently exhibited poor reliability and validity were omitted from subsequent analysis. The remaining scales exited good reliability and validity and were subsequently analysed using structural equation modelling. After appropriate model refinement, confirmatory factor analysis indicated that the refined conceptual model was a good fit to the empirical data. The structural model also exhibited a good fit to the empirical data.

The results of the structural model show that learning individually combined with learning in groups and scaffolding students learning activities and students being able to engage in reflective thinking are the most important factors for effective teaching and learning. Repetition, reinforcement, readiness, self-directed learning and providing worked examples are also important for effective learning. Results also show that cognitive loading should be an important consideration in curriculum design. Complex questions induce high levels of cognitive loading but also encourage self-directed learning.

The results suggest that individual learning, scaffolding, reflective thinking and group learning, in that order of importance, are fundamental to schema construction. Therefore, in order to promote schema construction, and so effective learning among, individual and group learning should be encouraged while guiding students to habitually reflect on what they are learning and appropriately scaffolding them when they encounter difficulty. Repetition, reinforcement, complex questions and worked examples are also important to schema construction because they indirectly influence it by influencing scaffolding. Repetition, reinforcement and worked examples scaffold learning activities, while complex questions stifle scaffolding and subsequently schema construction. Therefore, key learning points should be repeated and appropriate actions should be appropriately reinforced and students should be provided with worked examples especially for learning tasks which they find challenging. On the other hand, because questions which are perceived as being complex negatively impact scaffolding, they should be more strongly scaffolded to council out their negative effect on scaffolding. Also, complex questions induce a fairly large amount of cognitive loading. Strongly scaffolding the complex questions may also reduce the cognitive loading while reinforcing complex learning tasks will almost certainly reduce the cognitive loading. Readiness and self-directed learning are also important to schema construction since they also indirectly influence schema construction through reflective thinking. Therefore, students should be encouraged to prepare for class physically mentally and even emotionally. Self-directed learning should be encouraged in order to improve reflective thinking and subsequently, schema construction. Authentic problems, complex questions and worked examples are important for reflective thinking because they influence self-directed learning. While authentic problems and complex problems promote reflective thinking, worked examples impede it. Therefore, to promote self-directed learning and subsequently reflective thinking, assessment problems should be based on real world scenarios or questions which are perceived as being complex. However, it is important to appropriately scaffold and reinforce the students when the tasks are perceived as being complex in order to reduce the consequent cognitive loading.

CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

11.1 Introduction

This research sought to establish the most appropriate way to educate students of construction programmes in view of the criticisms against the quality of university graduates from construction programmes. In pursuing this objective, the research identified antecedents to effective teaching and learning espoused by three different theories of learning. Using empirical evidence, the research established the most important of the antecedents to teaching and learning based on their contribution to schema construction. The important antecedents to teaching and learning will be incorporated into a recommended IBL curriculum model for effectively teaching construction programmes. The curriculum model is based on IBL because, based on extant literature, it was established that IBL is significantly better at producing construction graduates who are closer to what the construction industry is looking for as compared to the traditional didactic teaching paradigm. This chapter highlights the research questions and summarises the keys findings of the research. The chapter then draws conclusions based on the findings and presents the recommended curriculum model for effectively teaching construction programmes. The chapter also makes recommendations for future research.

11.2 Research Questions, Aim and Objectives

The research addressed the central question of "What is the most appropriate way to educate students of construction programmes". Arising from this questions, the aim of the research was to establish the most appropriate way to educate students of construction programmes. Therefore, the main objective in achieving this research aim was to identify important antecedents to teaching and learning from theories of learning and to integrate them into an IBL curriculum appropriate for construction programmes. The specific questions addressed were:

1. What should be considered in the design of an IBL programme for the effective teaching and learning of a construction programme?
    a. What are the antecedents to effective teaching and learning from contemporary theories of learning?
    b. Which of the antecedents from the contemporary theories of learning impact learning the most?
2. What is the best way to integrate construction subject specialisations in an IBL approach to learning of construction programmes so as to provide learners with appropriate contextual understanding?
    c. What is the appropriate range of construction knowledge which should be included in a construction programme curriculum?
    d. What type of construction knowledge is best learnt through IBL?
    e. What type of construction knowledge is best learnt through the didactic approach?
    f. What construction areas of specialisations are best integrated and taught together in an IBL approach?
3. How can antecedents to teaching and learning from contemporary theories of learning be used for the effective teaching and learning of construction programmes?

11.3 Key Research Findings and Conclusions

The findings and conclusions for each of the research questions are as follows:

11.3.1 Question 1.

1. What should be considered in the design of an IBL programme for the effective teaching and learning of a construction programme?
    a. What are the antecedents to effective teaching and learning from contemporary theories of learning?

This question sought to establish the factors from different theoretical backgrounds which are required in a curriculum for an effective education programme so that they can be subsequently incorporated in an IBL curriculum for construction programmes. The question was answered by a review of extant literature. While the question was answered using existing literature, the question is important because no literature has not provided a structured list of what are the important antecedents to effective teaching and learning generally or in construction programmes specifically. The answer to the question was the basis for the empirical evaluation of significance of the antecedents in construction programmes.

11.3.1.1 Findings

Based on extant literature, the antecedents to teaching and learning from the theories of constructivism, connectionism and cognitive load theory are, namely

From Constructivism:

8. Scaffolding student learning activities
9. Engaging students in group learning activities
10. Encouraging self-directed learning
11. Encouraging reflective thinking
12. Engaging students in individual learning activities
13. Engaging students in active learning
14. Challenging students with tasks located in the Zone of proximal development

From Behaviourism:

15. Repetition of key lessons
16. Reinforcement of desirable student behaviour
17. Readiness for learning by students

From Cognitive Science:

18. Cognitive loading induced in students by learning tasks
19. Schema construction engaged in by students
20. Complexity and ambiguity of questions administered to students
21. Administering authentic problems to students
22. Administering worked examples to students
23. Administering completion problems to students

b. Which of the antecedents from the contemporary theories of learning impact learning the most?

This question sought to establish the relative importance of the factors which were identified to be necessary considerations in a curriculum based on how much they impact learning so that their application in a curriculum can be prioritised based on their significance to learning. The question was answered using empirical evidence from students studying undergraduate construction programmes at public universities. Structural equation modelling was used to establish the factors which significantly impact learning.

11.3.1.2 Findings

Based on empirical evidence, in order of importance, the following four factors were found to significantly impact learning directly, namely

1. Engaging students in individual learning activities
2. Scaffolding student learning activities
3. Encouraging reflective thinking
4. Engaging students in group learning activities

Based on empirical evidence, in order of importance, the following six factors were found to impact learning indirectly through at least one of these four factors, namely

1. Repetition of key lessons
2. Reinforcement of desirable student behaviour
3. Readiness for learning by students
4. Encouraging self-directed learning
5. Complexity and ambiguity of questions administered to students
6. Administering worked examples to students

Based on empirical evidence, in order of importance, the following two factors were found to affect learning indirectly through two other factors and these are:

1. Administering authentic problems to students
2. Cognitive loading induced in students by learning tasks

11.3.1.3 Conclusion

From the relative importance of the identified antecedents to teaching and learning from the contemporary theories of learning, an IBL curriculum for construction programmes should prioritise engaging students in both individual and group learning activities which should be appropriately scaffolded especially when students are struggling with the learning activities. Further, reflective thinking should be actively encouraged as students engage in the learning activities. After these are emphasised, it is important that key aspects of the lessons are repeated, students are positively reinforced and encouraged to be emotionally, physically and mentally ready to learn when they attend class. Also, students should be encouraged to engage in self-directed learning and given IBL questions which they perceive as being complex and these should be supplemented with worked examples. Also, students should be presented with IBL learning problems which model real world authentic problems. Finally, the cognitive load induced by the learning tasks should be monitored and managed to ensure that it does not interfere with learning.

11.3.2 Question 2.

2. What is the best way to integrate construction subject specialisations in an IBL approach to learning of construction programmes so as to provide learners with appropriate contextual understanding?
   a. What is the appropriate range of construction knowledge which should be included in a construction programme curriculum?

      This question sought to establish the broad knowledge areas required in a curriculum for a construction programme so that they can be appropriately grouped for subsequent delivery through IBL. The question was answered using extant literature because there is no accepted list or classification of the important range of knowledge for construction programmes. Therefore, a critique and condensation of the most important knowledge for construction programmes was necessary in order to identify what to include in the proposed curriculum and subsequently how best to deliver it.

11.3.2.1 Finding 1

Based on extant literature, the appropriate range of knowledge for a construction programme should include basic, core and optional knowledge areas.

a. *Basic knowledge areas*: team working, health and safety, accounting principles and procedure, business planning, conflict avoidance and dispute resolution, sustainability, ethics, client care among others.
b. *Core knowledge areas*: design economics, project planning and management, construction technology, contracts, procurement and tendering, cost control, quantification and computer literacy among others.
c. *Optional knowledge areas*: building information modelling (BIM), project evaluation, risk management, leadership, facilities management, whole life cycle costing, cost analysis, value management and research methodology. The three knowledge areas are modelled around the project nature of the construction industry. Therefore, they encompass the entire project life-cycle from inception to completion.

b. What type of construction knowledge is best learnt through the didactic approach?

This question acknowledges that not everything may be effectively taught through IBL and therefore sought to establish what types of knowledge in construction programmes are best delivered through the didactic approach.

11.3.2.2 Finding 2

The following knowledge areas are best learnt through didactic lectures because they form theoretical backing to knowledge areas which are more practically applicable in the construction industry:

Law, project evaluation, risk management, BIM (because it has not reached wide application in the South African construction industry and universities are ill-equipped to practice it with students), facilities management, health and safety, conflict avoidance, sustainability, client care, numeracy (mathematics), and statistics.

While these may be delivered through didactic lectures, their application should be incorporated in the IBL module.

c. What type of construction knowledge is best learnt through IBL?

This question sought to establish the type of knowledge best delivered through IBL so that it can be appropriately incorporated in an IBL curriculum for construction programmes.

11.3.2.3 Finding 3

The following construction knowledge areas are best learnt through IBL because they are directly practically applied on construction sites and involve activities or tasks which students will be required to perform.

Team working, ethics, procurement and tendering, quantification, computer literacy, project management, leadership, research, whole life cycle costing, cost analysis, value management, accounting, business planning, sustainability.

d. What construction areas of specialisations are best integrated and taught together in an IBL approach?

This question sought to establish which of the construction knowledge best delivered through IBL may be integrated and learnt together in an IBL exercise. This question was answered using extant literature because an empirical research of the question was outside the scope of this research and a critical review of literature was sufficient to identify the knowledge areas which were best integrated

11.3.2.4 Finding 4

Based on the review of extant literature, the following construction knowledge areas divided into the three broad stages of a construction project, namely the pre-tender, construction and post-construction stage are best integrated:

1. *Pre-tender stage*:
    a. quantification, procurement and tendering, value management, risk management, whole life cycle costing, sustainability, business planning
2. *Construction stage:*
    a. Construction technology, health and safety, project management
3. *Post-construction stage:*
    a. Accounting, cost analysis

Any other knowledge areas or specialisations deemed necessary for a construction programme but missing from this list may be appropriately inserted under the relevant section.

11.3.2.5 Conclusion

In keeping with standard IBL philosophy, introductory lectures and seminars as required should be given for all IBL activities to ensure that students have sufficient knowledge to proceed with the IBL task. Rather than use IBL for each one of the individual subjects, modules or knowledge areas highlighted, the subjects should be integrated based on how they relate with each other. Therefore, the IBL tasks should model how construction projects apply different knowledge. This way, all the relevant subjects, modules or knowledge areas contribute to the construction project one way or the other. Therefore, the curriculum should have an IBL task which should integrate different knowledge areas based on which stage of a construction project the task is performed in. Team working, ethics and computer skills transcend all the stages of a construction project and therefore should feature throughout in all the stages.

11.3.3 Question 3.

3. How can antecedents to teaching and learning from contemporary theories of learning be used for the effective teaching and learning of construction programmes?
   a. What is the best way to teach the IBL curriculum taking account of the relevant antecedents to teaching and learning from the contemporary theories of learning?

      This question sought to establish how best to combine the antecedents to teaching and learning from the different theories of learning into an IBL curriculum for construction programmes taking into account the various construction knowledge areas and how best they may be delivered. This question was answered by condensing findings from both the research empirical evidence and the critical review of literature.

11.3.3.1 Finding 1

Based on the review of extant literature and empirical evidence, the IBL curriculum for construction programmes is best delivered based on the three broad stages of a construction project and considering the important antecedents to effective teaching and learning.

11.3.4 Conclusion – Proposed IBL Curriculum Guide for Construction Programmes

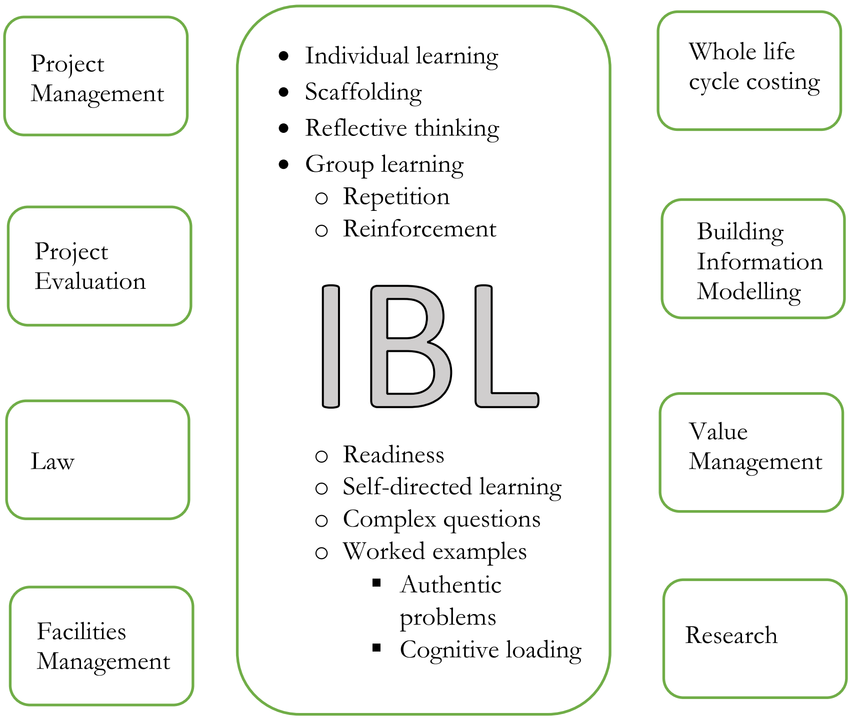
The proposed IBL curriculum based on the findings of this research is shown in Figure 11-1. The curriculum is comprised of an IBL module incorporating all the important antecedents to teaching and learning and some discrete modules. The IBL module is to be used for the topics which were identified as being best delivered through IBL because they complement each other on a construction project. The discrete modules are to be used for the topics which were identified as being best delivered through the didactic approach. Preferably, each semester should only have two, or utmost, three discrete modules so that more time is dedicated to the IBL module.

A detailed description of the curriculum is as follows:

1. Some modules should be taught through the traditional didactic approach. The topics in these modules should comprise of knowledge areas which are not applied directly during a construction project but provide knowledge which support the execution of tasks which can be described as core construction activities. This is based on the finding from literature that some topics may not be appropriate to be delivered through IBL. Further:
   a. A total of utmost three or other only two modules should be taught through the traditional didactic approach to leave time for IBL with its associated lectures, seminars and workshops among other scaffolding activities which may be used to support it.

Figure 11-1: Proposed IBL curriculum for Construction Programmes

   b. The content and activities in these modules should be aligned as much as possible with the IBL project in order to ensure appropriate contextual understanding of all topics supporting core construction activities.
   c. Any assignments and exams for these modules should relate to the IBL project as best as possible to further ensure appropriate contextual understanding.



2. IBL to be made up of a major project to cover the three major stages of a construction project to further ensure appropriate contextual understanding of all the aspects of construction and how they relate to each other. Further:
   a. Each semester to have a major IBL project. The IBL project should have elements of self-directed learning in tandem with the findings that self-directed learning is important for learning.
   b. The IBL project to progressively cover all activities in the major project stages of pre-contract, contract and post-contract stage within the semester so that students understand the complete cycle of a construction project. Further:
      i. The project should be divided into distinct aspects of a construction project to ensure that students understand the different distinct stages of a project and how they relate to each other.
      ii. Each distinct project section to have introductory lectures in order to equip the student's sufficient knowledge to start the IBL process and help reduce cognitive loading.
      iii. Emphasis to made to the students that distinct activities take place at distinct stages of the project and by distinct specialisations with the construction industry to ensure appropriate contextual understanding of the different specialisations and the roles they play in construction project.
   c. The IBL projects should be group projects but should also have aspects which are individual projects which should offshoot from the group projects because the findings show that engaging in both group and individual learning is key to effective learning.
      i. Individual projects arising from group projects may include students critiquing the group solution to the project. In these critiques, students may either agree or disagree with the group solution providing reasoned arguments for either position. This will lead students to systematically and continuously engage in reflective thinking as they think about the proposed solution to the project problem.
      ii. Students can also document lessons learnt measured against the desired learning outcomes. This will also lead students to engage in reflective thinking.
   d. Students to document the contribution of each of group member to promote equal participation. This is also likely to engender ethical conduct by the students in terms of the distribution of work. Since projects will iterate each semester though with increasing

complexity, project tasks which cannot be easily shared should be rotated to ensure that all students have an opportunity to learn the various lessons from the group activities.

e. Early years of study and semester to have IBL projects based on fairly simple projects in order to avoid inducing high levels of cognitive loading in students with little subject prior knowledge. These projects should be modelled around real wold authentic problems as much as possible because authentic problems were found to be important for learning but induced much less cognitive loading. Lower levels of cognitive loading are important for students who are just beginning because they would not have developed sufficient subject prior knowledge to deal with questions which are perceived as being complex. Project complexity should be increased gradually as student's progress to higher levels of study because they will have developed fairly sufficient skill and knowledge to deal with the consequent cognitive loading and the process of IBL because complex questions.
    i. The project cycle should repeat each semester to allow students sufficient practice on different IBL projects because repetition was found to be an important antecedent to effective learning.
    ii. Introductory lectures to be repeated but with greater detail and depth as the project complexity grows. When all teaching material is exhausted, the introductory lectures may be omitted from subsequent semesters because students would have gained sufficient knowledge to proceed with the IBL task without consequent high levels of cognitive loading.

f. The progress of students to be monitored continuously and when students are struggling with aspects of the project, they should be provided with appropriate scaffolding in the form of worked examples, seminars or supplementary lectures, among others, in order to avail them the required knowledge and skills to prevail. This is because scaffolding and worked examples were found to aid the learning.

g. Group sizes to progressively reduce each semester or each year of study until in the final year of study, students work in pairs but still with some aspects of individual projects. This will ensure that the students gain autonomy and are able to perform tasks on their own without significant help from peers.

11.4 Research Contribution to Knowledge

The research makes both theoretical and practical contributions to the body of knowledge. Theoretical contributions to the extant literature on contemporary pedagogy include the identification antecedents to teaching and learning derived from different schools of thought. Previous studies have only looked at the factors which contribute to effective teaching and learning from different theoretical backgrounds independent of each other. This research, therefore, contributes to extant literature by establishing the relative importance of factors identified as being important for teaching and learning from different theoretical backgrounds. The practical implication of this is that the design of pedagogy should consider the factors from the different schools of thought in the order of importance as established in the findings of this research in order to be effective.

The research also identified a set of knowledge areas critical for construction programmes. This is important considering the extent of knowledge explosion occasioned by rapid advances in technology in the last few decades. The implication of this is that the research highlights what educators need to consider in the design of a curriculum for construction programmes without having to worry about considering all the possible knowledge areas available as it is not possible to include everything in a curriculum. The research further shows that not all knowledge can be delivered through IBL. The research therefore recommended what knowledge areas to deliver through IBL and which should be delivered through the didactic approach. The practical implication of this is that even in a curriculum which is designed to be inquiry in nature, educators should note that not everything is best delivered through IBL. In order to achieve synergy among the various specialisations and improve contextual understanding, the research recommended what different areas of specialisation and topics are best integrated and delivered through IBL. The research also suggested an appropriate criterion for deciding which modules and topics to integrate in order to achieve synergy. The practical implication of this is that educators are guided on what knowledge areas to integrate in order to improve contextual understanding among students.

Based on all the above findings and conclusions, the research proposed a curriculum for construction programmes with integrated topics delivered through an IBL approach based on the identified antecedents to teaching and learning derived from different contemporary theories of learning.

This research further showed that self-directed learning, administering complex questions to students and questions which are in the zone of proximal development of students lead to high levels of cognitive loading. The implication of this is that students should not be tasked with complex questions when they have little subject prior knowledge and they are required to engage in self-directed learning, appropriate mechanisms for monitoring and managing cognitive loading should be implemented. The research also showed that the tenets of connectionisms, namely, repetition, reinforcement and readiness are necessary for students to engage in effective learning. The implication of this is that repetition and reinforcement are necessary for effective learning and students should be encouraged to be physically and emotionally ready to learn when they attend class. The research also showed that high levels of cognitive loading impede learning. Lecturers should therefore be mindful about the amount of cognitive loading which they subject their students to.

11.5 Research External Validity and Limitations

Because the research was based on a convenient sample, it has slightly questionable external validity and so the results and conclusions should be generalised to other populations and contexts with caution. It is possible that the research sample may differ significantly from the general population of interest even though no evidence was found to suggest so. Otherwise, other threats to external validity were fairly adequately addressed. For example, the operationalisation of the research constructs was done to avoid external validity issues and the research design and methods chosen do not have inherent external validity issues.

The research had several limitations. The survey was based on a convenient sample. Therefore, the research has some limitations on external validity and so may not be completely generalizable beyond the research sample. The research is based on survey instruments which were designed by the authors and so have not been extensively validated. Therefore, the reliability and validity of the research instruments may be questioned. For example, the research instruments were not sufficiently assessed for face validity through a panel of experts and other forms of reliability and validity such as predictive validity and constancy were not assessed. The data are based on self-report questionnaire and the results therefore have all the limitations associated with self-reporting. The limitations associated with self-reporting include honesty in response or social desirability, introspective ability of respondents, question understanding, interpretation of the rating scale and respondent response bias. Also, the study is based entirely on quantitative data. A mixed methods approach would have provided a check on the validity of the findings by comparing results from different data sources. Further, the proposed curriculum model was not validated by testing to see its efficacy when implemented.

11.6 Recommendations for Future Research

Based on the limitations, delimitations and research findings, there are the following areas of future research:

1. Based on the limitations due to sampling, the use of some instruments which have not been extensively tested and the use of a self-report questionnaire, future studies can replicate this study with a more representative sample and with other instruments which have been widely validated or indeed with instruments from this research to validate them and subsequently validate the findings and conclusions arrived at by this research. Also a different methodology may be used to validate results from this research.
2. Based on the delimitations of this study, future studies can consider other factors relevant for teaching and learning besides the ones considered by this research. Other factors for consideration can include student approaches to learning.
3. Based on the findings from this research, future studies could also could establish how lecturers could effectively deliver such a curriculum by considering, inter alia, the advantages and disadvantages of collaborative teaching versus individual teaching with some guest lectures from specialist lecturers. The research would also consider the relevant skills required by a lecturer to deliver such a curriculum.
4. Future studies could also look at how many students can be effectively taught through such a curriculum including the configuration of the appropriate space for conducting IBL and how cost

effective the model is based on the appropriate lecturer/student ratio and the space configuration requirements. The research could also look at how best to assess learning in such a curriculum.

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APPENDICES

13.1 Appendix 1 – Research Introduction Letter for Respondents

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

University of KwaZulu-Natal
School of Engineering
Department of Construction Studies
Howard College Campus
Durban 4041
South Africa

October 2017

Dear Student,

Re: Questionnaire for a PhD Study on Improving Construction Education in South Africa – Informed Consent

We are conducting a PhD research study which aims to recommend a different approach to undergraduate construction education in South Africa by suggesting a teaching and learning philosophy which is based on contemporary theories of learning and practices which are unlike what is currently obtaining.

Being a student enrolled in a construction related programme, you are invited to participate in this research study by completing the attached 4-paged questionnaire which only requires you to check an appropriate box after reading the accompanying statement. The exercise was pre-tested and found to take only between 15 to 30 minutes to complete. Your participation is vital to the success of this study and we cordially request that you treat the exercise with the importance it deserves. In so doing, you will be helping in the noble effort to deliver a better education to undergraduate construction students in South Africa.

Responding to the questionnaire is completely voluntary and you are guaranteed complete confidentiality in the treatment of your responses; you have the right not to respond to any questions which you may deem inappropriate and you are assured that the information collected will be used for academic purposes only. Should you wish to know the findings of the research, note that publications arising from the study will be sent to the contact person at your university for onward circulation to all participants.

Please sign the consent form provided separately to indicate that; a), you have read the above information; b), you are over 18 years old and; c) you voluntarily agree to participate. **If you do not agree** to any of the above, please do not fill in the questionnaire.

Thanking you in advance,

Mr Ephraim Zulu
PhD Scholar
Phone: +2731 260 2719 (Office)
Mobile: +2763 226 4599
E-mail: ephraimzulu2000@yahoo.co.uk and zulue@ukzn.ac.za

Prof. Theo C. Haupt
Professor and Program Co-ordinator: Construction Studies,
Phone: +2731 260 2712 (Office)
Mobile: +27 82 686-3457
E-mail: pinnacle.haupt@gmail.com and haupt@ukzn.ac.za

Humanities and Social Sciences Research Ethics Committee
Research Ethics Office
Govan Mbeki Building
Westville Campus
Phone: +2731 260 4557
Fax: +2713 260 4609
E-mail: mohunp@ukzn.ac.za

13.2 Appendix 2 – Research Measurement Instrument

Effective Learning Survey Questionnaire

Section A: Demographic Information of the Respondent

INSTRUCTIONS & DIRECTIONS: By way of a cross (X) or a tick (√), select the category which best describes you

What is your gender?

Male		Female	

What year of study best describes you?

1st		2nd		3rd		4th	

What is your programme of study?

Architecture	
Building Construction/Construction Management	
Civil Engineering	
Quantity Surveying	
Property Development	
Interior Design	
Landscape Architecture	
Other (Specify) e.g. Art/ Fine Art.____.	

Which university are you enrolled at? ____

Section B: Learning Approaches

INSTRUCTIONS & DIRECTIONS: By way of a cross (X) or a tick (√), Indicate the frequency of occurrence of the following based on your experience and judgement from the **last semester** on a scale of 1 to 5 with 1 = Almost never; 2 = Seldom; 3 = Sometimes; 4 = Often and 5 = Almost always

For responses which may vary depending on the module and/or lecturer, provide your response based on your assessment of the average for all the modules combined. For example, if an activity happened in one module only and you had five modules for the whole semester, then on average it happens in one module out of five which may can be interpreted as either almost never or sometimes depending on frequency in the module where it happens.

	Order Learning	Almost never	Seldom	Sometimes	Often	Almost always
1	I studied the basic elements of a point, an idea, experience, or theory, in depth and considered its components					
2	I combined and organised points, ideas, information, or learning experiences into new and more complex understanding, interpretations or relationships					
3	I judged the value of information, arguments, or methods and lessons that I learned.					
4	I applied theories or concepts that I learnt in class to practical problems or in new situations					

	Integrative Learning	Almost never	Seldom	Sometimes	Often	Almost always
1	I worked on assignments or projects that required using ideas or information from various sources and modules					
2	I looked at problems from several different points of view in class discussions or when writing assignments					
3	I used ideas or concepts from other modules when completing assignments or during class discussions					
4	I discussed ideas after studying or after classes with lecturers outside of class					
5	I discussed ideas from my studies or classes with others outside of class (classmates, other students, family members, co-workers, etc.)					

	Reflective Learning	1	2	3	4	5
1	I thought about the strengths and weaknesses of my own views and opinions on a topic					
2	I tried to understand other people's views by thinking about how an issue or point looked from their perspective or view point					
3	I learned something new or different that changed the way I understand things or a concept from another module					
4	I learned something new or different from discussing difficult questions that have no clear answers					
5	I used what I learned in a module in other modules					
6	I enjoy doing assignments that require a lot of thinking and mental effort					

	Memory Learning	1	2	3	4	5
1	I rehearse or practice until I can reproduce a definition word by word					
2	If I do not understand a part of the learning material I just memorise it so that I do not forget it					
3	I try to memorize everything that might be covered in my tests					
4	I memorize as much as possible					

	Zone of Proximal Development	1	2	3	4	5
1	I found tests and assignments to be very challenging					
2	I was given work which was beyond what I could manage to do on my own					
3	I was given work which required further guidance from the lecturers in order to complete it					
4	I was given work which required consulting with more knowledgeable people in order to do it well					

	Scaffolding	1	2	3	4	5
1	My lecturers helped me when I could not manage to do the assigned work on my own					
2	My lecturers gave me sufficient knowledge, information and support to do my work					
3	My lecturers gave me enough help when doing my work					
4	My lecturers gave me additional information when I could not manage to do my work					
5	I was guided when I could not manage to do the work on my own					
6	My lecturers helped me when I asked for help with my work					

Active Learning		Almost never	Seldom	Sometimes	Often	Almost always
1	I was required to do more than just listening in class					
2	I was required to perform practical work activities in class					
3	I was allowed to discuss the lecture content with fellow students during a lecture session					
4	I took my own notes while listening to the lecturer					
5	The lectures involved other activities besides listening to the lecturer					

Individual Cognition		1	2	3	4	5
1	I connected new concepts and principles (points) in a module with what I already knew					
2	I selected important points to remember from the lectures					
3	I used information from class to solve assigned work problems					
4	I recognised and noted useful points from the lectures					
5	I tried to remember everything from the lectures					

Sharing Ideas		1	2	3	4	5
1	The modules allowed for interaction with fellow students during class					
2	The modules had a variety of learning activities					
3	The lecturers allowed me to express myself					
4	The lecturer allowed me to share my experiences					

Self-Directed Learning		1	2	3	4	5
1	I was required to find additional knowledge and information on my own					
2	I was given work which required me to learn new concepts on my own					
3	I was expected to expand on what was taught in class on my own					
4	I was required to learn on my own					

Reflective Thinking		1	2	3	4	5
1	I question the way others do something and try to think of a better way					
2	I like to think over what I have been doing and consider alternative ways of doing it					
3	I reflect on my actions to see whether I could have improved on what I did					
4	I review my experience so I can learn from it and improve my next performance					

Repetition		1	2	3	4	5
1	My lecturers covered the key points of a lecture more than once					
2	My lecturers repeated some lectures					
3	Some topics were covered more than once					
4	My lecturers emphasised the key points of a lecture by repeating themselves					
5	My lecturer allowed for revision of the lecture material					

	Reinforcement	Almost never	Seldom	Sometimes	Often	Almost always
1	I was complimented for good conduct and doing good work					
2	I was recognised for good conduct and doing good work					
3	I was rewarded for good conduct and doing good work					
4	I was praised for good conduct and doing good work					
5	I was encouraged when my conduct and work were good					

	Readiness	1	2	3	4	5
1	I was emotionally, physically and mentally ready to learn					
2	I was well prepared for the lectures					
3	I was ready to learn when I went for lectures					
4	I prepared adequately for class					
5	I was well rested (not tired) when going to lectures					

	Schema Construction and Automation	1	2	3	4	5
1	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject					
2	My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew					
3	I connected points that I already knew with what I was being taught in class					
4	I organised, categorised or connected anything new that I learnt with what I already knew					
5	My lecturers clearly highlighted the main concepts and principles					

	Cognitive Loading	1	2	3	4	5
1	I was expected to remember too many things from each lecture					
2	I was overwhelmed with the amount of information I was expected to remember					
3	I was given with too much information during the lectures					
4	The information I was given during lectures was confusing					
5	The information I was given in class was complicated and difficult to understand					
6	I was overwhelmed with the amount of work I had to do					
7	I was given too many projects, assignments and tests					

	Complex and Ambiguous Questions	1	2	3	4	5
1	I was given assignments and tests which were difficult to understand and solve					
2	I was given problems which did not have enough information for me to solve them					
3	I was required to solve questions which were not clear as to what I was expected to do					
4	I was given questions which could be interpreted in more than one way					
5	I was given problems which were not easy to understand clearly					
6	I was given questions which were not expressed clearly					

Authentic Problems		Almost never	Seldom	Sometimes	Often	Almost always
1	I was given problems based on actual industry real life problems					
2	I was expected to use real life situations when doing my school work					
3	I was required to collect some real world information to do my school work					
4	I was given work which was relevant to actual current industry practice					
5	I was required to come up with my own solutions to problems					

Worked Examples		1	2	3	4	5
1	I was given some worked examples to practice on					
2	I was given examples with clearly defined steps on how to solve problems to practice on					
3	I was given problems with model solutions to practice on					
4	I was shown how to solve a problem before being asked to solve other problems					

Completion Problems		1	2	3	4	5
1	I was given partially worked examples to complete					
2	I was given partly finished model solutions to problems to finalise the solution					
3	I was given problems which were partly solved to practice on					
4	I was given problems and part of the solution to work on					
5	I was given problems which had gaps that I had to fill in					

Thank you for your contribution towards improving construction education in South Africa.

13.3 Appendix 3 – Ethical Clearance Application

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

COLLEGE OF ENGINEERING:

MASTERS/PHD RESEARCH PROPOSAL AND ETHICAL CLEARANCE APPLICATION

PLEASE NOTE THAT THE FORM MUST BE COMPLETED IN TYPED SCRIPT. HANDWRITTEN APPLICATIONS WILL NOT BE CONSIDERED

SECTION 1: PERSONAL DETAILS

1.1 Full Name & Surname of Applicant: Ephraim Zulu
1.2 Title (Ms/ Mr/ Mrs/ Dr/ Professor etc.): Mr
1.3 Applicants gender : Male
1.4 Applicants Race (African/ Coloured/Indian/White/Other) : African
1.5 **Student Number** (where applicable) : 215080940
Staff Number (where applicable) : Not applicable
1.6 School : Engineering
1.7 College : Agriculture, Engineering and Science
1.8 Campus : Howard College
1.9 Existing Qualifications : MSc., BSc.

1.10 Proposed Qualification for Project : PhD
(In the case of research of degree purposes)

2. Contact Details
Tel. No. : 031 260 2719
Cell. No. : 063 873 8739
e-mail : ephraimzulu2000@yahoo.co.uk
Postal address (in the case of students and external applicants) : Universty of KwaZulu-Natal, Howard College Campus, Durban
Centenary Building, Room 131

Proposal for:
PhD Thesis: 100% 100 000 words 384 credits X

Dissertation 100% 40 000 words 192 credits □
Coursework Dissertation 66.6% 28 000 words 128 credits □
Short Dissertation 50% 20 000 words 96 credits □
Treatise 33.3% 14 000 words 64 credits □

In the case of coursework degree, provide a brief description of degree programme:
(e.g. nature of degree, number and names of modules passed)

Not applicable

Each research proposal should be submitted together with a fully completed

- ***Contract between Supervisor and Candidate.***

We are satisfied with the academic merit and viability of the proposal and research project, subject to ethical clearance:

1 Supervisor:

Name:PROF THEO C HAUPT Signature: Date: October 03, 2016

2. Academic Leader (Discipline):

Name:..Signature:..Date:...................................

3. Academic Leader (Research)

Name:..Signature:..Date:................................
...

3. SUPERVISOR/ PROJECT LEADER DETAILS

NAME	TELEPHONE NO.	EMAIL	DEPARTMENT / INSTITUTION	QUALIFICATIONS
3.1 Prof TC Haupt	031 260 2712	haupt@ukzn.ac.za	UKZN – Construction Studies	Ph.D., M.Phil.
3.2				
3.3				

SECTION 2: PROJECT DESCRIPTION

2.1 Project title
(40 words)
(Give a short title, be specific, and include key terms)

Curriculum Development for an Inquiry Approach to Construction Education

Problem statement

The didactic lecture teaching approach with its associated learning experiences does not adequately prepare undergraduate construction students for construction professional practice and therefore demands an alternative teaching and learning approach to address the deficiencies.

2.1.1 Review of Literature (1400 words for PhD and 1000 words for Masters Degrees)
(Outline previous work/literature relevant to your study, who are the main thinkers/researchers/protagonists in the area? (Please do not provide long annotations but demonstrate a broad awareness of the body of literature that exists on your topic. Show where there are gaps and limitations in current research and how this study will seek to make a contribution to the academic debate)

The quality of university construction graduates worldwide is being criticised for being at variance with what the construction market expects (Ayarkwa, Ayirebi, Andinyira and Amoah, 2011; Love, Haynes and Irani, 2001). For example, while analysing the perception of the Ghanaian construction industry on the performance of industry entry level graduates, Ayarkwa *et al.* (2011) noted that graduates lacked practical building knowledge, problem solving skills, communication skills (inter-personal skills in generally) among several other skills. Love *et al.* (2001) equally noted the absence of all these skills and competences in a survey of construction managers and construction companies in Australia.

The traditional didactic lecture approach to university education with its associated student learning experiences have been blamed for some of the observed poor quality (Candela, Dalley and Benzel-Lindley, 2006b; Mihaela, Amilia and Bogdan, 2015b). The content driven curricula hardly leaves any time for the development of critical thinking and reasoning (Candela *et al.*, 2006b).

The traditional didactic lecture approach to education is modelled around old theories of knowledge and learning derived from old philosophies (Bodner, 1986b). The traditional didactic lecture approach to teaching and learning is based on the 400 BC philosophy of realism, empiricism and positivism which hold that in acquiring knowledge, the mind simply tries to discover the existing knowledge of the world by building mental images of it and educators therefore try to show passive learners pictures of this existing world as it is in their minds. Based on these theories and conception, traditionally, educators have focused on transferring knowledge from their minds into the minds of learners (Ibid). Through the lessons and with emphasis and repetition, the educators expect leaners to replicate the knowledge contained in their own memory. Further, centred on these theories and conceptions, education curricula emphasised scientific subject matter of the physical world with orderly and discipline specific content in tandem with defined scientific disciplines. Throughout the process, students are kept passive and only expected to listen to the lecture.

Contemporary theories of learning have since rebuffed the proposition that learners can passively acquire knowledge (Bodner, 1986b; Field, n.d.). John Dewey (1859 – 1952) proposed the "Theory of Inquiry" which postulates that knowledge is created by an active response to the environment and not a passive observation of the environment and drawing correspondence with reality (Field, n.d.). Following on from the theory of inquiry, further work by Maria Montessori (1870 – 1952), Jean Piaget (1896 – 1980) and Lev Vygotsky (1896 – 1934), among many others, led to a new paradigm in the philosophy of learning called constructivism (Ultanir, 2012a). Constructivism, which is the contemporary theory of knowledge and learning in philosophy, postulates that learners are creators of their own meaning and knowledge and that learning and knowledge construction happen through experience and reflecting on experiences to construct understanding (Ultanir, 2012a; von Glasersfeld, 1989, 1991).

The epistemology of constructivism from philosophy is not the only school of thought which has a theory about learning. Behaviourism from psychology has proposed several theories about how learning happens. Behaviourism generally considers learning as a change in behaviour. The contemporary theory of learning in behaviourism is the theory of connectionism proposed by Edward Thorndike (1874 – 1949) which postulates that learning happens when sufficient stimulus - response (S-R) associations are positively rewarded thereby creating lasting connections between the S-R associations (Guey *et al.*, 2010; Kohlenberg and Tsai, 2000). This postulation is based on three other theories about how learning happens which are the law of effect, the law of readiness and the law of repetition all of which were also postulated by Thorndike. The law of effect states that responses that create satisfying results in a particular situation are more likely to be repeated in that situation, and responses that create discomforting results are less likely to be repeated in that situation. The law of readiness states that people learn best when they are physically, mentally and emotionally ready to learn and the law of repetition states that what is often repeated is best remembered. Experimental work B.F. Skinner (1904 – 1990) provided further support to the theory of connectionism and added to it the law of reinforcement which postulates that actions which are rewarded are more likely to be repeated (Donahoe, 2002).

The field of cognitive science has also proposed theories about learning. Cognitive science is the study of the mind, mental processes and the nature of intelligence whose purpose is to develop models and theories that help to explain human cognition in the form of perception, thinking and learning (Srinivasan, 2011; Talkhabi and Nouri, 2012). It is interdisciplinary in nature and encompasses the fields of philosophy, psychology, artificial intelligence, neuroscience, linguistics and anthropology (Srinivasan, 2011). Cognitive science acknowledges that while long term memory is almost unlimited in capacity, working memory, which is more critical to learning has a limited capacity. Based on the limit of the working memory, John Sweller (1946 -) proposed the cognitive load theory which postulates that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998a). Therefore, according to the cognitive load theory, for effective learning to take place, the limits of the working memory should be considered in the design of the teaching and learning approach (Kirschner, 2002; Sweller *et al.*, 1998a; van Bruggen *et al.*, 2002).

Therefore, "the limited view of teaching as presentation of knowledge no longer fits with current understandings of how and what students learn" (UNICEF, 2000: 15). However, notwithstanding the fact this is well known, the traditional didactic teaching approach remains the modus-operandi in construction undergraduate education. Attempts have been made to incorporate tenets of the contemporary theories of learning in teaching and learning whereby constructivism has been used in the some modules while the programme as a whole still remains delivered through a didactic lecture approach (da Cunha, Contento and Morin, 2000; Dopson and Tas, 2004b; Eliot and Joppe, 2009a). Views from cognitive load theory have also been applied and found to be effective (Hoogerheide *et al.*, 2014; Mihalca *et al.*, 2015; Sweller, 1994; Sweller *et al.*, 1998a; Van Gerven *et al.*, 2002). While the value of contemporary approaches to teaching and learning are acknowledged, they are only sporadically applied as a small part of the old teaching and learning paradigm of didactic lectures. Further, the contemporary approaches to teaching and learning are mostly researched and applied separately since the different schools of thought develop in isolation of each other. An integrated contemporary teaching and learning model incorporating antecedents to effective learning drawn from all three schools of thought conceptualising learning would benefit education but is missing from literature. This study therefore seeks to identify antecedents to effective learning drawn from the different schools of thought and incorporate these into a contemporary model of teaching and learning in undergraduate construction education.

Structure of the study:

Chapter One: Introduction – Chapter one presents the background, problem statement, hypothesis, objectives, methodology, limitations, definitions, ethical statement and chapter outline.

Chapter Two: How does learning happen? – This chapter explores three main theories of learning, namely, constructivism from philosophy, behaviourism from psychology and cognitive load theory form cognitive science and their application and influence on educational practice. The chapter identifies antecedents to effective learning.

Chapter Three: Inquiry Based Learning - This chapter explores the concept of IBL by investigate the delivery of IBL, its effectiveness, student and lecturer experiences, role of the lecturer, assessment in IBL and the types of IBL problems used. The chapter generally identifies antecedents to IBL.

Chapter Four: Construction Education – This chapter explores education generally and construction education in particular and identifies and categorises the key knowledge areas that are relevant for construction education

Chapter Five: Theoretical and conceptual model – This chapter presents theoretical framework and develops the conceptual model of the research and also presents the development of the research hypotheses.

Chapter Six: Methodology – This chapter discusses the research methods used and develops the tool which will be used for collecting data for testing the proposed structural model and its associated hypotheses.

Chapter Seven: Findings– This chapter presents the analysis of data gathered from the survey, interviews and focus groups. The data analysis focuses on testing the proposed structural model and associated hypothesis while responding to the research problem and objectives.

Chapter Eight: Discussion of findings – The results from the data analysis will be discussed in tandem with literature.

Chapter Nine: Conclusion and Recommendations – Conclusions and recommendations will be drawn based upon data analysis, linking them to the problem statement, hypothesis and objectives of the subject under investigation. A teaching and learning model for undergraduate construction education addressing the shortfalls of the didactic lecture approach will be recommended.

2.2 Location of the Study (100 words)

(Geographic – spatial, Temporal – time period, Social – socio-political-economic context)

The study will be conducted at various universities in KwaZulu-Natal, Gauteng and the Free State provinces of South Africa from February to June 2017.

2.3 Objectives

(Set out the major objectives/aims of the study. State these explicitly)

The objectives of this study are:

1. To identify contemporary theories of learning relevant for effective teaching and learning of undergraduate construction studies
2. To identify antecedents to effective teaching and learning in undergraduate construction education based on contemporary theories of learning
3. To establish the relative importance of the antecedents to effective teaching and learning in undergraduate construction education
4. To establish the extent to which the antecedents to effective teaching and learning are incorporated construction education in South African universities
5. To develop a teaching and learning model for undergraduate construction education based on antecedents to effective teaching and learning

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2.4 Questions to be Asked

(Set out the critical questions which you intend to answer by undertaking this research –these must be directly correlated to the objectives)

1. What contemporary theories of learning should be considered when designing a model for effective teaching and learning of undergraduate construction studies?
2. What are the antecedents to effective teaching and learning in undergraduate construction education?
3. Which are the most important antecedents to effective teaching and learning of undergraduate construction studies?
4. Which of the antecedents to effective teaching and learning are incorporated in undergraduate education construction studies in South Africa?
5. What is the best way to incorporate the antecedents to effective teaching and learning in construction studies?

2.5 Research Methods / Approach to Study (400 words)

(Explain *how* you will go about answering the main research questions and the approach within which you will work. Describe the design of the study, sampling and sampling method with rationale, data collection methods, and data analysis methods - be specific)

The research methodology will involve the following, namely:

- Extensive literature review of contemporary theories of learning to identify antecedents of effective learning and the identification and categorisation of knowledge areas critical to construction education;
- Development of a theoretical and conceptual model of the antecedents to effective learning:
- Data collection by means of a questionnaire survey;
- Validation of the proposed theoretical and conceptual model through the analysis of the data collected using structural equation modelling (SEM); and
- Conclusion and formulation of recommendations including a proposal for a model for effective construction education based on the identified and validated antecedents to effective learning and the critical knowledge areas for construction education

Sampling and sampling methods – The target population for the study is all students pursuing undergraduate construction related studies at South African public universities because the study is limited to undergraduate construction education in South Africa. A sample of at least 400 participants is required to fulfil the requirements of performing structural equation modelling. The universities to be sampled will be purposively selected from the total of 26 universities. Non-probability sampling was used due to the difficulty in establishing a comprehensive list of all eligible students from the 26 universities in South Africa and the resulting cost and time of accessing them in person and the envisaged problem of low response rates to email or internet based questionnaires administered to students. Stratified random sampling was ruled on the basis of high cost and more time required to access universities far from the research base should these be included in the random strata sample. For these reasons, convenience sampling will be used to select universities near the research base. From the convenient sample of the universities, all eligible students present at the day of sampling and consent to participate in the study will be provided with the questionnaire to complete. The questionnaires will be distributed to students at the beginning of a class session with the help of and in consultation with the respective heads of departments and lecturers responsible for the particular class session.

Data collection methods – Paper copies of the self-administered questionnaire of Likert scale questions will be circulated to students who will be asked to complete the questionnaire preferable at either the start or the end of a lecture. Paper copies of questionnaires were preferred over email or internet surveys due to the low response rates for these formats among students.

Data analysis methods – Structural Equation Modelling using SPSS AMOS V23 will be performed on the data to validate the proposed structural model. SEM is the contemporary data analysis approach for validation of conceptual models. It has several advantages over traditional statistical analyses in that it combines elements from several analyses and allows for the proposed model, with all its hypotheses, to be tested simultaneously.

In **Appendix One** you are required to attach copies of all your **'instruments'**: questionnaires; discussion outlines, interview schedules/questions; coding sheets etc.

2.5.1 Validity and Reliability and Rigour 400 words (in the case of empirical research)

(Provide a brief account of the validity and rigour of your study predicated on your theoretical/methodological approach. What are the limitations of your study?)

Internal validity and reliability – To ensure internal validity and reliability of the study, where applicable, verified and tested measures whose internal validity and reliability was established were adopted or adapted. For measures which were developed, the questionnaire will be pre-tested and monitored for internal validity and reliability. Internal validity and reliability will be monitored through exploratory factor analysis and confirmatory factors analysis of the data and using the Cronbach Alpha. Construct validity was first ensured by a thorough review and discussion of the questionnaire with an expert and will be monitored in the pre-test analysis by convergent and discriminate validity which will be checked for conformity to accepted norms.

External validity – To ensure external validity so that results of the study can be generalised to study population, firstly at least 30% (6) of the 26 public universities will be sampled. Secondly, a fairly large sample of at least 500 participants will be used. Notwithstanding that the public universities will be conveniently sampled, a large enough sample will still ensure external validity.

Limitations – The study is limited by the non-probability sampling method which threatens the external validity of study. This will be mitigated by selecting a fairly large convenient sample of the universities and including all students from the conveniently sampled universities to improve external validity. The resulting improvement in the external validity of the study is premised on the fact that since all the students come from the same educational background and are subject to the same general educational experience, the whole population has similar population characteristics in so far as the constructs under study are concerned and a large convenient sample will therefore remain representative of population.

In **Appendix Two** illustrate how informed consent is to be achieved by providing a copy of an **informed consent** form (including translations if appropriate).

2.6 Proposed work plan

(Set out your intended plan/timetable of work for the research, indicating important target dates necessary to meet your proposed deadline as agreed with your supervisor).

STEPS	**DATES**
1. Gate keeper applications to various universities	October 2016 – February 2017
2. Instrument to be distributed to students at various universities in South Africa	February – June 2017
3. Follow up procedures	February – June 2017
4. Data capture and encoding	March - July 2017
5. Data analysis	August – November 2017
6. Writing up findings and complete draft dissertation	February – June 2018
7. Submit completed dissertation for examination	July – August 2018

2.7 Cost Estimate

(Provide a working budget for your research)

Not applicable

2.8 Anticipated Problems/Limitations

(What problems may occur with your project, and how would you deal with them? Logistical/ethical/theoretical)

I do not anticipate any problems with conducting the surveys

2.9 References

(Provide a list of references. Keep to the 'house style' of your School: Psychology – APA; History – Footnotes, Others - Harvard).

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SECTION 3: ETHICAL ISSUES

The UKZN Research Ethics Policy applies to all members of staff, graduate and undergraduate students who are involved in research on or off the campuses of University of KwaZulu-Natal. In addition, any person not affiliated with UKZN who wishes to conduct research with UKZN students and / or staff is bound by the same ethics framework. Each member of the University community is responsible for implementing this Policy in relation to scholarly work with which she or he is associated and to avoid any activity which might be considered to be in violation of this Policy.

All students and members of staff must familiarize themselves with AND sign an undertaking to comply with the University's "Code of Conduct for Research".

QUESTION 3.1

Does your study cover research involving:	**YES**	**NO**
Children		X
Persons who are intellectually or mentally impaired		X

Persons who have experienced traumatic or stressful life circumstances		X
Persons who are HIV positive		X
Persons highly dependent on medical care		X
Persons in dependent or unequal relationships		X
Persons in captivity		X
Persons living in particularly vulnerable life circumstances		X

If "Yes", indicate what measures you will take to protect the autonomy of respondents and (where indicated) to prevent social stigmatisation and/or secondary victimisation of respondents. If you are unsure about any of these concepts, please consult your supervisor/ project leader.

QUESTION 3.2

Will data collection involve any of the following:	YES	NO
Access to confidential information without prior consent of participants		X
Participants being required to commit an act which might diminish self-respect or cause them to experience shame, embarrassment, or regret		X
Participants being exposed to questions which may be experienced as stressful or upsetting, or to procedures which may have unpleasant or harmful side effects		X
The use of stimuli, tasks or procedures which may be experienced as stressful, noxious, or unpleasant		X
Any form of deception		X

If "Yes", explain and justify. Explain, too, what steps you will take to minimise the potential stress/harm.

QUESTION 3.3

Will any of the following instruments be used for purposes of data collection:	YES	NO
Questionnaire	X	
Survey schedule		X
Interview schedule		X
Psychometric test		X
Other/ equivalent assessment instrument		X

If "Yes", attach copy of research instrument. If data collection involves the use of a psychometric test or equivalent assessment instrument, you are required to provide evidence here that the measure is likely to provide a valid, reliable, and unbiased estimate of the construct being measured. If data collection involves interviews and/or focus groups, please provide a list of the topics to be covered/ kinds of questions to be asked.

QUESTION 3.4

Will the autonomy of participants be protected through the use of an informed consent form, which specifies (in language that respondents will understand):	**YES**	**NO**
The nature and purpose/s of the research	X	
The identity and institutional association of the researcher and supervisor/project leader and their contact details	X	
The fact that participation is voluntary That responses will be treated in a confidential manner	X	
Any limits on confidentiality which may apply	X	
That anonymity will be ensured where appropriate (e.g. coded/ disguised names of participants/ respondents/ institutions)	X	
The fact that participants are free to withdraw from the research at any time without any negative or undesirable consequences to themselves	X	
The nature and limits of any benefits participants may receive as a result of their participation in the research	X	

If not, this needs to be explained and justified, also the measures to be adopted to ensure that the respondents fully understand the nature of the research and the consent that they are giving.

QUESTION 3.5

Specify what efforts have been made or will be made to obtain informed permission for the research from appropriate authorities and gate-keepers (including caretakers or legal guardians in the case of minor children)?
Gate keeper permission will be sought from all participating universities. Gatekeeper permission application letter has been annexed.

QUESTION 3.6

STORAGE AND DISPOSAL OF RESEARCH DATA: **Please note that the research data should be kept for a period of at least five years in a secure location by arrangement with your supervisor.**
How will the research data be disposed of? Please provide specific information, e.g. shredding of documents incineration of videos, cassettes, etc. The questionnaires will be kept in the storage space along with other similar documents at the office of my research supervisor, Prof. Haupt, for a period of not less than five years as per UKZN ethics committee requirements. The questionnaires will be shredded at the end of the required time period. Soft copies of the data will be kept in a secure location on a UKZN computer for at least five years and deleted from all storage devices after that. All other duplicate soft copies of the data will be deleted from all storage devices after the dissertation is accepted and all appropriate analyses and data for academic publications have been extracted.

QUESTION 3.7

In the subsequent dissemination of your research findings – in the form of the finished thesis, oral presentations, publication etc. – how will anonymity/ confidentiality be protected?

The data will be aggregated so that no reference to any particular person or organization will be made.

Publications arising from the data will be emailed to the contact person at each university for onward circulation to all participants.

QUESTION 3.8

Is this research supported by funding that is likely to inform or impact in any way on the design, outcome and dissemination of the research?	YES	NO
		X

If yes, this needs to be explained and justified.

QUESTION 3.9

Has any organisation/company participating in the research or funding the project, imposed any conditions to the research?

NO

If yes, please indicate what the conditions are.

N/a

SECTION 4: FORMALISATION OF THE ETHICS APPLICATION

APPLICANT

I have familiarised myself with the University's Code of Conduct for Research and undertake to comply with it. The information supplied above is correct to the best of my knowledge.

NB: PLEASE ENSURE THAT THE ATTACHED CHECK SHEET IS COMPLETED

....	**3 October 2016**
SIGNATURE OF APPLICANT	**DATE**

SUPERVISOR

NB: PLEASE ENSURE THAT THE APPLICANT HAS COMPLETED THE ATTACHED CHECK SHEET AND THAT **THE FORM IS FORWARDED TO YOUR SCHOOL ETHICS COORDINATOR FOR FURTHER ATTENTION**
DATE: October 3, 2016 **SIGNATURE OF SUPERVISOR/ PROJECT LEADER :**

RECOMMENDATION OF SCHOOL ETHICS COORDINATOR

The application is (please tick):

	Approved
	Recommended and referred to the Human and Social Sciences Ethics Committee for further consideration
	Not Approved, referred back for revision and resubmission

* Senate has delegated powers to School Committee to:

- Approve Undergraduate and Honours projects
- Approve Masters projects (if the required capacity exists within the School)
- Approve PhD projects (if the required capacity exists within the School)

NAME OF CHAIRPERSON:
____________________________________SIGNATURE:_____________________________

DATE ....

RECOMMENDATION OF SCHOOL RESEARCH ETHICS COMMITTEE

NAME OF CHAIRPERSON:____________________________________SIGNATURE____________________________

DATE.....

UNIVERSITY OF KWAZULU-NATAL

RESEARCH OFFICE

COLLEGE OF ENGINEERING

CHECK SHEET FOR APPLICATION

PLEASE TICK

1. Form has been fully completed and all questions have been answered	√
2. Questionnaire attached (where applicable)	√
3. Informed consent document attached (where applicable)	√
4. Approval from relevant authorities obtained (and attached) where research involves the utilization of space, data and/or facilities at other institutions/organisations	N/A
5. Signature of Supervisor / project leader	√
6. Application forwarded to School Ethics Coordinator for recommendation and transmission to the Research Office	√

13.4 Appendix 4 – Provisional Ethical Clearance

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

14 November 2016

Mr Ephraim Zulu 215080940
School of Engineering
Howard College Campus

Dear Ms Zulu

Protocol Reference Number: HSS/1763/016D
Project title: Curriculum Development for an Inquiry approach to Construction Education

Provisional Approval - Expedited Application

I wish to inform you that your application received on 18 October 2016, in connection with the above has been granted provisional approval, subject to the following:

- ***Gatekeeper permission being obtained***

Kindly submit your response / documents to Dr Shenuka Singh (Chair), **as soon as possible.**

This approval is granted provisionally and the final approval for this project will be given once the above condition has been met. Research may not begin until full approval has been received from the HSSREC.

Yours faithfully

....

Dr Shenuka Singh (Chair)
Humanities & Social Sciences Research Ethics Committe

/pm

cc Supervisor: Prof TC Haupt
cc. Academic Leader Research: Prof C Trois
cc. School Administrator: Ms Nombuso Dlamini

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

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13.5 Appendix 5 – Full Ethical Clearance Approval

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

21 July 2017

Mr Ephraim Zulu 215080940
School of Engineering
Howard College Campus

Dear Mr Zulu

Protocol Reference Number: HSS/1763/016D
Project title: Curriculum Development for an Inquiry approach to Construction Education

Full Approval – Expedited Application

In response to your application received 18 October 2016, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: **Research data should be securely stored in the discipline/department for a period of 5 years.**

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Shamila Naidoo (Deputy Chair)
Humanities & Social Sciences Research Ethics Committee

/pm

cc Supervisor: Prof TC Haupt
cc. Academic Leader Research: Prof C Trois
cc. School Administrator: Ms Nombuso Dlamini

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

13.6 Appendix 6 – Sample Gatekeeper Application Letter

University of KwaZulu-Natal
School of Engineering
Department of Construction Studies
Howard College Campus
Durban 4041

The Registrar
University of KwaZulu-Natal
Privaet5 Bag X54001
Durban

24th October 2016

Dear Sir/Madam,

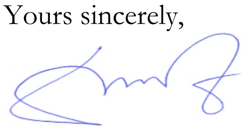
Re: Application for gatekeeper permission to conduct a questionnaire survey for a PhD research study on improving construction education in South Africa

We are conducting a PhD research study which seeks to identify antecedents to effective learning drawn from contemporary theories of learning and practices and to use them to recommend an appropriate philosophy of approaching undergraduate construction education which is based on contemporary theories of learning.

Being guardians of the students at your university while they are on the university premises and in tandem with UKZN research ethics requirements, your consent is required to proceed with the questionnaire survey at your university. Find attached a sample of the questionnaire for your information. The survey is scheduled to take place during the first semester of the 2017 academic year. The survey will target students enrolled in construction related programmes who will be required to complete the attached 4 paged questionnaire which requires between 15 to 30 minutes to complete. Even with your consent, student participation in the survey is completely voluntary and students are guaranteed complete confidentiality in the treatment of their responses and the information collected will be used for academic purposes only.

At your option, publications arising from the study will be made available to you for your information.

Yours sincerely,



Mr Ephraim Zulu
PhD Scholar
Phone: +2731 260 2719 (Office)
Mobile: +2763 873 8739
E-mail: ephraimzulu2000@yahoo.co.uk and zulue@ukzn.ac.za

Prof. Theo C. Haupt
Professor and Program Co-ordinator: Construction Studies,
Phone: +2731 260 2712 (Office)
Mobile: +27 82 686-3457
E-mail: pinnacle.haupt@gmail.com and haupt@ukzn.ac.za

Humanities and Social Sciences Research Ethics Committee
Research Ethics Office
Govan Mbeki Building
Westville Campus
Phone: +2731 260 4557
Fax: +2713 260 4609
E-mail: mohunp@ukzn.ac.za

13.7 Appendix 7 – Gatekeeper Letter 1

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

28 October 2016

Mr Ephraim Zulu
School of Engineering
College of Agriculture, Engineering & Science
Howard College Campus
UKZN
Email: zulue@ukzn.ac.za

Dear Mr Zulu

RE: PERMISSION TO CONDUCT RESEARCH

Gatekeeper's permission is hereby granted for you to conduct research at the University of KwaZulu-Natal (UKZN), towards your postgraduate studies, provided Ethical clearance has been obtained. We note the title of your research project is:

"Curriculum Development for an Inquiry Approach to Construction Education".

It is noted that you will be constituting your sample by handing out questionnaires to students enrolled in construction related programmes on the Howard College Campus.

Please ensure that the following appears on your questionnaire/attached to your notice:

- Ethical clearance number;
- Research title and details of the research, the researcher and the supervisor;
- Consent form is attached to the notice/questionnaire and to be signed by user before he/she fills in questionnaire;
- gatekeepers approval by the Registrar.

Data collected must be treated with due confidentiality and anonymity.

You are not authorized to distribute the questionnaire to staff and students using Microsoft Outlook address book.

Yours sincerely

MR SS MOKOENA
REGISTRAR

Office of the Registrar
Postal Address: Private Bag X54001, Durban, South Africa
Telephone: +27 (0) 31 260 8005/2206 Facsimile: +27 (0) 31 260 7824/2204 Email: registrar@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

13.8 Appendix 8 – Gatekeeper Letter 2

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DIRECTORATE FOR RESEARCH AND POSTGRADUATE SUPPORT

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946
E-mail: moyos@dut.ac.za

20th February 2017

Mr Ephraim Zulu
c/o School of Engineering
Department of Construction Studies
Howard College Campus
University of KwaZulu-Natal

Dear Mr Zulu

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research Committee (IRC) has granted permission for you to conduct your research "Curriculum development for an inquiry approach to construction education" at the Durban University of Technology.

We would be grateful if a summary of your key research findings can be submitted to the IRC on completion of your studies.

Kindest regards.
Yours sincerely

PROF. S. MOYO
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT

13.9 Appendix 9 – Gatekeeper Letter 3

Mangosuthu
University of Technology

UMLAZI - KWAZULU NATAL

P.O. Box 12363 Jacobs 4026 Durban Tel: 031 907 7111 Fax: 031 907 2892

07 July, 2017

Dear Mr E Zulu

Durban University of Technology

It is my pleasure to inform you that permission to conduct project titled: "Curriculum Development for an Inquiry-Based Learning Approach to Construction Education" among MUT academics and students in Quantity Surveying, Construction Management and Civil Engineering, has been granted.

Permission to conduct the project is granted on the condition that any changes to the project must be brought to the attention of the MUT Research Ethics Committee as soon as possible.

Good luck with your research.

Yours faithfully,

Prof. K Shale

Director: Research (Acting)

031 9077354/7450

Karabo.shale@mut.ac.za

13.10 Appendix 10 – Publication 1 - An Analysis of Types of Assessment Questions and Cognitive Loading in Undergraduate Students of Construction Studies at The University of Kwazulu-Natal

ASOCSA2017- [086]

An Analysis of Types of Assessment Questions and Cognitive Loading in Undergraduate Students of Construction Studies at the University of KwaZulu-Natal

Ephraim Zulu

School of the Engineering, College of Agriculture, Engineering and Science, University of Kwazulu-Natal, Howard Campus, King George V Avenue, Durban, 4001, South Africa
zulue@ukzn.ac.za

orcid.org/0000-0002-5999-7808

Theodore C. Haupt

Research Professor: Engineering, Mangosuthu University of Technology, 511 Mangosuthu Highway, Umlazi, Durban, 4031, South Africa
haupt@ukzn.ac.uk

Orcid.org/0000-0002-2531-3789

ABSTRACT AND KEYWORDS

Purpose of this paper. The study aims to quantify the relative amount of cognitive loading induced in students of construction studies by academic problems of varying complexity.

Design/methodology/approach. A deductive quantitative research approach was favoured using a cross sectional questionnaire survey to collect the data. Non probability sampling was used yielding a sample of 75 students from the University of KwaZulu-Natal. Factor analysis, correlation analysis and bivariate linear regression analysis were performed on the data.

Findings. Complex and ambiguous problems account for a much larger variation in cognitive loading compared to worked examples and completion problems.

Research limitations/implications (if applicable). The instruments used are new and their external validity is yet to be established. The results may not be readily generalizable since they are based on a convenience sample.

Practical implications (if applicable). To reduce cognitive loading in students of construction studies with little subject prior knowledge, complex and ambiguous questions should be avoided and simpler problems favoured especially in modules with high item interaction until students have gained sufficient subject knowledge.

What is original/value of paper. New instruments for measuring cognitive loading, use of complex and ambiguous problems, worked examples, completion problems and authentic problems have been suggested and their psychometric properties reported. The paper also provides some validation for findings indicating that complex and ambiguous questions induce high cognitive loading while worked examples and completion problems have much lower cognitive loading.

Response to conference theme. The paper responds to the theme on *Construction education, training and skills development.*

Keywords: Cognitive loading; Worked examples; completion problems; complex questions; authentic questions

1. INTRODUCTION

The cognitive load theory (CLT) posits that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998a). The theory further suggests that since working memory has a very limited capacity, it can be easily overloaded with activities that impede rather than aid learning. University students in general and students studying construction related studies in particular are frequently faced with very high cognitive loading from the heavy curriculum work load they have to deal with. CLT suggests that highly complex academic problems induce high cognitive loading especially in students with little subject prior knowledge while less complex problems induce much less cognitive loading and subsequently aid learning. Some of the less complex academic problems recommended by proponents of the CLT include worked examples and completion problems. Proponents of student centred approaches on the other hand prefer the use of complex and ambiguous questions and authentic problems over less complex ones in inquiry based learning approaches. This study therefore aims firstly to propose a set of instruments for measuring cognitive loading and a number of academic problems of varying complexity and secondly to assess the relative amount of cognitive loading induced in students of construction studies by complex and ambiguous problems, worked examples, completion problems and authentic problems which represent academic problems of varying complexity.

THEORETICAL BACKGROUND

1.1 Cognitive Load Theory

The human memory is comprised of a short-term memory (aka working memory) and a long-term memory and cognition, according to cognitive science, is comprised of processing information on the working memory and subsequently storing it on long-term memory (Moons and De Backer, 2013; Reedy, 2015; Tasir and Pin, 2012; A. Wong, Leahy, Marcus and Sweller, 2012). Working memory has a limited storage capacity and a short information decay period with visual information retained for only about several hundred milliseconds and a verbal-linguistic decay period of about 12 – 30 seconds (Moons and De Backer, 2013 citing Artkinson and Shiffrin, 1968). Long-term memory on the other hand is virtualy unlimited in capacity and has a permanent retention period (Moons and De Backer, 2013). Working memory is used for conscious activity in organising, contrasting, comparing and working on information and while it can hold only about seven items at a single time, it can only process two or three items simultaneously and it is the only memory which can be monitored (Kirschner, 2002; Sweller *et al.*, 1998a). Long term memory (LTM) on the other hand, while unlimited in capacity, its contents cannot be directly monitored unless they are loaded onto working memory.

Based on this architecture of cognition, John Sweller (1946-) postulated the cognitive load theory (CLT) which posits that learning will take place best when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock *et al.*, 2002; Sweller, 1994; Sweller *et al.*, 1998a). The theory further suggests that since working memory has a very limited capacity, it can easily be overloaded with activities that impede rather than aid learning. In this regard, three different loads on working memory have been suggested, vis-à-vis, intrinsic cognitive load (ICL), extraneous cognitive load (ECL) and germane cognitive load (GCL). ICL is the cognitive load demanded by the intrinsic nature of the subject matter being learnt (Bannert, 2002; Kirschner, 2002; van Bruggen et al., 2002). ECL is generated by the design of the instructional approach used in teaching while GCL is the cognitive load generated by the construction and automation of schemata which only occurs when there is free working memory capacity available (Bannert, 2002; Kirschner, 2002; van Bruggen et al., 2002).

Knowledge stored in LTM is stored as schemata. A schema is anything that is learnt and is treated as a single entity by working memory and can incorporate a large and complex amount of information (Kirschner, 2002; van Bruggen et al., 2002). Schema can combine elements of information and production rules and become automated therefore needing less storage capacity and processing (van Bruggen et al., 2002).

CLT suggests that reducing cognitive load will make more working memory available for actual learning (Bannert, 2002). ICL, being intrinsic to subject matter being learnt, cannot be reduced while ECL, which does not contribute to learning but instead, especially for poorly designed instructional approaches, reduces working memory capacity, is the only cognitive load which can be reduced (Bannert, 2002; Kirschner, 2002). Instructional approaches that reduce ECL will also increase GCL provided the total CL remains within the limits (Bannert, 2002; Kirschner, 2002).

Learning will hardly take place if there is little or no schemas in LTM on the subject matter because the cognitive load will be too high (Valcke, 2002). Learning involves storing information including large, complex interactions and procedures in LTM and inducing changes in the structure of the schemata (Sweller *et al.*, 1998a). It is achieved by establishing patterns in data sets which are best chosen based on the simplicity with which they explain the data and connected to existing schemas (Chater and Vitányi, 2003). Existing schemas help to interpret new information and link it with the existing schemas thereby reducing cognitive load because schemas in LTM can be easily manipulated and stored (Valcke, 2002). Owing to the significance of working memory to schemata construction and automation, Kirschner (2002); (Sweller *et al.*, 1998a; Van Gerven *et al.*, 2002) posit that working memory plays a more significant role than intellectual ability in learning new skills because cognition does not stem from complex chains of reasoning in working memory which is incapable of any such complex interaction.

1.2 Types of Assessment Questions

Solving conventional problems in the absence of adequate schemas requires the deployment of a substantial amount of cognitive effort which generates a large extraneous cognitive load and is therefore not ideal for schemata construction or learning (Sweller *et al.*, 1998a). Sweller *et al.* (1998a) argued that "means-end" search increases ECL when students with little subject prior knowledge attempt to solve conventional problems.

One strategy for reducing means-end analysis is studying worked examples which focuses attention on problem states and associated operators therefore reducing cognitive load and helping students to create schemas (Sweller *et al.*, 1998a). The effectiveness of worked examples has been demonstrated by several authors (Fred Paas and van Gog, 2006; Rourke and Sweller, 2009; Schwonke *et al.*, 2009; Sweller, 2006). For example, in an experimental study comparing worked examples, tutored problems erroneous examples which also represented high assistance instruction approaches and untutored problem solving which represented a low assistance instruction approach, McLaren *et al.* (2016a) found that there was no difference based on the instruction approach in learning outcomes. However, significant differences in learning outcomes were found in both instructional approaches based on the worked examples which showed that students expended far less time and effort to achieve the learning outcomes. The reduction in time was between 46% and 68%. Mulder *et al.* (2014) also reported the effectiveness of worked examples in an inquiry based learning scenario. In an experimental study design of IBL through a computer simulation programme where students were required to produce computer models, the experimental group was given heuristic worked examples to refer to while the control group was not given. It was found that the heuristic worked examples improved the students' inquiry behaviour and improved the quality of the computer models produced. However, few students produced a model with evidence of full understanding. It was proposed to improve the worked examples used.

However, some studies on worked examples have found little or no advantage in worked examples over conventional examples. In an experimental study aimed at assessing the efficiency of worked examples over conventional practice problems in both young and elderly adults, Van Gerven *et al.* (2002) found that young students did not profit from worked examples with mean scores even suggesting a negative effect when training with worked examples. In this instance, it was also found that studying using both worked examples and conventional problems produced relatively little cognitive load and led to nearly the same level of performance. However, it was concluded that the young may have attained their upper performance limit.

Completion problems have also been found to reduce cognitive load. In a series of experimental studies comparing completion problems, conventional problems and learner controlled condition van Merriënboer *et al.* (2002) found that completion problems reduce cognitive load and the completion problems group showed the highest training efficiency but a disappointing transfer performance. Mihalca *et al.* (2015) also found that completion problems were effective for students with low subject prior knowledge while students with higher subject prior knowledge performed better with conventional problems.

However, it should be noted that reduction of cognitive load does not guarantee that the free working memory will be used for schemata construction and automation (Bannert, 2002). Free working memory will only be effectively used in learning when the attention of learners is directed away from extraneous cognitive processes towards the germane cognitive processes of schema construction and automation (Bannert, 2002; Sweller *et al.*, 1998a).

All the suggested instructional approaches which consider CLT are applicable to students with little prior knowledge. Worked examples, and completion problems are all reported to lose their advantage in more experienced learners (Hoogerheide *et al.*, 2014; Mihalca *et al.*, 2015; Sweller *et al.*, 1998a; Van Gerven *et al.*, 2002).

2. Research design, strategy and procedures

A deductive quantitative research approach was favoured using a cross sectional questionnaire survey to collect the data because of the objectivity and low cost associated with the use of surveys compared to other methods of data collection and a deductive quantitative research approach lends itself well to descriptive studies. Non probability sampling was used for convenience and economy yielding a sample of 75 2nd and 3rd year students from the University of KwaZulu-Natal in Durban, South Africa. Factor analysis, correlation analysis and bivariate linear regression analysis were performed on the data using IBM SPSS 23.

The scales in the questionnaire were operationalized by developing new instruments after suitable existing instruments could not be found. Four scales were developed for measuring Cognitive Loading (CL), Complex and Ambiguous Questions (CAP), Worked Examples (WE), Completion Problems (CP) and Authentic Problems (APr). While cognitive loading is made up of three components namely, intrinsic, extraneous and germane cognitive loads, for this study, it was conceptualised and operationalised as total cognitive load which therefore reflect only two of the three elements namely intrinsic and extraneous cognitive load. It was conceptualised mainly as the extent to which students felt overwhelmed during their previous semester and so captured total cognitive loading from all academic activities for a period of time. The concept of complex and ambiguous questions was operationalised as the frequency with which assessment questions were complex and ambiguous. The concept of worked example was operationalised mainly as the frequency with which worked examples were used in the various modules over the course of the previous semester and the same for completion problems and authentic problems. The item wording was simplified to make it appropriate for the selected sample to understand since English is not their first language. The instrument was measured on a 5 point Likert scale with 5=almost never; 4=often; 3=sometimes; 2=seldom; and 1=almost never

3. Findings

The items in the measurement instruments are shown in Table 3.1 while the statistics for reliability and validity of the instrument are shown in Table 3.2. The Cronbach's alpha for all the scales ranged between 0.825 to 0.929 and the item-to-total correlations ranged from 0.501 to 0.878 indicating good internal reliability. Composite reliability ranged from 0.667 to 0.895 with one scale falling below the 0.70 recommended threshold and the average variance extracted ranging from 0.502 to 0.712 all above the recommended threshold of 0.50. Cronbach's alpha is affected by the number of measurement items with few items generally yielding low values and therefore the low alpha for the Worked Example measure by three items. Factor analysis using principle components with Varimax rotation and listwise deletion for missing data yielded factor loadings ranging from 0.573 to 0.910 after dropping two items from one scale because they did not converge on the a priori construct. Correlation analysis among the constructs are all less than 0.80 indicate good discriminant validity. Therefore, all the items converged well on their respective constructs and are good measures of their respective constructs.

Table 3.1 Measurement Instrument

Construct		**Mean**	**Std. Dev.**
Complex and Ambiguous Questions	CAQ		
I was given assignments and tests which were difficult to understand and solve	CAQ1	3.250	0.960
I was given problems which did not have enough information for me to solve them	CAQ2	3.153	1.002
I was required to solve questions which were not clear as to what I was expected to do	CAQ3	3.306	1.043
I was given questions which could be interpreted in more than one way	CAQ4	3.292	0.985
I was given problems which were not easy to understand clearly	CAQ5	3.11	0.928
I was given questions which were not expressed clearly	CAQ6	3.056	1.112
Authentic Problems	AP		
I was given problems based on actual industry real life problems	AP1	3.556	0.933
I was expected to use real life situations when doing my school work	AP2	3.817	0.883
I was required to collect some real world information to do my school work	AP3	3.831	0.862

I was given work which was relevant to actual current industry practice	AP4	3.887	0.903
I was required to come up with my own solutions to problems	AP5	3.750	0.868
Worked Examples	WE		
I was given some worked examples to practice on	WE1	3.411	1.039
I was given examples with clearly defined steps on how to solve problems to practice on	WE2	3.438	0.957
I was given problems with model solutions to practice on	WE3	3.274	1.109
Completion Problems	CP		
I was given partially worked examples to complete	CP1	2.767	1.137
I was given partly finished model solutions to problems to finalise the solution	CP2	2.822	1.170
I was given problems which were partly solved to practice on	CP3	2.836	1.214
I was given problems and part of the solution to work on	CP4	3.00	1.323
I was given problems which had gaps that I had to fill in	CP5	2.973	1.213
Cognitive Loading	CL		
I was expected to remember too many things from each lecture	CL1	3.487	0.910
I was overwhelmed with the amount of information I was expected to remember	CL2	3.438	0.882
I was given with too much information during the lectures	CL3	3.324	0.761
The information I was given during lectures was confusing	CL4	3.069	0.983
The information I was given in class was complicated and difficult to understand	CL5	3.162	1.007
I was overwhelmed with the amount of work I had to do	CL6	3.473	1.023
I was given too many projects, assignments and tests	CL7	3.432	0.952

Table 3.2 Measurement Instrument Analysis

Research Constructs		Mean	Cronbach's Test		C.R.	AVE	Item Loadings
			Item-total	α Value			
Complex and Ambiguous Questions	CAQ1	3.194	0.550	0.848	0.744	0.564	0.610
	CAQ2		0.734				0.842
	CAQ3		0.805				0.873
	CAQ4		0.501				0.633
	CAQ5		0.613				0.779
	CAQ6		0.598				0.729
Authentic Problems	AP1	3.794	0.591	0.855	0.813	0.622	0.706
	AP2		0.782				0.865
	AP3		0.761				0.837
	AP4		0.607				0.773
	AP5		0.613				0.753
Worked Examples	WE1	3.374	0.595	0.825	0.667	0.502	0.752
	WE2		0.780				0.753
	WE3		0.685				0.610
Completion Problems	CP1	2.879	0.800	0.929	0.895	0712	0.846
	CP2		0.841				0.887
	CP3		0.878				0.910
	CP4		0.781				0.760
	CP5		0.728				0.807
Cognitive Loading	CL1	3.811	0.473	0.856	0.720	0.543	0.573
	CL2		0.624				0.711
	CL3		0.683				0.779
	CL4		0.535				0.685
	CL5		0.732				0.842
	CL6		0.724				0.822
	CL7		0.604				0.712

Table 3.3 Rotated Component Matrix[a]

	Component			
	1	2	3	4

CAQ1	0.610		0.512	
CAQ2	0.842			
CAQ3	0.873			
CAQ4	0.633			
CAQ5	0.779			
CAQ6	0.729			
AP1		0.706		
AP2		0.865		
AP3		0.837		
AP4		0.773		
AP5		0.753		
WE1			0.752	
WE2			0.753	
WE3			0.610	0.525
WE4				0.649
CP1				0.846
CP2				0.887
CP3				0.910
CP4				0.760
CP5				0.807

The factor analysis with principle component analysis and Varimax rotation with Kaiser normalisation converged in 6 iterations. KMO and Bartlett's test for the factor analysis of 0.782 shown in Table 3.4 indicates a very acceptable sample size for the factor analysis.

Table 3.4 KMO and Bartlett's Test for Types of Questions

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.782
Bartlett's Test of Sphericity	Approx. Chi-Square	860.623
	Df	190
	Sig.	0.000

Work Examples had 4 items but only 3 converged on a single construct after factor analysis while two items from worked examples loaded on completion problems. The distinction between completion problems and worked examples is little and so they exhibit fairly similar properties.

Table 3.4 shows that all the inter-construct correlations are less than 0.80 indicating good discriminant validity. The results indicate that cognitive loading is positively correlated with deep learning but the correlation is weak and not significant while it is moderately positively and significantly correlated with surface learning. Deep learning approach is positively correlated with schema construction and the correlation is moderate and significant at 95% confidence level and surface learning approach is positively correlated with schema construction but the correlation is weak and not significant. Cognitive loading is positively correlated with schema construction, but the correlation is not significant.

Table 3.5 Correlations

		CAQ	AP	WE	CP	CL
CAQ	Pearson Correlation	1				
AP	Pearson Correlation	0.100	1			
WE	Pearson Correlation	0.246*	0.294*	1		
CP	Pearson Correlation	0.271*	0.179	0.592**	1	
CL	Pearson Correlation	0.644**	0.185	0.306**	0.395**	1

*. Correlation is significant at the 0.05 level (2-tailed).

4.1 Regression Analysis

It was expected that cognitive loading would be higher in complex questions (CAP) and the relationship between CL and CAP was tested. The correlation between these two variables is shown in Table 3.5 and is 0.644 and significant at 99% confidence interval suggesting that when the level of complexity of assessment questions increase, the value of CL would increase quite considerably. From the regression Model 1 in Table 3.6, there is a linear relationship between CL and CAP since the R^2 value is greater than 0 (0.415) and the relationship is significant at 99% confidence interval as shown in Table 3.7 with 41.50% variance in CL explained by CAP. The null hypothesis that there is no relationship between CL and CAP is rejected and it can be concluded that there is a statistically significant relationship between the two variables.

It was expected that cognitive loading will be lower when worked examples (WE) were used. The correlation between the two variables is shown is 0.306 and statistically significant at 99% confidence interval and is shown in Table 3.5 suggesting that worked examples also increase the value of CL. The regression Model 2 in Table 3.6 and Table 3.7 show that there is a linear relationship between CL and WE and the relationship is statistically significant at 99% confidence interval with only 9.40% of variation in in CL accounted for by WE.

It was expected that cognitive loading will be lower when completion problems (CP) were used. The correlation between the two variables is 0.395 and statistically significant at 99% confidence interval and the two variables also have a statistically significant linear relationship as shown by the regression Model 3 with 15.60% of variation in CL being explained by CP suggesting that completion problems also induce some cognitive load.

It was expected that cognitive loading will be higher when authentic problems (APr) are used. While there is a positive relationship between the two variables, it is not statistically significant and even the regression Model 4 is not statistically significant. Therefore, any co-variation in the two variables can be attributed to chance.

Table 3.6 Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.644[a]	0.415	0.406	0.52529
2	0.306[b]	0.094	0.081	0.65157
3	0.395[c]	0.156	0.144	0.62864
4	0.185[d]	0.034	0.021	0.67257

Predictors: (Constant), CAP
Predictors: (Constant), WE
Predictors: (Constant), CP
Predictors: (Constant), AP
Dependent Variable: CL

Table 3.7 ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.693	1	13.693	49.626	0.000[b]
	Residual	19.315	70	0.276		
	Total	33.008	71			
2	Regression	3.114	1	3.114	7.334	.008[b]
	Residual	30.142	71	0.425		
	Total	33.256	72			
3	Regression	5.198	1	5.198	13.153	0.001[b]
	Residual	28.058	71	0.395		
	Total	33.256	72			
4	Regression	1.139	1	1.139	2.517	0.117[b]
	Residual	32.117	71	0.452		
	Total	33.256	72			

a. Dependent Variable: CL
b. Predictors: (Constant), CAP

4. Discussion and Implications of Findings

This study reported results of the psychometric properties of the instruments developed and also the results of the measures from the instruments. The results show that cognitive loading follows a continuum with simple type problems being statistically significantly associated with lower levels of cognitive loading and the complex questions being associated with much higher cognitive loading in students consistent with findings by many others. Worked examples represent about the simplest type of problems which can be given to student while completion problems are a little more complex and on the extreme end of the continuum lies complex and ambiguous questions.

These findings have both theoretical and practical implications. The theoretical implications are that by conceptualising and operationalising cognitive loading, use of complex and ambiguous problems, worked examples, completion problems and authentic problems different from other authors, new instruments are proposed for measuring these constructs. The psychometric properties of these instruments indicate that they are reliable measures with good scores for Cronbach's alpha, composite reliability, average variance extracted and item factor loadings and so provide a reliable alternative for measuring these constructs which is of value to any researcher looking to measure these constructs. The new instruments can provide a starting point for establishing the appropriate level of cognitive loading for effective learning. The practical implications for teaching and learning of construction related disciplines are that problems which are highly complex and ambiguous and which are often favoured by construction related disciplines induce comparatively high levels of cognitive loading compared to problems which are more simplistic. Since high levels of cognitive loading impede effective learning especially in students with little subject prior knowledge and more so for modules with high item interaction, it would be more appropriate to assign students with more simplistic problems until they have gained sufficient subject knowledge.

5. Limitations

The study is limited by the fact that measurement instruments used are new and their psychometric properties have not been validated. Therefore, further research on different populations would be required to validate both the measurement instruments and the results of this study. The study is further limited by the fact that the sample used was purposively selected. Therefore, a more representative sample using random sampling over the population of students in construction studies in South Africa would better establish the validity of the results found in this study.

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13.11 Appendix 11 – Publication 2 - An Analysis of Connectionism and Schema Construction in Construction Studies Undergraduate Students

An Analysis of Connectionism and Schema Construction in Construction Studies Undergraduate Students

Ephraim Zulu
Department of Construction Studies.
University of KwaZulu-Natal
Durban, South Africa
ephraimzulu@yahoo.co.uk

Theodore Haupt
Quantity Surveying and Construction Management
Mangosuthu University of Technology
Durban, South Africa
Haupt@ukzn.ac.za

***Abstract*— T**he elements of the old theory of connectionism namely, repetition, reinforcement and readiness have been applied to educational practice for a long time now and still play a significant role in contemporary educational practice. Connectionism is a theory from behaviorism which posits that learning happens when desirable associations between stimulus and response are positively rewarded and so create lasting associations. Many studies have reported the efficacy of the elements of connectionism in educational practice. However, being an old theory, its usefulness in relation to modern learning theory is little researched. Therefore, this study investigates the significance of the elements of connectionism in relation to the contemporary conception of learning as schema construction as defined by the contemporary schema theory. A schema is a set of common and logical notions which constitute a network of relationships that make up a person's knowledge and understanding structure. Factor, correlation, and regression analyses and an independent samples *t*-test show that connectionism is relevant to the creation of schemata. Readiness was found to be the most significant element from connectionism relevant for schema construction with a coefficient of determination (R^2) of 0.49 and a medium to large effect size. Therefore, while repetition and reinforcement have significant contributions to schema construction, the extent to which students are physically, emotionally and psychologically ready to learn is very important to achieving effective learning.

Keywords—Connectionism; Schema Construction; Repetition; Reinforcement; Readiness

I Introduction

Connectionism is an old theory about learning derived from the field of behaviorism. It was psychologies' first theory of learning and has played a significant role in shaping educational practice. It posits that learning is a behavior which happens when sufficient response-reinforcement (R-R) associations get positively rewarded and so create lasting connections between the R-R associations. This is based on the law of effect or reinforcement, the law of readiness and the law of repetition [1]. Repetition, reinforcement and readiness have been applied to educational practice for a long time now and their importance to learning have been validated by many studies. Being an old theory, its efficacy to modern educational practice is little researched. For example, its relationship with contemporary conceptions of learning based on schema theory is not researched.

Therefore, this study seeks to establish whether the tenets of connectionism still play a significant role in contemporary educational practice. The study specifically sought to establish the relative contribution of each of the three facets of connectionism, namely repetition, reinforcement and readiness, to schema construction among students of Construction Studies.

To achieve the objective, data were assessed for reliability and validity and met the minimum accepted requirements. The data were also assessed for suitability to perform parametric tests and found suitable. Finally, regression analysis and an independent samples *t*-test were performed to establish the relative contribution of each of the three facets of connectionism to schema construction. The paper starts with a review of the literature which is divided into the theoretical grounding of the study followed by an empirical review of each of the study variables. The research study design is then presented followed by the results and their discussion and then the study implications and limitations.

II Connectionism

A. Theoretical Grounding

The theory of connectionism is a learning theory which states that learning happens when sufficient response-reinforcement (R-R) associations are positively rewarded. The associations then create lasting connections between the R-R associations in tandem with the law of effect, the law of readiness and the law of repetition. It is a theory from behaviorism which draws from operant conditioning suggested by B.F. Skinner (1904 – 1990) and furthered by Edward Thorndike (1874-1949). Thorndike used operant conditioning to suggest three laws of learning which are readiness, repetition and effect and application [1]. B.F. Skinner (1904 – 1990) showed that repeating R-R associations led to the associations being firmly established [1].

B. Repetition

Repetition has received wide educational application and several authors have showed that it still has significant modern applications [2-5]. One of the most significant applications of repetition in education is spaced repetition which involves the review of study material at intervals to aid retention [6]. Repetition has also received wide application in the learning of a second language [7, 8].

C. Reinforcement

Besides repetition, B.F. Skinner (1904 – 1990) found that reinforcement was an important factor in creating lasting R-R associations. Reinforcement is widely used in educational practice and several authors have reported its efficacy in learning. For example, Valeria and Maria [10] recommended positive reinforcement for 7-8-year-old pupils to encourage them to act on their knowledge of environmental related attitudes and behaviors. In a study of primary school pupils from Slovakia and from England, Andreánska [11] found that intercultural differences in educational systems are reflected in the perception of rewards and punishment of students in England and Slovakia. The effect of reinforcement has also been explored with educational games.

D. Readiness

The law of readiness posits that people learn best when they are physically, mentally and emotionally ready to learn. Readiness was found to influence the extent to which students adapt to a higher learning environment [12]. Literature on the state of readiness of students for learning is very scant. Most research dealing with student readiness focuses on the readiness of students to engage in a program of study among other aspects rather than readiness for lectures [13-15].

E. Schema Construction

A schema is a group of common and logical notions which constitute a network of relationships that make up a person's knowledge and understanding structure. It is anything that is learnt and is treated as a single entity by working memory [16]. It can incorporate a large and complex amount of information [16]. The development and automation of schemata are very cardinal to effective learning [17].

Schemata and its automation are important, necessary and cardinal to the ability to apply acquired knowledge and skills to situations and problems different from those in which the knowledge was acquired [18,19]. This is because problem solving involves recognizing that a particular problem is related to a particular set of schemata and identifying the related operations to reach a solution [18, 19].

III Research Methods

A. Research Design

The study follows a quantitative research design and a positivist philosophy using a deductive research approach because it sought to test relationships among the study variables to which the quantitative design, a positivist philosophy and a deductive approach are all suited. A cross sectional questionnaire survey was the favored data collection method due to the objectivity and low cost associated with its use compared to other methods of data collection. Non probability sampling was used for convenience and economy.

B. Operationalization

The scales in the questionnaire were developed for this study since no suitable measures were found. Four measures were used namely repetition (5 items), reinforcement (5 items), readiness (4 items) and schema construction (7 items). Repetition was operationalized on the basis of the frequency with which lecturers repeated, whole lectures, parts of lectures or emphasized main aspects of the learning material. Reinforcement was operationalized on the basis of the frequency with which the lecturers recognized, complemented, praised, rewarded or encouraged good conduct and good work. Readiness was operationalized on the basis of the extent to which students prepared physically, emotionally as well as mentally to engage in learning when they turned up for classes. The operationalization of repetition, reinforcement and readiness are all in tandem with their description as postulated in the theory of connectionism [1, 6]. Schema construction was operationalized as the extent to which students were encouraged to create associations of any new knowledge with knowledge they already possessed and also the extent to which they attempted to achieve this on their own. The questionnaire along with the study were reviewed by the university research ethics committee and approved. The items in the questionnaire are shown in Table II. The instrument was measured on a 5 point Likert scale with 5=almost never; 4=often; 3=sometimes; 2=seldom; and 1=almost never.

C. Data Collection Procedure

The questionnaires were circulated to students who had gathered for a talk by a professional body. The students were not informed beforehand that questionnaire will be circulated. Therefore, attendance was not influenced by the study. Notwithstanding, the attendance may have been influenced by the talk, with students who may have found the talk unnecessary absconding. However, no evidence suggests that some students preferred not to attend the talk and so it can be concluded that the available sample of students was representative of the population of interest and that students who absconded were purely random.

Students were requested to fill in the questionnaire at the end of the talk after explaining to them the details of the study and the instruction for filling in the form. The students were informed of their right to not participate in the study if they did not wish to do so and they were assured of confidentiality and anonymity if they chose to participate. An informed consent form was circulated along with the questionnaire to ensure adherence to ethical research conduct. A sample of 75 2nd and 3rd year students studying towards a bachelor's degree in Construction Studies from a public university in South Africa was obtained.

IV Results and Data Analysis

A. Demographic Information of Respondents

Table I shows the profile of the respondents. The profile shows a fairly even distribution in terms of the level of study while there are more male students than there are girls. The gender distribution is consistent with the general proportion of students across the program surveyed.

TABLE 1. DEMOGRAPHIC INFORMATION

Year of Study	Frequency	Percentage
1	20	27.0%
2	13	17.6&
3	18	24.3%
4	23	31.1%

Total	74	100%
Gender	**Frequency**	**Percentage**
Male	46	62.2%
Female	28	37.8%
Total	**74**	**100%**

B. Reliability and Validity of Measurement Instrument

The measurement instrument for the constructs under study is shown in Table II. The instrument was subjected to factor analysis with principle components extraction and Oblimin with Kaiser Normalization rotation and using eigenvalues greater than 1. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.795 which indicates that the sample is sufficient for factor analysis. The analysis produced 4 factors with all items loading on the *a priori* constructs with no cross loadings when factor loadings less than 0.50 were suppressed. The four factors explained 67% of the total variance explained. The factor loadings are fairly strong and shown in Table III.

TABLE II. MEASUREMENT INSTRUMENT

		Mean	Std. Dev.
Repetition	***REP***	***3.594***	
My lecturers covered the key points of a lecture more than once	REP1	3.822	0.788
My lecturers Repeated some lectures	REP2	3.135	1.162
Some topics were covered more than once	REP3	3.417	1.017
My lecturers emphasised the key points of a lecture by Repeating themselves	REP4	3.726	0.804
Reinforcement	***REF***	***3.140***	
I was complimented for good conduct and doing good work	REF1	3.260	1.080
I was recognised for good conduct and doing good work	REF2	3.192	1.076
I was rewarded for good conduct and doing good work	REF3	2.918	1.115
I was praised for good conduct and doing good work	REF4	2.959	1.184
I was encouraged when my conduct and work were good	REF5	3.370	1.173
Readiness	***RED***	***3.472***	
I was emotionally, physically and mentally ready to learn	RED1	3.541	1.125
I was well prepared for the lectures	RED2	3.534	1.107
I was ready to learn when I went for lectures	RED3	3.575	1.079
I prepared adequately for class	RED4	3.243	1.156
I was well rested (not tired) when going to lectures	RED5	3.122	1.216
Schema Construction	***SCO***	***3.811***	
My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject	SCO1	3.878	0.776
My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew	SCO2	3.770	0.768
I connected points that I already knew with what I was being taught in class	SCO3	3.716	0.884
I organised, categorised or connected anything new that I learnt with what I already knew	SCO4	3.689	0.859
My lecturers clearly highlighted the main concepts and principles	SCO5	4.000	0.860

After factor analysis, the resulting constructs were assessed for reliability and validity. Reliability was assessed with Cronbach's alpha and item-to-total correlations while convergent validity was assessed using composite reliability (CR) and Average Variance Extracted (AVE) and discriminant validity was assessed using inter-construct correlations which should be less that the square root of AVE. The reliability statistics are shown in Table III. The Cronbach's alpha for all the scales was above 0.70 and item-to-total correlations greater than 0.50 which means the scales meet the minimum criteria for acceptability. All but one construct had a composite reliability less than the recommended 0.70 at 0.682 while all the AVE were above the recommended 0.50. Therefore, all items converged very well on the respective constructs and exhibited fairly good psychometric properties.

Correlation of the summated scales was used to assess construct discriminant validity. The correlations are shown in Table IV. All the inter-construct correlations are less than 0.80 indicating a good general discriminant validity because no two constructs are too strongly correlated and so each depicts a different concept. Also, all inter-construct correlations are less than the square root of the respective AVE. All constructs are significantly correlated with SCO consistent with the theory of connectionism and so the constructs have good discriminant validity. Further, it is not surprising that REP is significantly correlated with REF (p=0.01) since it should be expected that students are most likely going to receive some reinforcement in the process of repetition of subject matter in class. It is also not surprising that REF is correlated with RED (p=0.05) since students who are well prepared to learn are likely to perform well and will therefore receive positive reinforcement from the lecturer. The absence of a significant relationship between REP and RED further provides evidence of discriminant validity since the extent to which a student is ready for class cannot influence or be influenced by the extent to which the lecturer repeats aspects of the lesson. The measurement scales therefore exhibit very good discriminant validity.

C. Regression Analysis

Having assessed that the instrument is fairly reliable and valid, relationships among the variables were tested. A normality test was performed to assess whether the bivariate relationship needed to be assessed with parametric or non-parametric tests. Results of the Shapiro-Wilk normality test shown in Table V indicate that all scales (p=0.174; p=0.161 and p=0.06), save for RED (p=0.001) show evidence of being drawn from a normally distributed population because a significant ($p<0.05$) test statistic for the Shapiro-Wilk test suggests that the data are significantly different from a normal distribution. Since the RED variable was negatively skewed, a reflect and Log10 transformation was performed using the formula NEWREDx = (6-REDx). The constant 6 was used based on the of criteria of the largest possible variable value, which was 5 from the 5-point Likert scale, plus 1 so as to yield reflected values greater than zero. Both the original and transformed normality statistics for RED are shown in Table V. Since all the variables are now normally distributed, parametric analyses can be performed.

TABLE III. MEASUREMENT INSTRUMENTS ANALYSIS

Research Constructs		Mean	Cronbach's Test		C.R.	AVE	Item Loadings
			Item-total	α Value			
Repetition	REP1	3.594	0.459	0.813	0.777	0.590	0.680
	REP2		0.639				0.819
	REP3		0.712				0.822
	REP4		0.702				0.795
	REP5		0.563				0.713
Reinforcement	REF1	3.140	0.761	0.918	0.901	0.718	0.827
	REF2		0.852				0.887
	REF3		0.824				0.865
	REF4		0.767				0.805
	REF5		0.747				0.853
Readiness	RED1	3.472	0.771	0.909	0.914	0.738	0.846
	RED2		0.857				0.902
	RED3		0.851				0.881
	RED4		0.707				0.803
Schema Construction	SCO1	3.811	0.514	0.792	0.682	0.513	0.809
	SCO2		0.618				0.683
	SCO3		0.615				0.715
	SCO4		0.649				0.731
	SCO5		0.471				0.631

TABLE IV. CORRELATIONS BETWEEN CONSTRUCTS

Construct	REP	REF	RED
REP	1		
REF	0.233*	1	
RED	0.192	0.399**	1
SCO	0.302**	0.328**	0.498**

TABLE V. TESTS OF NORMALITY

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
REP	0.113	73	0.021	0.976	73	0.174
REF	0.114	73	0.019	0.975	73	0.161
RED	0.138	73	0.001	0.931	73	0.001
REDT	0.100	73	0.062	0.968	73	0.054
SCO	0.101	73	0.062	0.968	73	0.060

a. Lilliefors Significance Correction

To assess how well the independent variables explain the dependent variable, a total of 4 linear regression models comprising of 3 bivariate linear regression models and 1 multiple linear regression model were run. Linear regression was used because a visual inspection of normal probability plots (P-P plots) showed that the variables visibly shared a linear relationship and so are suitable for regression analysis.

Model 1 regressed REP with SCO as the independent variable yielding an R^2 of 0.091 (p=0.009) shown in Table VI and Table VII. Therefore, REP accounted for 9.10% variation in SCO in the bivariate relationship and the variation is significant at 99% confidence interval (CI). Model 2 regressed REF with SCO as the independent variable yielding an R^2 of 0.108 (p=0.005) shown in Table VI and Table VII. Therefore, REF accounted for 10.80% of the variation in SCO in the bivariate relationship and the variation is significant at 99% CI. Model 3 regressed RED with SCO as an independent variable yielding an R^2 of 0.239 (p=0.000) shown in Table VI and Table VII. Therefore, RED accounted for 23.90% variation of SCO in the bivariate relationship and the variation is significant at 99% CI. All the three facets of connectionism significantly contribute to schema construction with readiness accounting for a larger contribution that repetition and reinforcement.

TABLE VI. MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.302[a]	0.091	0.079	0.589
2	0.328[a]	0.108	0.095	0.588
3	0.498[a]	0.248	0.238	0.536

a. Predicators: (Constant), REP
b. Predicators: (Constant), REF
c. Predicators: (Constant), RED

TABLE VII. ANOVAA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.512	1	2.512	7.234	0.009[b]
	Residual	24.999	72	0.347		
	Total	27.511	73			
2	Regression	2.957	1	2.957	8.565	0.005[b]
	Residual	24.509	71	0.345		
	Total	27.466	72			
3	Regression	6.831	1	6.831	23.783	0.000[b]

	Residual	20.680	72	0.287
	Total	27.511	73	

a. Dependent Variable: SCO
b. Predicators: (Constant), REP
c. Predicators: (Constant), REF
d. Predicators: (Constant), RED

Finally, a multiple regression model with SCO as the dependent variable and REP, REF and RED as independent variables was run to assess how well the collective of the variables explain the variation in SCO. This is necessary to establish what the overall effect of the three treatments would be on SCO since the treatments would hardly be administered independent of each other in class.

Model 4 is the multiple linear regression model and it yielded an adjusted R^2 of 0.273 (p=0.000) shown in Table VIII and Table XI. For multiple regression analysis, the adjusted R^2 rather than the R^2 is preferred as a measure of the amount of variation explained. Therefore, the collective of REP, REF and RED account for 27.30% of variation in SCO and the variation is significant at 99% CI. The total amount of schema construction explained by connectionism is 27.30%. Given that readiness on its own accounted for 23.90% while repetition and reinforcement accounted for 9.10% and 10.80% respectively, readiness is comparatively much more important to schema construction than repetition and reinforcement.

TABLE VIII. MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
4	0.551[a]	0.303	0.273	0.53658

a. Predicators: (Constant), RED, REP, REF

TABLE XI. ANOVA[A]

Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	8.334	3	2.778	10.018	0.000[b]
	Residual	19.133	69	0.277		
	Total	27.466	72			

a. Dependent Variable: SCO
b. Predicators: (Constant), RED, REP, REF

A. Independent Samples t-test

Having shown that REP, REF and RED have statistically significant relationships with SCO with varying amounts of variation in SCO explained by each of the variables individually but also collectively, it is important to assess the magnitude of the effect of each of the independent variables on SCO. To achieve this, an independent samples t-test was performed. The independent samples t-test is appropriate for the data since the data were shown to come from a normally distributed population based on the results of the Shapiro-Wilk test shown in Table V. However, the original, rather than the transformed values for RED were used since reflecting and transforming data changes the means and the *t*-test is still "reasonably robust" to violations in normality. The SCO data were split into two halves to create a grouping variable with a lower and upper half of the SCO scores. The two halves were created by keeping the two sample sizes in each half as close to each other as possible. Therefore, the lower half of the scores was defined by summated scores equal to or less than 3.60 and the upper half was defined by summated scores greater than 3.60. this grouping yielded a lower half sample size of 35 and an upper half sample size of 39. The respective groups were labeled LoSCO for the lower summated scores of SCO and HiSCO for the upper summated scores.

TABLE X. GROUP STATISTICS

	SCO	N	Mean	Std. Deviation	Std. Error Mean
REP	LoSCO	35	3.385	0.737	0.125
	HiSCO	39	3.782	0.632	0.102
REF	LoSCO	34	2.794	0.982	0.168
	HiSCO	39	3.441	0.879	0.141
RED	LoSCO	35	3.155	0.994	0.168
	HiSCO	39	3.756	0.897	0.144

Table XI. t-TEST FOR EQUALITY OF MEANS

						95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
REP	2.476	67.412	0.016	0.397	0.160	0.077	0.718
REF	2.948	66.888	0.004	0.647	0.219	0.209	1.085
RED	2.723	68.923	0.008	0.602	0.221	0.161	1.043

The resulting descriptive scores are shown in Table X and show that respondents with HiSCO had higher mean scores for all variables (REP, REF and RED). The t-statistics in Table XI show that the differences in the mean scores between HiSCO and LoSCO is statistically different (p=0.016, p=0.004, p=0.008) with all the variables (REP, REF, RED). Therefore, students with higher mean scores in REP, REF and RED all ranked in the HiSCO bracket.

The effect size was computed to establish the effect of each of the treatments (REP, REF and RED) on SCO. Two measures for effect size associated with the independent samples t-test were computed namely the Cohen's d and the effect size *r*.

Cohen's d can be calculated using the formula:

$$d = 2t / \sqrt{(df)}$$

Effect size *r* can be calculated using the formula:

$$r_{y} = \sqrt{(t^2 / (t^2 + df))}$$

The results for the effect sizes for the study constructs are shown in Table XII while their interpretation is shown in Table XIII. Cohen's d for all the constructs is greater than 0.50 but less than 0.80 indicating a medium to large effect while all the effect size r are greater than 0.25 indicating a large effect. Therefore, the effect of REP, REF and RED on SCO lies between medium to large.

TABLE XII. COHEN'S d AND EFFECT SIZE r_{y1}

	Cohen's d	r_{yi}
REP	0.603	0.289
REF	0.721	0.339
RED	0.656	0.312

TABLE XIIII. NTERPRETATION OF COHEN'S d AND EFFECT SIZE r

Cohen's d		Effect sire *r*
0.20	Small effect	0.01
0.50	Medium effect	0.09
0.80	Large effect	0.25

V Discussion of Findings

This study sought to establish the relative contribution of each of the three facets of connectionism, namely repetition, reinforcement and readiness, to schema construction. among students of construction studies. While many studies have reported the relationship between these variables and learning, this study used a different conception of learning derived from cognitive science and schema theory in particular. The study also developed new measures for repetition, reinforcement and readiness based on the laws of effect, repetition and readiness which underpin the theory of connectionism from behaviorism.

The results indicate that the impact of readiness on schema construction was more than twice that of each of the other two factors. Therefore, the extent to students are ready to learn when they enter the learning spaces is very important to the ability of students to engage in meaning learning. The results also, corroborate other findings on connectionism. They indicate that repetition, reinforcement and readiness from connectionism are necessary factors for learning and further highlight the relative importance of each of these factors to effective learning. All the three factors were found to have statistically significant associations and small to medium impact with schema construction and with effect sizes ranging between medium and large. Therefore, repetition of key lessons by lecturers help students to construct and automate schemata which is the creation of lasting associations between any knew information presented to them with knowledge they already possess. This is consistent with the theory of connectionism that learning happens when sufficient response-reinforcement associations are positively rewarded thereby creating lasting connections. Reinforcement of the learning activities by lecturers helps students with the construction and automation of schemata by reassuring them that they are doing the right thing and that they should persist when the reinforcement is positive. The extent to which students are ready to learn when they come to class also affects the extent to which the students will engage in the construction and automation of schemata. Generally, the more key lessons are repeated, reinforced and students are ready for classes, the more students will engage in meaningful learning by constructing and automating schemata. Among the three factors, readiness was found to be more important to schema construction than repetition and reinforcement.

Albeit being fairly dated, the theory of connectionism is still very relevant to contemporary educational practice. It can be incorporated in contemporary pedagogy to achieve effective learning. Therefore, incorporating elements of repetition, reinforcement and readiness in curriculum delivery can positively influence effective learning.

VI Implications of the study

The study has both practical and theoretical implications pertaining to the ability of students to engage in effective learning through the construction and automation of schemata. The practical implications are relevant for both students and lecturers.

Practical implications are that lecturers should try as much as possible to repeat key aspects of all lessons to help students grasp fundamental concepts necessary for the students to build relevant schemata. Lecturers should also reinforce the student learning activities so that students feel encouraged to continue with desired activities. More importantly, students should be encouraged to be rested, well prepared and ready to learn by being physically, emotionally and mentally ready to participate in class.

Theoretical implications of the study are that it provided an indication of the relative importance of the three factors from connectionism. The study further corroborates other findings on the relationship between connectionism and learning. Also, because connectionism is an old theory, in light of newer theories and resulting pedagogies, connectionism runs the risk of being relegated from teaching and learning. Therefore, the findings from this study highlight that, old as it may be, when considered in relation to the more contemporary schema theory, connectionism is still relevant to education practice.

VII Limitations and future research

While the study has some significant practical and theoretical contributions, it was limited in some ways and so some future research avenues are suggested. Firstly, the data were collected from one university and the sample size of 74 is relatively small. Also the instruments are new and their psychometric properties have not been validated with other populations. Therefore, future studies can be extended to a larger geographical area of the country and the instruments tested with other populations. Further, several other factors influence the extent to which students engage in schema construction and automation and so will mediate and moderate the relationship between learning and repetition, reinforcement and readiness. For example, motivation and even social economic background are likely to affect the relationship between schema construction and repetition, reinforcement and readiness. Therefore, future studies can expand the conceptual model to include other factors so that the moderating or mediating effect of these can be understood.

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13.12 Appendix 12 – Publication 3 – The Influence of Cognitive Loading on Schema Construction and Automation and Approaches to Learning in Students Studying Construction

The Influence of Cognitive Loading on Schema Construction and Automation and Approaches to Learning in Students Studying Construction

Ephraim Zulu
Department of Construction Studies.
University of KwaZulu-Natal
Durban, South Africa
ephraimzulu@yahoo.co.uk

Theodore Haupt
Quantity Surveying and Construction Management
Mangosuthu University of Technology
Durban, South Africa
Haupt@ukzn.ac.za

***Abstract* —** Cognitive loading is important to learning because effective learning cannot happen if the memory capacity of students is overloaded. Effective learning consists in creating and automating schemata. To achieve learning, students adopt different approaches to learning. Based on the cognitive load theory, it cannot be expected that schema construction and automation will happen if the memory limits of students are exceeded notwithstanding what approach to learning students adopt. Several empirical studies have reported the relationship between cognitive loading and learning and between approaches to learning and academic achievement. However, no attention has been given to the relationship between cognitive loading and approaches to learning. Therefore, this study sought to investigate this relationship using factor, correlation and regression analyses. The study further investigated the relationship between cognitive loading and learning by conceptualizing learning as schema construction and also the relationship between schema construction and approaches to learning. The findings show that cognitive loading is influenced by learning approach. The results also corroborate other findings on the relationship between cognitive loading and learning and between approaches to learning and effective learning.

Keywords—cognitive loading; schema construction; learning approaches; construction students; cognitive load theory

I Introduction

Cognitive loading is important to learning because effective learning cannot happen if the cognitive load induced by learning exceeds the capacity of working memory [4, 6, 7]. Learning consists of creating and automating schemata. In response to their assigned work, students use different approaches to learning. Several studies have reported the relationship between cognitive loading and learning and between approaches to learning and academic achievement. However, it is still unknown how different learning approaches favored by students affect cognitive loading and how schema construction is influenced by learning approaches favored by students. It is also unclear how cognitive loading affects schema construction and automation as postulated by schema theory. The influence of cognitive loading on schema construction could be important for learning because effective learning consists of creating and automating schemata which would, according to the cognitive load theory, be impeded by cognitive overload. Different approaches to learning could have an influence on both cognitive loading and schema construction and automation. This study therefore addresses three main objectives namely:

1. The amount of cognitive loading induced by either the surface of a deep learning approach
2. The amount of cognitive loading induced by engaging in schema construction and automation
3. The amount of schema construction and automation which can be explained by either the surface or a deep learning approach

To achieve the objectives, the data were assessed for reliability and validity and met the minimum accepted requirements. The data were also assessed for suitability to perform parametric tests and found suitable. Finally, regression analysis was performed to establish how much of cognitive loading was explained by the different approaches to learning and by schema construction and automation and how much of schema construction and automation were explained by the different approaches to learning.

II Literature Review

A. Cognitive Load Theory

The cognitive load theory (CLT) postulates that learning happens when the cognitive load in working memory is directed towards construction and automation of relevant schemata [4-6]. Further, since working memory has a very limited capacity, it can be easily overloaded with activities that impede rather than aid learning [4-6]. This postulation is based on the information processing theory of cognition which posits that human cognition involves processing of information stored in long term memory (LTM) which is brought to working memory [6-8]. Working memory can hold about seven items at a single time and can only process two or three items simultaneously [6, 7]. Long term memory (LTM), on the other hand, is unlimited in capacity but its contents cannot be directly monitored unless they are loaded onto working memory. CLT suggests that reducing cognitive load will make more working memory available for actual learning [9].

B. Cognitive loading

Cognitive load is the cognitive effort or mental load on working memory expended in executing cognitive functions such as perceiving, thinking and learning among others. Sweller, Merrienboer, and Paas [6] suggest that cognitive loading plays a more important role in learning than does intellectual ability. Because working has a very limited capacity, it tends to get overloaded and overwhelmed when its limits are stretched. Cognitive overload often manifests as stress with students with lower levels of cognitive load exhibiting less stress compared to those with high levels of cognitive load [2, 10]. Instructional approaches which induce lower levels of cognitive load result in better learning outcomes for students [7, 11, 12]. Therefore, lower levels of cognitive loading induced in students will work to yield more effective learning than when the memory limits of students are ignored and the cognitive load is left to exceed the memory limit. Scheiter, Gerjets, Vollmann and Catrambone [10] found that students with lower levels of cognitive load exhibited better problem-solving performance. Similar circumstances and learning environment induce different levels of cognitive load in the students [13, 14]. Therefore, individual differences influence the amount of cognitive loading experienced by students.

C. Schemata

A schema is anything that is learnt and is treated as a single entity by working memory and can incorporate a large and complex amount of information [7]. It is therefore a cognitive structure which holds a set of information often as a group of common and logical notions which constitute a network of relationships that make up a person's knowledge and understanding structure. Learning will hardly take place if there is little or no schemata in LTM on the subject matter because the cognitive load will be too high. Learning involves storing information including large, complex interactions and procedures in LTM and inducing changes in the structure of the schemata [6]. Existing schemata help to interpret new information and link it with the existing schemas thereby reducing cognitive load because schemata in LTM can be easily manipulated and stored. Schemata is also important to problem solving because problem solving involves recognizing that a particular problem is related to a particular set of schemata and identifying the related operations to reach a solution [11, 16]. Therefore, educational instruction should focus on directing students to acquire new schemata and automating existing ones [11, 16]. Several studies have reported that managing cognitive load in students leads to better learning and academic achievement [11, 15] and so better schema construction and automation.

D. Approaches to learning

Approach to learning refers to the strategies adopted by students in responding to learning situations and the way they do their assigned work [1]. Students differ in their approaches to learning and this has a direct influence on their academic achievement [1-3]. Learning approaches are generally grouped into two, namely deep approaches and surface approaches [1-3]. Deep learning approaches consist of exploring a topic to the greatest possible extent to achieve a greater understanding of the topic while surface learning consist of learning only what is needed to pass and are often characterized by superficial knowledge of the topic through memorization. Students were found to change their learning approach when subjected to different levels of cognitive loading [13]. Several studies have reported the importance of learning approaches to academic achievement. For example, deep learning approaches were found to positively influence mathematics achievement while surface approaches negatively influenced it [17].

Deep learning leads to better academic achievement because it develops new knowledge by integrating prior knowledge with new ideas, information and concepts [18, 19]. It expands the knowledge base and creates knowledge previously unknown to the student by focusing on the underlying meaning of the information [18, 19]. Deep learning develops the learning creativity of students and emanates from a higher need for cognition which is the tendency to engage in and enjoy effortful cognitive activities and thinking [20]. Surface learning is associated with a low need for cognition which has no interest in effortful cognitive activities [20]. It is characterized by assimilating information often through rote learning to avoid failing tests or exams rather than to understand the concepts and how they apply in different circumstances [1]. It does not lead to much meaningful learning. Hasnor, Ahmad and Nordin [1] found surface approach to be inversely related to academic achievement.

III Methodology

A. Research Design

The study follows a quantitative research design and a positivist philosophy using a deductive research approach because it sought to test relationships among the study variables to which the quantitative design, a positivist philosophy and a deductive approach are all suited. A cross sectional questionnaire survey was the favored data collection method due to the objectivity and low cost associated with its use compared to other methods of data collection. Non probability sampling was used for convenience and economy.

B. Operationalization

The scales in the questionnaire were operationalized on the basis of existing instruments where these were available while new ones were developed for measures without scales appropriate to the study. The deep learning scale was adapted from the National Survey of Student Engagement (NSSE) which is a survey of student engagement administered to a representative sample of university students in the United States of America [23]. The item wording was simplified to make it appropriate for the selected sample to understand since English is not their first language. Surface learning was operationalized by adapting two items from an existing instrument and adding three more items all focusing on the extent to which students attempt to memorize study material. Schema construction and cognitive loading were developed by the authors after suitable existing measures could not be found. Cognitive loading was operationalized mainly as the extent to which students are overwhelmed by the amount of assigned work and being expected to remember too much information which was complex, difficult and confusing to understand. This conception is shared by others [14, 21] and is also supported by the findings which show that high levels of cognitive loading lead to students being overwhelmed [10, 2]. Schema construction was operationalized as the extent to which students were encouraged to create associations of any new knowledge with knowledge they already possessed and also the extent to which they attempted to achieve this on their own. The questionnaire, along with the entire study, were reviewed by the university research ethics committee and approved. The instrument was anchored on a 5 point Likert scale with 5=almost never; 4=often; 3=sometimes; 2=seldom; and 1=almost never.

C. Data Collection Procedure

The questionnaires were circulated to students who had gathered for a talk by a professional body. The students were not informed beforehand that a questionnaire would be circulated. Therefore, attendance was not influenced by the study. No evidence suggests that there was any systematic order to the nature of students who did not to attend the talk. Therefore, absconding students were purely random and it can be concluded that the available sample of students was representative of the population of interest and that students. Students were requested to fill in the questionnaire at the end of the talk after explaining to them the details of the study and the instructions for filling in the form. The students were informed of their right to not participate in the study and to withdraw at any time for any reason. The students were also assured of both confidentiality and anonymity if they chose to participate. A sample of 74 students studying towards a bachelor's degree in Construction Studies at a public university in South Africa was obtained.

IV Results and Data Analysis

A. Demographic Information of Respondents

Table I shows the profile of the respondents. The profile shows a fairly even distribution in terms of the level of study while there are more male students than there are girls. The gender distribution is consistent with the general proportion of students across the program surveyed.

TABLE I. MEASUREMENT INSTRUMENTS ANALYSIS

Year of Study	**Frequency**	**Percentage**
1	20	27.0%
2	13	17.6&
3	18	24.3%
4	23	31.1%
Total	**74**	**100%**
Gender	**Frequency**	**Percentage**
Male	46	62.2%
Female	28	37.8%
Total	**74**	**100%**

B. Preliminary Analysis – Reliability and Validity of Measuring Instrument

The measurement instruments for the constructs under study are shown in Table II. Due to pagination limitations, only the first two items per construct are shown. The instrument was subjected to factor analysis using eigenvalues greater than 1 with principle components extraction and Oblimin with Kaiser Normalization rotation and produced 9 factors with 3 of the factors arising from cross loading. Therefore, 6 interpretable factors were retained. Oblimin rotation was favored because it is an oblique rotation method and so accounts for correlations among the factors since some research constructs were correlated. All items loaded on the *a priori* item groupings except for the items measuring a deep learning approach which factored into three rather than four interpretable factors with items as shown in Table III. The factors loadings for the respective items are relatively strong and are shown in Table III.

After factor analysis, the resulting factors were assessed for reliability and validity. Reliability was assessed with the Cronbach's alpha, item-to-total correlations, composite reliability (CR) and average variance extracted (AVE) while discriminant validity was assessed using inter-construct correlations.

TABLE II. MEASUREMENT INSTRUMENT

		Mean	Std. Dev
High Order Learning	***HL***		
I studied the basic elements of a point, an idea, experience, or theory. in depth and considered its components	HL1	3.616	0.775
I combined and organized points, ideas, information, or learning experiences into new and more complex understanding. interpretations or relationships	HL2	3.521	0.729
Integrative Learning	***IL***		
I worked on assignments or projects that required using ideas or information from various sources and modules	IL1	4.288	0.808
I looked at problems from several different points of view in class discussions or when writing assignments	IL2	3.836	0.746
Reflective Learning	***RL***		
I thought about the strengths and weaknesses of my own views and opinions on a topic	RL1	3.569	0.976
I tried to understand other people's views by thinking about how an issue or point looked from their perspective or view point	RL2	3.514	0.949
Memory Learning	***ML***		
I rehearse or practice until I can reproduce a definition word by word	ML1	3.384	1.232
If I do not understand a part of the learning material I just memorize it so that I do not forget it	ML2	3.301	1.089
Schema Construction	***SC***		
My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject	SC1	3.878	0.776
My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew	SC2	3.770	0.768
Cognitive Loading			
I was expected to remember too many things from each lecture	CL1	3.486	0.910
I was overwhelmed with the amount of information I was expected to remember	CL2	3.438	0.882

The statistics for reliability of the instrument are shown in Table III. After deleting some items, the Cronbach's alpha for all the scales was above 0.70 while all the item-to-total correlations were greater than 0.30 which means the scales meet the minimum criteria for acceptability. The initial three scales of a deep learning approach namely High Order Learning, Integrated Learning and Reflective learning did not factor into the respective *a priori* groups. While these measures were adapted from validated measures, it is observed that items whose wording are even slightly convoluted and long become rather unreliable measures for the respondents whose first language is not English. Therefore, based on factor analysis, the three different factors of a deep learning approach were collapsed into two and the first factor renamed High Order and Reflective Learning because it combines initial items from High Order Learning and Reflective Learning. The second factor was still named Integrative Learning because all items from Integrative Learning loaded onto it with two other from Reflective Learning.

TABLE III. MEASUREMENT INSTRUMENTS ANALYSIS

Research Constructs		Mean	Cronbach's Test		C.R.	AVE	Item Loadings
			Item-total	α Value			
Hi Order and Reflective Learning	HO1	3.773	0.510	0.748	0.510	0.393	0.713
	HO2		0.395				0.772
	HO3		0.507				0.579
	RL1		0.479				0.603
	RL2		0.531				0.519
	RL3		0.508				0.535
Integrative Learning	IL1	3.710	0.454	0.788	0.461	0.312	0.581
	IL2		0.538				0.406

	IL3		0.565				0.468
	IL4		0.594				0.679
	IL5		0.450				0.522
	RL5		0.483				0.725
	RL6		0.528				0.733
Surface Learning	ML1	3.517	0.655	0.827	0.827	0.637	0.708
	ML2		0.605				0.806
	ML3		0.783				0.913
	ML4		0.591				0.751
Schema Construction	SC1	3.811	0.514	0.792	0.682	0.513	0.809
	SC2		0.618				0.683
	SC3		0.615				0.715
	SC4		0.649				0.731
	SC5		0.471				0.631
Cognitive Loading	CL1	3.343	0.473	0.856	0.784	0.511	0.511
	CL2		0.624				0.712
	CL3		0.683				0.756
	CL4		0.535				0.788
	CL5		0.732				0.885
	CL6		0.724				0.791
	CL7		0.604				0.686

Composite reliability (CR) and average variance extracted (AVE) both met the minimum criteria for acceptance of 0.70 and 0.50 respectively for all scales except for two reconstructed scales of a deep learning approach. This can be attributed to the re-specification of the items. It follows therefore that when measurement items are adapted in a different setting and especially were the language proficiency of respondents is not the same, it may be appropriate to rephrase the questions and more simply were the new respondents are less proficient in tandem with recommendations by Sekaran and Bougie [22]. Item factor loadings were all greater than 0.50. Therefore, except for the lower than optimum scores for CR and AVE of the deep learning constructs, all items converged well on the respective constructs.

A cross tabulation correlation of the summative measures of the eventual five constructs was drawn to further check for construct validity. The results are displayed in Table IV. The absence of a significant correlation between SC and ML suggest good discriminant validity of the two scales because it is not expected that memorizing learning material would lead to schema construction. On the other hand, SC exhibits a significant relationship with both IL and HLandRL consistent with literature that a deep learning approach yields understanding and so further suggests good discriminant validity of the respective scales. Also, the absence of a significant relationship between ML and IL suggest good discriminant validity of the two scales because it cannot be expected that memory learning, which is a surface learning approach, would be significantly correlated with integrated learning, which is a deep learning approach since the two learning approaches represent diametrically opposed ends of a continuum. This is further corroborated by a fairly strong and significant relationship between IL and HLandRL which represent the factors of a deep learning approach and provide further support for the validity of the IL and HLandRL scales. However, the significant relation between ML and HLandRL is not expected and since ML showed good discriminant validity and other psychometric measures while HLandRL exhibited a few problems from the onset, it can be concluded that HLandRL, as operationalized in this study, may suffer some validity issues.

TABLE IV. CORRELATIONS AMONG CONSTRUCTS

Construct	**CL**	**ML**	**SC**	**IL**	**HLandRLTr**
CL	1				
ML	0.306**	1			
SC	0.100	0.127	1		

IL	0.115	0.231	0.458**	1	
HLandRLTr	0.086	0.269*	0.452**	0.801**	1

C. Regression Analysis

Bivariate linear regression was used to the amount of cognitive loading induced by the two approaches to learning, namely the deep learning approach, the amount of cognitive loading induced by schema construction and also the amount of schema construction explained by the two approaches to learning. Bivariate linear regression analysis requires that the variables share a linear relationship and follow a normal distribution. Visual inspection of the normal probability plots (P-P plots) showed that the relationship between all regressed variables was visibly linear. The measures were tested for normality using the Shapiro-Wilk test of normality and the results are shown in Table V. The Shapiro-Wilk tests the null-hypothesis that the sample is drawn from a normally distributed population. Only HLandRL, has an alpha value less than 0.05 and so violates normality. Since the HLandRL variable was negatively skewed, a reflect and Log10 transformation was performed to normalize the data using the formula HLandRLTr = (6-HLandRL). The constant 6 was used based on the of criteria of the largest possible variable value, which was 5, from the 5-point Likert scale, plus 1 so as to yield reflected values greater than zero. Both the original and transformed normality statistics for HLandRL are shown in Table V. Since all variables are now normally distributed, parametric analyses can be performed.

TABLE V. TESTS OF NORMALITY

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CL	0.096	70	0.181	0.978	70	0.253
ML	0.088	70	0.200*	0.970	70	0.095
SC	0.111	70	0.032	0.966	70	0.053
IL	0.084	70	0.200*	0.982	70	0.415
HLandRL	0.121	70	0.013	0.962	70	0.031
HLandRLTr	0.098	70	0.092	0.978	70	0.256

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

A total of 8 bivariate linear regression models were run. The models were grouped into two with the first group comprising of 4 models treating CL as the dependent variable and HLandRLTr, IL, ML and SC as the predictor variables numbered Model 1 to 4 respectively and shown in Table VI. The Models 1 to 3 assess the amount of cognitive load induced by the different learning approaches while Model 4 assesses the amount of cognitive load induced by engaging in effective schema creation and automation and respond to objectives 1 and 2 of the study. Model 1 regressed CL with HLandRLTr and yielded a very small R^2 of 0.007 (p=0.474) which is not significant as shown in Table VI and Table VII. Therefore, the variation of 0.70% of CL accounted for by HLandRLTr is no more than a sampling chance. Model 2 shows that IL has an R^2 of 0.013 (p=0.344) when regressed with CL and so explains a variation of 1.30% of CL but it is not significant and therefore only a chance occurrence.

TABLE VI. MODEL SUMMARY A

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.086[a]	0.007	-0.007	0.68263
2	0.115[b]	0.013	-0.001	0.68753
3	0.306[c]	0.094	0.081	0.65102
4	0.100[d]	0.010	-0.004	0.68026

a.	Predictors: (Constant), HLandRLTr	d.	Predictors: (Constant), SC
b.	Predictors: (Constant), IL	e.	Dependent Variable: CL
c.	Predictors: (Constant), ML		

Model 3 with ML regressed against CL on the other hand has a significant R^2 of 0.094 (p=0.009) indicating that a variation of 9.40% of CL can be explained by ML. Model 4 with SC regressed against CL yields an R^2 of 0.010 (p=0.396) and so accounts for 1.00% variation in CL but the relationship is non-significant. The results show that a surface learning approach, which is characterized by memorizing learning material, consistently induces a higher cognitive load while a deep learning approach does not yield a statistically significant amount of cognitive loading. Further, engaging in effective schema construction does not yield a statistically significant amount of cognitive load.

TABLE VII. ANOVA A

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.299	1	0.299	0.642	0.474[b]
	Residual	32.561	70	0.465		
	Total	32.860	71			
2	Regression	0.430	1	0.430	0.910	0.344[b]
	Residual	32.144	68	0.473		
	Total	32.574	69			
3	Regression	3.060	1	3.060	7.221	0.009[b]
	Residual	29.668	70	0.424		
	Total	32.729	71			
4	Regression	0.338	1	0.338	0.730	0.396[b]
	Residual	33.319	72	0.463		
	Total	33.657	73			

a.	Dependent Variable: CL	a.	Predictors: (Constant), SL
b.	Predictors: (Constant), HLandRLTr	a.	Predictors: (Constant), SC
a.	Predictors: (Constant), IL		

TABLE VIII. MODEL SUMMARY B

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
5	0.452[a]	0.204	0.193	0.55741
6	0.458[b]	0.210	0.198	0.54702
7	0.127[c]	0.016	0.002	0.61792

a.	Predictors: (Constant), HLandRLTr	c.	Predictors: (Constant), ML
b.	Predictors: (Constant), IL	d.	Dependent Variable: SC

TABLE IX. ANOVA B

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	4.936	1	4.936	15.424	0.000[b]
	Residual	22.404	70	0.320		
	Total	27.340	71			
6	Regression	5.410	1	5.410	18.080	0.000[b]
	Residual	20.348	68	0.299		
	Total	25.758	69			
7	Regression	0.436	1	0.436	1.143	0.289[b]
	Residual	26.728	70	0.382		
	Total	27.164	71			

a.	Dependent Variable: SC	c.	Predictors: (Constant), IL
b.	Predictors: (Constant), HLandRLTr	d.	Predictors: (Constant), ML

Models 5 to 7 treated SC as the dependent variable in order to assess the amount of schema construction accounted for by the different approaches to learning and respond to the 3rd objective of the study. The results are shown in Table VIII and Table XI. Model 5 regressed HLandRLTr with

SC and yielded an R^2 of 0.204 (p=0.000) which is significant indicating that 20.40% of variation in SC can be explained by HLandRLTr while Model 6 regressed SC with IL and yielded an R^2 of 0.210 (p=0.000) which is significant indicating that 21.00% of variation in SC can be explained by IL. ML on the other hand yielded a non-significant R^2 of 0.016 (p=0.289) indicating that any variation in SC explained by ML is only due to chance. The results show that a surface learning approach, which is characterized by memorizing learning material, does not significantly contribute to schema construction. A deep learning approach, on the other hand, has a statistically significant contribution to schema construction.

V Discussion of Findings

The study sought to assess 1) the amount of cognitive loading induced by two different approaches to learning; 2) the amount of cognitive loading induced by schema construction and automation and 3) the amount of schema construction explained by two different approaches to learning. The relationship between cognitive loading and approach to learning has not been empirically researched. The relationship between cognitive loading and schema construction equally has no empirical evidence but can be inferred from the relationship between cognitive loading and learning or academic achievement since schema construction is one way of conceptualizing learning. Likewise, the relationship between schema construction and approaches to learning can be inferred from the relationship between learning or academic achievement and learning approaches.

The results show that students experience more cognitive loading when they engage in a surface learning approach while engaging in deep learning does not strain the cognitive capacity of students. Further, deep learning significantly accounts for some schema construction while surface learning does not and schema construction does not induce a statistically significant amount of cognitive load.

The finding that students experience cognitive load when they engage in surface learning resonates with many other findings which have concluded that when students are subjected to lower levels of cognitive loading, they attain better learning outcomes than when the cognitive load is high [11, 12]. This conclusion is also supported by the cognitive load theory in that since working memory can only process a limited amount of information at a time, attempts to memorize large amounts of information, which is characteristic of the surface learning approach will yield a significant amount of cognitive loading. Conversely, working with information already in long term memory and attempting to create links between that information and any new information, which is characteristic of deep learning, will induce a much lower cognitive load compared to any attempts to memorize all the new information.

The finding that schema construction, which represents effective learning, is significantly associated with deep learning while surface learning is not, is consistent with other findings which show that deep learning leads to better academic achievement while surface learning does not [18, 19]. This is also consistent with the CLT in that when students attempt to cram information into a very limited memory, they overload their memory capacity and consequently hinder learning [4-6]. This is congruent with the finding that deep learning does not induce a significant amount of cognitive loading because working with information already in long term memory and attempting to create links between that information and any new information will yield a much lower cognitive load compared to any attempts to memorize all the new information.

The evidence that approaches to learning affect cognitive loading also supports the conclusion by Scheiter, Gerjets, Vollmann and Catrambone [10] among several others that there are other variables which affect cognitive loading and weaken the direct relationship between instructional design and cognitive load which is the traditional assumption in CLT. In this regard, student approach to learning, will moderate the relationship between instructional approach and cognitive loading. The favored approach to learning also explains some of the variation in cognitive load under the same environment and circumstances reported by Chang and Yang [13] but attributed to differences in prior knowledge.

VI Implications of the study

The study has both practical and theoretical implications pertaining to cognitive loading and how it is influenced by approaches to learning and how it influences learning. Practical implications are that students should be encouraged to engage in deep learning approaches to achieve effective learning while memory learning should be discouraged. This will not only help them achieve better learning outcomes but it will also significantly reduce the amount of cognitive loading they are subjected to and so reduce stress. Educators can help students to engage in deep learning approaches by focusing their teaching and learning and assessments on student understanding rather than memory. Focusing away from the need to memorize material may eventually lead students away from attempting to memorize large amounts of information and focus on actual learning. The importance of guiding students away from surface learning to deep learning is shared by others including Hasnor, Ahmad and Nordin [1]. On the theoretical front, the study provides an insight into how learning approaches affect cognitive loading which as yet is not reported in literature. The study also provides further evidence for the relevance of cognitive loading to effective learning.

VII Limitations and future research

The study is limited by the variables measuring a deep learning approach which had poor composite reliability and average variance extracted. Therefore, further studies on the relationship between cognitive loading and approaches to learning are required to validate the finding that cognitive loading is influenced by the approach to learning.

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13.13 Appendix 13 – Publication 4 – Mediation of Cognitive Loading on Complex Questions and Schema Construction in Students of Construction Programmes

ASOCSA2018- [47]

Mediation of Cognitive Loading on Complex Questions and Schema Development in Students of Construction Programmes

Ephraim Zulu[1], Theodore C. Haupt[2] and Vittorio Tramontin[3]

[1,3]School of Engineering, College of Agriculture, Engineering and Science, University of Kwazulu-Natal, Howard Campus, King George V Avenue, Durban, 4001, South Africa
zulue@ukzn.ac.za, tramontin@ukzn.ac.za

orcid.org/0000-0002-5999-7808

[2]Research Professor: Engineering, Mangosuthu University of Technology, 511 Mangosuthu Highway, Umlazi, Durban, 4031, South Africa
haupt@ukzn.ac.uk

Orcid.org/0000-0002-2531-3789

ABSTRACT AND KEYWORDS

Purpose of this paper

The aim of the research is to assess the mediating effect of cognitive loading on the relationship between complex questions and schema construction.

Design/methodology/approach

The research used a self-administered questionnaire survey to collect data from a purposively selected sample of university students. The students were drawn from three public universities in South Africa studying towards undergraduate degrees in construction studies. The data were analysed using structural equation modelling and mediation analysis.

Findings

Cognitive loading has a fairly large mediating effect on the relationship between complex questions and schema construction. These findings corroborate other findings which show that complex questions induce fairly large amounts of cognitive loading which then impedes learning.

Research limitations/implications

The results of the research are limited because the survey is based on purposive sampling. Also, the research is based on measurement instruments whose reliability and validity have not been extensively tested. Therefore, future studies can replicate the study with a random sample and with other instruments which have been extensively tested.

Practical implications

Appropriate scaffolding should be used when questions which are perceived as being complex are administered to students. Scaffolding will help to manage the resulting cognitive loading and help students to achieve better learning outcomes. The scaffolding may include, but not limited to,

supplementary lectures and seminars to provide students with the appropriate level of knowledge to deal with the perceived question complexity and subsequently reduce the cognitive loading.

Keywords: Mediation, Cognitive Loading, Complex Questions, Schema Construction, Construction Education

1. INTRODUCTION

Cognitive loading is the mental load on working memory expended in executing cognitive functions such as perceiving, thinking and learning (Sweller & Paas, 2017). These mental functions are performed in working memory. Working memory is used for conscious activity in organizing, contrasting, comparing and working on information. It can hold about seven items at a single time but can only process two or three items simultaneously and it is the only memory which can be monitored (Kirschner, 2002; Sweller, et al., 1998). Long term memory (LTM) on the other hand, has an unlimited capacity but its contents cannot be directly monitored unless they are loaded onto working memory. Because working memory has a very limited capacity, it tends to get overloaded and overwhelmed when its limits are stretched (Leppink, 2017). Therefore, lower levels of cognitive loading induced in students will work to yield more effective learning than when the memory limits of students are ignored and the cognitive load is left to exceed the memory limit. This is based on the cognitive load theory (CLT) which posits that since working memory has a very limited capacity, it can be easily overloaded with activities that impede rather than aid learning. Subsequently, effective learning happens when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Sweller et al., 1998).

The information processing theory suggests that knowledge is stored in LTM as schemata. A schema is anything that is learnt and is treated as a single entity by working memory and can incorporate a large and complex amount of information (Kirschner, 2002; van Bruggen, Kirschner, & Jochems, 2002). Schema can combine elements of information and become automated therefore needing less storage capacity and processing (van Bruggen et al., 2002).

In order to achieve learning or schema construction, students are often administered complex questions. Questions may be classified as complex when their answers need to be collated from information scattered in many different documents (Chali, Hasan, & Mojahid, 2015) or from different bodies of knowledge in different disciplines. Using complex questions is expected to challenge students to acquire knowledge they previously did not possess and therefore achieve learning. However, based on the CLT, complex questions are also expected to induce large amounts of cognitive loading.

While it is understood that complex questions induce cognitive loading and that cognitive loading impedes learning it is not clear as to what extent complex questions achieve learning. Also, it is not clear as to the extent to which cognitive loading mediates the relationship between complex questions and schema construction. Therefore, this study aims to assess the mediating role of cognitive loading on the relationship between complex

questions and schema construction. The resulting conceptual model is shown in Figure 1.

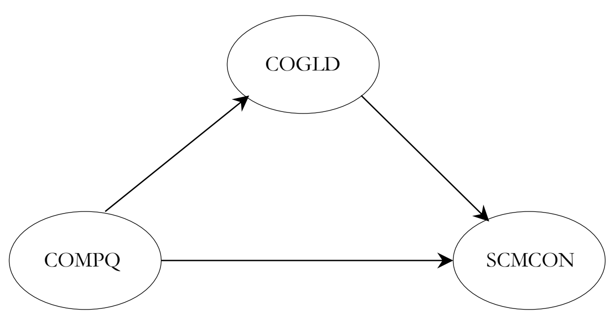

Figure 1: Conceptual Model of the Mediating Role of Cognitive Loading on the Relationship between Complex Questions and Schema Construction

Legend: COMPQ = Complex Questions; COGLD = Cognitive Loading; SCMCON = Schema Construction

2. RESEARCH DESIGN, STRATEGY AND PROCEDURES

A quantitative research design with a positivist philosophy and a deductive research approach were used because the study sought to test hypothesized relationships among the study variables to which the quantitative design, a positivist philosophy and a deductive approach are all well suited. The favoured data collection method was a cross sectional questionnaire survey due to the objectivity and low cost associated with its use compared to other methods of data collection. Non probability sampling was used for convenience and economy.

The target population for the study were students undertaking construction studies at public universities in South Africa. Three public universities in the KwaZulu-Natal province were conveniently selected for the study. All students present in class at the time of the data collection were included in the sample. In keeping with ethical research conduct, the students were informed of their right to not participate in the study and to withdraw at any time for any reason. The students were also assured of both confidentiality and anonymity if they chose to participate. A sample of 543 students studying towards bachelor's degrees in either Construction Management, Quantity Surveying or Property Studies at the three public universities was obtained.

Table 1 shows the profile of the respondents. All academic years of study from first to fourth year were represented in the sample with first year students accounting for the highest number (34.10%) followed by fourth year students (23.00%) and then second year students (23.20%). With no single year of study being markedly larger or smaller than any other, the distribution of the academic year of study is representative of a typical four years' university program. The gender distribution has more males (59.80%) than females which is consistent with the general gender distribution at public universities in South Africa. Therefore, the gender distribution is also representative of the population of interest. The programs of study sampled were from the disciplines of Construction Management, Quantity Surveying, Property Studies and Architecture. The highest number of respondents came from the discipline of Construction Management (47.70%) while Property Studies accounted for only 8.80% and Architecture only 14.90%.

Table 1. Sample Demographic Statistics

Year of Study	Frequency	Percentage
1	185	34.10
2	126	23.20
3	107	19.70
4	125	23.00
Total	**543**	**100**
Gender	**Frequency**	**Percentage**
Male	324	59.80
Female	219	40.20
Total	**543**	**100**
Programme of Study	**Frequency**	**Percentage**
Construction Management	259	47.70
Quantity Surveying	155	28.60
Property Studies	48	8.80
Architecture	81	14.90
Total	**543**	**100**

The research questionnaire with its associated descriptive statistics are shown in Table 2. The scales in the questionnaire were developed by the authors based on the operational definition of the research constructs.

Table 2: Measurement Model

Research Constructs		Mean	Std. Dev	Skewness	Kurtosis
Cognitive Loading	**COGLD**				
1 I was expected to remember too many things from each lecture	COGLD1	3.497	1.056	-0.233	-0.649
2 I was overwhelmed with the amount of information I was expected to remember	COGLD2	3.461	1.037	-0.294	-0.443
3 I was given too much information during the lectures	COGLD3	3.298	1.020	-0.065	-0.533
4 The information I was given during lectures was confusing	COGLD4	2.789	1.087	0.121	-0.528
5 The information I was given in class was complicated and difficult to understand	COGLD5	2.785	1.085	0.154	-0.538
Complex Questions	**COMPQ**				
1 I was given assignments and tests which were difficult to understand and solve	COMPQ1	2.829	1.076	0.130	-0.431
2 I was given problems which did not have enough information for me to solve them	COMPQ2	2.693	1.119	0.304	-0.501
3 I was required to solve questions which were not clear as to what I was expected to do	COMPQ3	2.837	1.119	0.151	-0.640
4 I was given questions which could be interpreted in more than one way	COMPQ4	3.108	1.063	-0.042	-0.515
5 I was given problems which were not easy to understand clearly	COMPQ5	2.875	1.098	0.091	-0.566
6 I was given questions which were not expressed clearly	COMPQ6	2.772	1.163	0.137	-0.725
Schema Construction	**SCMCON**				
1 My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject	SCMCON1	3.779	0.950	-0.640	0.297
2 My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew	SCMCON2	3.733	0.9114	-0.488	-0.091
3 I connected points that I already knew with what I was being taught in class	SCMCON3	3.791	0.877	-0.438	-0.032
4 I organised, categorised or connected anything new that I learnt with what I already knew	SCMCON4	3.695	0.916	-0.428	0.010
5 My lecturers clearly highlighted the main concepts and principles	SCMCON5	3.944	0.936	-0.666	0.000

Cognitive loading was operationalized mainly as the extent to which students are overwhelmed by the amount of assigned work and the extent to which they were expected to remember too much information which was complex, difficult and confusing to understand. This conception is shared by others (Hadie & Yusoff, 2016) and is also supported by the findings which show that high levels of cognitive loading lead to students being overwhelmed (Scheiter, Gerjets, Vollmann, & Catrambone, 2009).

The concept of complex questions was operationalized by extent to which students were given assessment problems which were difficult to understand, had no defined solution and required combining information from different subject areas and sources in tandem with the conception of complex questions by (Chali et al., 2015).

Schema construction was operationalised based on the definition of a schema from schema theory. The instrument was anchored on a 5-point Likert scale with 5=almost never; 4=often; 3=sometimes; 2=seldom; and 1=almost never. The questionnaire, along with the entire study, were reviewed by the university research ethics committee and approved. The resulting questionnaire and its associated descriptive statistics are shown in Table 2. The results exhited mild skewness and kurtosis.

3. FINDINGS

The results were analysed, firstly, with Structural Equation Modelling (SEM) using IBM SPSS AMOS v25 and, secondly, with the PROCESS macro v3 in IBM SPSS by Andrew F. Hayes. SEM was used to assess model fitness also to assess reliability and validity from the resulting factor loading and mediation was assessed using the PROCESS macro.

3.1 Structural Equation Modelling

Structural Equation Modelling (SEM) was used to assess the goodness of fit of the theoretical mediation model to the empirical data using Maximum Likelihood Estimation (ML) with 500 bootstrap samples. Absolute and incremental fit indices were used to assess model fitness. The fit indices are shown in Table 3 and the SEM model is shown in Figure 2.

Table 3: Model Fit Indices

Model Fit Index	Acceptable Threshold	Study Threshold	Met/Not Met
Absolute Fit Indices			
Chi-Square Significance		P=0.000	Not Met
Relative Normed Chi-Square value (λ^2/df)	<3	2.575	Met
Random Measures of Sample Error Approximation (RMSEA)	<0.080	0.055	Met
(RMR)	>0.0	0.053	Met
Goodness of Fit Index (GFI)	>0.900	0.946	
Incremental Fit Indices			
Incremental Fit Index (IFI)	>0.900	0.964	Met
Comparative Fit Index (CFI)	>0.900	0.963	Met
Tucker Lewis Index (TLI)	>0.900	0.952	Met

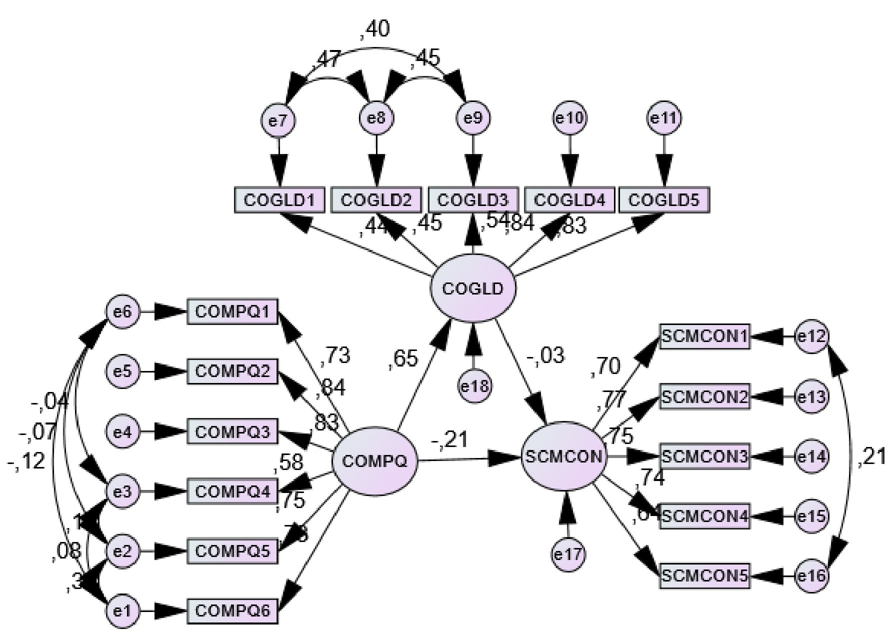

Figure 2: Structural Equation Model with Standardised Coefficients

The fit indices in Table 3 show that the overall mediation model exhibits a good fit with the empirical data based on recommended model fitness index thresholds (Anderson & Gerbing, 1988; Fornell & Larcker, 1981; Hu & Bentler, 1999; Hulland, 1999; Tabachnick & Fidell, 2013). The theoretical model displays a good fit to the empirical data and so inferences made from the conceptual model are both theoretically and empirically valid.

The test statistics were then assessed for reliability and validity. Table 4 shows the results of the reliability and validity statistics. Reliability was assessed using Cronbach's alpha and Composite Reliability (CR) while validity was assessed using Average Variance Extracted (AVE). Cronbach's alpha for all constructs ranged between 0.735 and 0.841. Therefore, all the constructs exceeded the recommendation of 0.70 by Byrne (2006). Hulland (1999) recommended a threshold of 0.70 for CR and all the constructs exceeded this threshold. Therefore, based on the Cronbach's alpha and the CR, the research constructs exhibit good reliability. For validity, Fornell and Larcker (1981) recommended AVE values to be greater than 0.50 and all the constructs exceeded this threshold. Therefore, the measurement instrument is both reliable and valid.

The structural relationships from the SEM analysis in Figure 2 are tabulated in Table 5 and show that COMPQ is significantly negatively associated with SCMCON (R^2=-0.207, p=0.005). COMPQ is also significantly positively associated with COGLD (R^2=0.651, p=0.0001). While COGLD shows a negative association with SCMCON, the relationship is not statistically significant (p=0.714).

Table 4: Reliability and Validity Statistics

Research Constructs		Cronbach's Test		C.R.	AVE	Item Loadings
		Item-total	α Value			
Cognitive Loading	COGLD1	0.585	0.822	0.734	0.558	0.441
	COGLD2	0.605				0.446
	COGLD3	0.659				0.545
	COGLD4	0.617				0.844
	COGLD5	0.608				0.834
Complex Questions	COMPQ1	0.638	0.885	0.841	0.651	0.731
	COMPQ2	0.756				0.837
	COMPQ3	0.767				0.827
	COMPQ4	0.579				0.583
	COMPQ5	0.744				0.745
	COMPQ6	0.704				0.729
Schema Construction	SCMCON1	0.665	0.848	0.817	0.626	0.704
	SCMCON2	0.701				0.771
	SCMCON3	0.650				0.745
	SCMCON4	0.658				0.745
	SCMCON5	0.611				0.635

Table 5: Structural Relationships

	Proposed Hypothesis				R^2 Estimate	P Level
1	SCMCON	<---	COMPQ	H_1	-0.207	0.005
2	COGLD	<---	COMPQ	H_2	0.651	0.000
3	SCMCON	<---	COGLD	H_3	-0.027	0.714

3.2 Mediation Analysis

The Preacher and Hayes (2004) bootstrapping procedure is a very good procedure for analysing mediation among latent variables (Field, 2018). Therefore, the mediating role of cognitive loading on the relationship between complex questions and schema construction was assessed using the IBM SPSS PROCESS macro. Additionally, the procedure by Preacher and Hayes, unlike other alternatives, does not rely on the assumption of normality of the indirect effects whilst at the same time being suitable for smaller sample sizes (Preacher, 2008). The confidence interval (CI) for the indirect effect is a bias corrected accelerated (BCa) bootstrapped CI based on 5000 samples. The results of the analysis are shown in Figure 3.

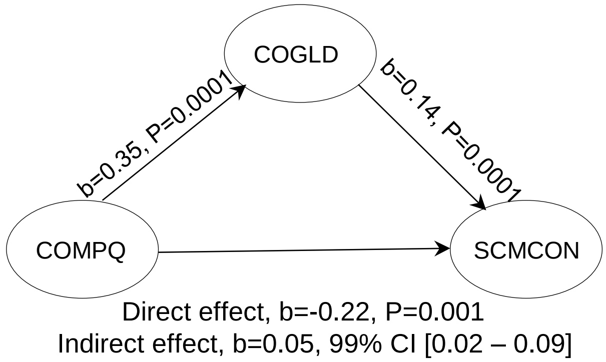

Figure 2: Model of Complex Questions as a Predictor of Schema Construction Mediated by Cognitive Loading

The indirect effect of COMPQ on SCMCON through COGLD was significant (indirect effect = 0.05, 99% CI = 0.02 to 0.09). This shows that cognitive loading mediates the relationship between complex questions and schema construction.

4. DISCUSSION OF FINDINGS AND CONCLUSION

Studies have shown that administering complex questions induces significant amounts of cognitive loading in students and that high levels of cognitive loading impede learning (Huang, Shadiev, & Hwang, 2016; Leppink, 2017; Sweller & Paas, 2017). Using a different methodology from established studies, the aim of this study was to assess the extent of cognitive loading which can be attributed to complex questions using mediation analysis. The study also assessed the extent to which complex questions achieve learning. Mediation was assessed using the PROCESS macro by Andrew F. Hayes in IBM SPSS. A supplementary structural equation model was used to assess the model fitness of the theoretical mediation model. The structural relationships in the model assessed the extent to which complex questions achieve learning.

Consistent with other studies, the structural relationships from structural equation modelling show that administering complex questions significantly impedes the development of schemata in students. Therefore, complex questions do not help to achieve learning but in fact work against learning. Also, consistent with other studies, complex questions induce quite large amounts of cognitive loading. However, the results suggest that cognitive loading in itself does not necessarily hinder learning. This is because, while it has a negative relationship with schema construction, the relationship is not statistically significant.

On one hand, the results are in tandem with other findings showing that complex questions lead to increased levels of cognitive loading. The results also agree with other studies which show that complex questions impede rather than aid learning. However, it is unclear about the effect of cognitive loading alone on schema construction. It was expected, based on other studies, that cognitive loading would be significantly negatively associated with schema construction.

However, the mediation analysis, on the other hand, shows that complex questions would impede schema construction less if cognitive loading was not induced in the students. This, therefore, shows that cognitive loading affects schema construction indirectly through mediation. This is demonstrated in the mediation model when the relationship between complex questions and schema construction reverses from negative to positive when cognitive loading is a mediator. That is, when complex questions are administered to students and the resulting levels of cognitive loading are high, the students will not be able to construct any schema. Conversely, if complex questions are administered and cognitive loading is not high, students will be able to construct some schemata. This significant improvement in schema construction when complex questions are used and cognitive loading reduced explains why cognitive loading is found to be lower in more knowledgeable learners. More knowledgeable learners already have some schemata on the subject matter and so are able to deal with complex questions with much lower levels of cognitive loading. Prior subject knowledge places less demand on working memory when dealing with complex questions and so indices lower levels of cognitive loading.

These findings add to the fairly new body of knowledge on cognitive loading. The findings also have practical implications for educational practice. When questions which are perceived by students as being complex are administered in assessments, appropriate measures should be put in place to help the students deal with the consequent levels of cognitive loading. Otherwise, the high levels of cognitive loading will impede learning. Cognitive loading can be reduced by appropriate scaffolding. Scaffolding could include, but not limited to, supplementary lectures and seminars to provide students with the appropriate level of knowledge to deal with the perceived complexity.

6. LIMITATIONS

While this study makes contributions to the body of knowledge and to educational practice, it has some limitations. Firstly, the data were purposively collected using instruments which have not been extensively tested. Therefore, future studies may validate the instruments used in this study or use other established instruments for the constructs under study to test the validity of the results and conclusions arrived at by this study. Future studies could also test to establish whether in fact cognitive loading has moderating rather than mediating effect on the relationship between complex questions and schema construction. This model is a plausible representation of the empirical data given that cognitive loading did not exhibit a significant relationship with schema construction in the structural model.

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13.14 Appendix 14 – Publication 5 – Cognitive Loading due to Self-directed Learning, Complex Questions and Tasks in the Zone of Proximal Development of Students

COGNITIVE LOADING DUE TO SELF-DIRECTED LEARNING, COMPLEX QUESTIONS AND TASKS IN THE ZONE OF PROXIMAL DEVELOPMENT OF STUDENTS

Ephraim Zulu

University of KwaZulu-Natal, School of Engineering, Construction Studies Department, Durban, South Africa
E-mail: ephraimzulu2000@yahoo.co.uk

Theodore Haupt
Mangosuthu University of Technology, Durban, South Africa
E-mail: theo.haupt@mut.ac.za

Vittorio Tramontin

University of KwaZulu-Natal, School of Engineering, Construction Studies Department, Durban, South Africa
E-mail: Tramontin@ukzn.ac.za

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Abstract

The aim of the research was to explore the levels of cognitive loading induced by certain tenets of constructivist pedagogy namely self-directed learning complex questions and zone of proximal development. The study also sought to investigate the associations between these constructs and with cognitive loading and complex questions. Data for the research were collected using a questionnaire survey of a sample of students studying towards undergraduate degrees in construction-related studies at - public universities in South Africa. The data were factor analyzed to determine the factor structure of the constructs and to assess instrument validity and reliability. The relationships between the various constructs were analyzed using structural equation modelling (SEM). Consistent with other studies, the research found that complex questions induce a statistically significant amount of cognitive loading in students. The study also found that self-directed learning does not induce cognitive loading while subjecting students to tasks which are in their zone of proximal development is likely to induce some cognitive loading albeit much less than that from complex questions. Locating tasks in the zone of proximal development of students is likely to lead students to engage in some self-directed learning. It was also found that complex questions had a small significant association with self-directed learning. To reduce the amount of cognitive loading which students are subjected to, complex questions should be avoided for students with little subject prior knowledge, otherwise, students should be appropriately scaffolded. Students should be encouraged to engage in self-directed learning in order to reduce cognitive loading. Learning tasks assigned for self-directed learning should not be complex relative to the knowledge of the students as this discourages students from persisting with self-directed learning due to high cognitive loading.

Key words: *Cognitive Loading, Complex Questions, Self-Directed Learning, Zone of Proximal development.*

Introduction

Constructivism with its associated pedagogy is becoming the widely accepted approach to teaching and learning due to its reported efficacy of being student-centered. Constructivist pedagogies typically engage students in active learning through asking questions on a topic and proposing hypotheses about the questions and collecting, investigating and analyzing available information to answer the questions thereby discovering knowledge previously unknown to the students (Hmelo-Silver, Duncan & Chinn, 2007; Kori, Mäeots and Pedaste, 2014; Lazonder and Harmsen, 2016; Mäeots and Pedaste, 2014; Pedaste and Sarapuu, 2006; Scanlon, Anastopoulou, Kerawalla and P.Mulholland, 2011; Spronken-Smith, Bullard, Ray, Roberts and Keiffer, 2008). In constructivist pedagogies, students engage in self-directed learning by actively collecting information and investigating the problem.

Constructivist approaches include Inquiry Based Learning (IBL), Problem Based Learning (PrBL), Project Based Learning (PBL), Studio Based Learning (SBL), Case Based Learning (CBL), Discovery Learning and Action Learning. All of these approaches are based on students learning while working proposing a solution to a problem. Problems that may be investigated can be a group or individual project, a case study, field work, research activities or any type of problem for students to explore (Lim, 2004; Meijerman, Storm, Moret and Koster, 2013; Spronken-Smith and Kingham, 2009; White and Frederiksen, 1998). For example, Spronken-Smith (2005) used an authentic problem developed with a potential employer. At the Massachusetts Institute of Technology (MIT), Hansman (2009) used a real world engineering project to develop a flight vehicle that would serve as an airborne sensing platform for high precision antenna calibration commissioned by a government entity. Other examples include a project commissioned by the National Aeronautics and Space Administration (NASA) for students to conceive, design, and build Estes Model rockets and launch them with the goal of launching the most massive payload possible to 300ft at minimal cost (CDIO, 2018). Another one was to design and fabricate a skyscraper capable of sustaining a load capable of handling an "earthquake," by first and second year engineering students (Gray, 2011).

In constructivist pedagogies, students are often exposed to questions which are fairly complex relative to the knowledge they possess. Questions may be classified as complex when their answers need to be collated from information scattered in many different documents (Chali, Hasan and Mojahid, 2015) or from different bodies of knowledge in different disciplines. Using complex questions is expected to challenge students to acquire knowledge they previously did not possess. Therefore, complex questions are located in what Lev Vygotsky called the zone of proximal development (Vygotsky, 1978).

There is some disagreement about the most appropriate types of problems to address in constructivist pedagogies. Kahn and O'Rourke (2004) suggested that IBL questions should be complex and open ended with a variety of solutions. Spronken-Smith et al. (2008) felt that questions need to be broad to allow for multiple perspectives and exploration scope. Harinarain and Haupt (2016) suggested that problems should be authentic, ill-structured, complex, open ended, messy and ambiguous in beginnings, means and ends with neither correct nor incorrect multiple solutions.

However, when they used complex and ambiguous questions, Harinarain and Haupt (2016) reported that students felt negatively about this type of inquiry problem. Spronken-Smith et al. (2008) felt that it was not necessary to have a variety of solutions. Lim (2004) argued against having too many diverse tasks stating that this may not help students focus on learning tasks and if activities are too complex, students may easily lose interest in the module. Lim (2004) therefore suggested that it is important to avoid too many complex questions and necessary to make tasks or processes manageable because tasks which are too complex easily overwhelm the students.

Research from cognitive science agrees with the suggestion by Lim (2004) arguing that complex tasks induce high levels of cognitive loading in students. Situations of high cognitive loading have been found to impede meaningful learning (Kirschner, Sweller and Clark, 2006; Srinivasan, 2011; Sweller, Merrienboer and Paas, 1998; Yuan, Steedle, Shavelson, Alonzo and Oppezzo, 2006). Since solving or attempting to solve complex problems leads to high cognitive loading, more so in students with little prior knowledge, highly complex problems may not be the most appropriate problems for students to engage with.

Problem of Research and Research Focus

According to cognitive science, cognitive loading should be a major consideration in any pedagogy. The association between complex questions and cognitive loading has been widely researched and it is widely accepted that complex questions induce high levels of cognitive load (Kirschner *et al.*, 2006; Srinivasan, 2011; Sweller *et al.*, 1998; Yuan *et al.*, 2006). However, the level of cognitive loading induced by some tenets of constructivist pedagogies is not reported in literature. For example, the association between Self-Directed Learning (SDL) and cognitive loading are not reported in extant literature. The effect of complex questions and locating learning tasks in the Zone of Proximal Development (ZPD) of students on their cognitive load and the aptitude of students for SDL is also not investigated. The specific research questions being addressed are:

1. What is the level of cognitive loading induced when students engage in SDL and when their assessment questions are located in the ZPD?
2. How does the cognitive loading from complex questions and questions located in the ZPD affect the aptitude of students for SDL?

The research is important because it has implications for constructivist pedagogy. Constructivist pedagogy often uses complex questions while expecting students to engage in self-directed learning. However, the consequent cognitive loading in is largely ignored and often not even acknowledged. Therefore, the results of this research are expected to have practical implications by providing empirical evidence of the consequent cognitive loading on students due to some of the tenets of constructivist pedagogy. It is expected that this empirical knowledge will lead to recommendations on how to deal with the cognitive loading. The research is also expected to add to the growing body of knowledge on cognitive loading in general.

Cognitive Loading

Cognitive loading is the mental load on working memory expended in executing cognitive functions such as perceiving, thinking and learning among others (Sweller & Paas, 2017). Because working memory has a very limited capacity, it tends to get overloaded and overwhelmed when its limits are stretched (Leppink, 2017). Educational approaches which induce lower levels of cognitive load result in better learning outcomes for students while those which ignore the limits of working memory often inhibit learning (Kirshner, 2002; Van Gerven et al., 2002; Tasir & Pim, 1994). Therefore, lower levels of cognitive loading induced in students will work to yield more effective learning than when the memory limits of students are ignored and the cognitive load is left to exceed the memory limit. This is based on the cognitive load theory (CLT) which posits that since working memory has a very limited capacity, it can be easily overloaded with activities that impede rather than aid learning. Subsequently, effective learning happens when the cognitive load in working memory is directed towards construction and automation of relevant schemata (Pollock et al., 2002; Sweller et al., 1998). Scheiter et al. (2009) found that students with lower levels of cognitive load exhibited better problem-solving performance.

Cognitive loading is an important consideration in educational practice since learning will hardly take place if the limits of working memory are ignored (Sweller et al., 1998; Van Gerven et al., 2002). Therefore, pedagogies which ignore cognitive loading are unlikely to achieve maximum efficiency in learning since the working memory capacity of students is likely to be exceeded (Bannert, 2002; Sweller, G., van Merrienboer, & Paas, 1998).

Zone of Proximal Development

The Zone of Proximal Development (ZPD) is 'the distance between the actual developmental level of a student as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978: 86 cited in Berkiryazicic, 2015). Therefore, learning consists of challenging students to perform tasks located in their ZPD and providing them with assistance in performing the task until the students are able to perform the task on their own (Naeini, 2014; Shooshtari & Mir, 2014). This allows the students to continually increase the range of tasks they can perform on their own. Therefore, challenging students with tasks in the ZPD ensures that students are cognitively challenged to broaden the range of tasks they can confidently perform without supervision. The change in the range of tasks which students can perform quintessentially defines cognitive development and so learning (Christmas, Kudzai and Josiah, 2013).

Self-Directed Learning

Self-directed learning (SDL) refers to the ability for students to engage in independent learning activities without any explicit direction from anyone (Alharbi, 2017; Din et al., 2016). It involves students identifying their own learning needs, setting learning goals, identifying appropriate learning resources, choosing and applying appropriate learning strategies and evaluating learning outcomes (Alharbi, 2017; Din et al., 2016). It is a strong predictor of and enhances academic performance and learning (Alharbi, 2017; Alotaibi, 2016; Lee, Yeung, & Ip, 2017) and can also improve quality of life (Din, Haron, & Rashid, 2016). Its importance has been argued in many studies (Alharbi, 2017; Alotaibi, 2016; Din et al., 2016; Lee et al., 2017; Louws, Meirink, van Veen, & van Driel, 2017; Nasri, 2017; Rashid & Asghar, 2016; Slater & Cusick, 2017; Zhoc & Chen, 2016). SDL is becoming increasingly important in the current era of knowledge explosion being experienced due to the rapid developments in technology and information and telecommunications. This knowledge explosion is placing a huge burden on both lecturers and students to stay abreast the large volume of knowledge and its application which are being constantly generated (Alotaibi, 2016; Zhoc & Chen, 2016). Consequently, it is becoming increasingly difficult for lecturers to teach, and for students to learn, all the disciplinary knowledge in class. Subsequently, SDL is becoming a critical avenue through which the gap between what can be taught and learnt in class and what ultimately needs to be learnt can be bridged (Alotaibi, 2016).

Cognitive Loading in Minimally Guided Pedagogy

Kirschner, Sweller, and Clark (2006) classified problem and project-based learning approaches as minimally guided pedagogical approaches and argued that they are less effective than instructional approaches which are more strongly guided. Kirschner, Sweller, and Clark (2006: 75) argued that minimally guided approaches:

> "ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide 'internal' guidance."

Fundamentally, Kirshner, Sweller, and Clark argue against the use of problem or project-based learning in students with little prior subject knowledge due to the resulting levels of cognitive loading. Proponents of the cognitive load theory argue against instructional approaches which require some level of complex reasoning from students in the absence of adequate subject prior knowledge which is often the case in constructivist pedagogies (Amadieu, van Gog, Paas, Tricot, & Mariné, 2009; Ayres, 2006; Kirschner, 2002; Paas & van Gog, 2006). The argument by Kirshner, Sweller, and Clark and others led to the research hypotheses and conceptual framework.

Hypothesis Development and Conceptual Framework

Complex Questions and Cognitive Loading

Based on the cognitive load theory, asking students to solve complex questions will induce high levels of cognitive loading (Amadieu, van Gog, Paas, Tricot, & Mariné, 2009; Ayres, 2006; Kirschner, 2002; Paas & van Gog, 2006). This led to the first research hypothesis which can be stated as:

H_1: There is a positive association between complex questions (CQue) and cognitive loading (CogLd)

ZPD and Cognitive loading

No empirical studies on the relationship between ZPD and cognitive loading were found. Nevertheless, since working in the ZPD means working with tasks which students cannot perform on their own unless with appropriate help (Naeini, 2014; Shooshtari & Mir, 2014), it is expected that tasks located in the ZPD will induce some amount of cognitive loading. Therefore, assessment tasks located in the ZPD of students will also induce cognitive loading but less than that induced by complex questions. This is because tasks which are located in the ZPD can be resolved with help from a more experienced person while complex tasks may in fact be located outside the ZPD. Therefore, the second research hypothesis was stated as:

H_2: There is a positive association between ZPD and cognitive loading (CogLd)

SDL and Cognitive Loading

There were no empirical studies found on the relationship between SDL and cognitive loading. Notwithstanding, since in SDL, students control the pace and amount of work engaged and so the mental effort expended (Alharbi, 2017; Din et al., 2016), it is not expected to induce a significant amount of cognitive loading. Therefore, it is unlikely that the cognitive load while engaging in SDL would exceed the limits of the working memory of students. This is because cognitive load induces stress and students will naturally limit the amount of stress they will expose themselves to voluntarily. This argument led to the third hypothesis which was stated as:

H_3: There is no statistically significant association between SDL and cognitive loading (CogLd)

Complex Questions and ZPD

There were no studies found relating complex questions to ZPD. It can be argued that since solving complex questions requires the collation of information found in different sources and often from different bodies of knowledge, the students will fail to solve the complex problems unless with guidance from a very knowledgeable person. Therefore, complex questions are located in the ZPD closer to the zone of tasks which students cannot perform even with supervision. This argument led to the hypothesis that:

H_4: There is a positive association between complex questions (CQue) and the ZPD.

ZPD and SDL

Learning consists of students increasing the range of tasks which they can perform without guidance from a more knowledgeable person. Essentially, it consists of converting some of the ZPD into the zone of what can be done without help. Therefore, when students engage in SDL, rather than attempting to solve problems which they can already handle on their own, they will most likely work on problems which are in the ZPD. This led to the hypothesis that:

H_5: There is a positive association between ZPD and SDL.

Complex Questions and SDL

When engaging in SDL, students are expected to attempt questions located in the ZPD rather than what they can already do comfortably on their own. Considering that complex questions are expected to be located in the ZPD, it should also be expected that SDL will lead students to attempt some complex questions. However, it is also expected that the resulting high levels of cognitive loading and subsequent stress will cause students to abandon many such attempts. Therefore, is expected that there will be few and abortive attempts to engage with complex questions in the absence of sufficient guidance. Therefore, since some attempt at working on complex questions can be expected, albeit little and abortive, it was hypothesized that:

H_6: That there is a small positive association between SDL and complex questions (CQue)

Following from the proposed hypotheses, the proposed conceptual model can be presented as follows:

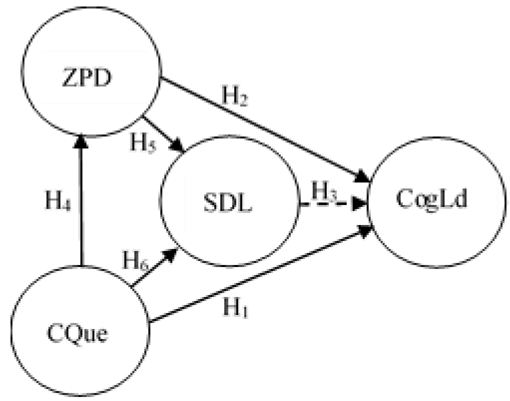

Figure 1: Conceptual Model of the Research Constructs

Methodology of Research

General Background of Research

A quantitative research design with a positivist philosophy and a deductive research approach were used because the research sought to test hypothesized associations among the study variables to which the quantitative design, a positivist philosophy and a deductive approach are all well suited. The research type is descriptive in nature and so the hypotheses tested are non-causal. While constructivist pedagogy has many distinct tenets, the scope of the research is delimited only to the constructs presented in the conceptual model in Figure 1. The favored data collection method was a cross sectional questionnaire survey due to the objectivity and low cost associated with its use compared to other methods of data collection. The data were collected from August to November 2017. Non probability sampling was used for convenience and economy.

Sample and Data Collection Procedures

The target population for the research were students undertaking construction studies at public universities in South Africa. Three public universities in the KwaZulu-Natal province were conveniently selected for the research. All students present in class at the time of the data collection were included in the sample. The students were not informed beforehand that a questionnaire would be circulated and so attendance was not influenced by the study. Therefore, absconding students were purely random and it can be concluded that the available sample of students was representative of the population of interest. The questionnaires were circulated to students at the start of lectures. Arrangements were made with respective lecturers responsible for different classes to allow 30 minutes at the start of their lectures to administer the questionnaires. Students were requested to fill in the questionnaire after explaining to them the details of the study and the instructions for filling in the form. The students were informed of their right to not participate in the study and to withdraw at any time for any reason. The students were also assured of both confidentiality and anonymity if they chose to participate. A sample of 543 students studying towards bachelor's degrees in either Construction Management, Quantity Surveying or Property Studies at the three public universities was obtained.

Demographic Statistics of Sample

Table 1 shows the profile of the respondents. All academic years of study from first to fourth year were represented in the sample with first years accounting for the highest number (34.10%) followed by fourth years (23.00%) and then second years (23.20%). With no single year of study being markedly larger or smaller than any other, the distribution of the academic year of study is representative of a typical four years' university program. The gender distribution has more males (59.80%) than females which is consistent with the general gender distribution in the population of interest. Therefore, the gender distribution is also representative of population of interest. The programs of study sampled were from the disciplines of Construction Management, Quantity Surveying, Property Studies and Architecture. The highest number of respondents came from the discipline of Construction Management (47.70%) while Property Studies accounted for only 8.80% and Architecture only 14.90%. Arguably, the Property Studies sample is small compared to the rest, given that the Property Studies qualification is a foundation degree for a specialization in either Construction Management or Quantity Surveying at fourth year level at the particular university. Therefore, the Property Studies in this sense is in fact quite the same as either Construction Management or Quantity Surveying. The Architecture sample, however, is rather underrepresented because only two of the three sampled universities offered Architecture and also the Architecture classes had much fewer students than the other classes.

Table 1. Sample Demographic Statistics

Year of Study	**Frequency**	**Percentage**
1	185	34.10
2	126	23.20
3	107	19.70
4	125	23.00
Total	**543**	**100**
Gender	**Frequency**	**Percentage**
Male	324	59.80
Female	219	40.20
Total	**543**	**100**
Program of Study	**Frequency**	**Percentage**
Construction Management	259	47.70
Quantity Surveying	155	28.60
Property Studies	48	8.80
Architecture	81	14.90
Total	**543**	**100**

Measurement Instrument and Procedures

The scales in the questionnaire were developed based on the operational definition of the research constructs. Cognitive loading was operationalized mainly as the extent to which students are overwhelmed by the amount of assigned work and the extent to which they are expected to remember too much information which was complex, difficult and confusing to understand. This conception is shared by others (Çolak & Kaya, 2014; Hadie and Yusoff, 2016) and is also supported by the findings which show that high levels of cognitive loading lead to students being overwhelmed (Scheiter et al., 2009; Çolak & Kaya, 2014). The concept of complex questions was operationalized by extent to which students were given assessment problems which were difficult to understand, hand no defined solution and required combining information from different subject areas and sources. Zone of proximal development (ZPD) was operationalized as the extent to which students were presented with problems which were beyond what they could comfortably solve without further guidance. Self-directed learning was operationalized by the extent to which the students were expected to engage in learning activities on their own and without further guidance. All the resulting scales are shown in Table 2. The instrument was anchored on a 5-point Likert scale with 5=almost never; 4=often; 3=sometimes; 2=seldom; and 1=almost never. The questionnaire, along with the entire research, were reviewed by the university research ethics committee and approved.

Measurement Instrument Assessment

The measurement instrument was assessed for reliability and validity. Firstly, factor analysis with principle components extraction rotated using Promax with Kaiser normalization was used for data reduction to examine the factor structure of the measurement instrument. The cut off of eigenvalue-greater-than-one rule suggested by Kaiser (1974) was preferred for determining the number of factors to return. Prior to this, the data were assessed for their adequacy for factor analysis using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett's test of sphericity.

Table 2. Measurement Model Assessment

	Research Constructs		Mean	Std. Dev	Item-correlations	Factor Loadings
Cognitive Loading		**CogLd**				
1	I was expected to remember too many things from each lecture	CogLd1	3.49	1.07	0.57	0.78
2	I was overwhelmed with the amount of information I was expected to remember	CogLd2	3.45	1.06	0.55	0.86
3	I was given too much information during the lectures	CogLd3	3.28	1.03	0.65	0.86
4	The information I was given during lectures was confusing	CogLd4	2.78	1.10	0.61	0.54
5	The information I was given in class was complicated and difficult to understand	CogLd5	2.77	1.10	0.61	0.54
6	I was overwhelmed with the amount of work I had to do	CogLd6	3.30	1.11		
7	I was given too many projects, assignments and tests	CogLd7	3.22	1.21		
Complex and Ambiguous Questions		**CQue**				
1	I was given assignments and tests which were difficult to understand and solve	CQue1	2.87	1.73	0.44	0.51
2	I was given problems which did not have enough information for me to solve them	CQue2	2.68	1.13	0.72	0.81
3	I was required to solve questions which were not clear as to what I was expected to do	CQue3	2.84	1.13	0.75	0.87
4	I was given questions which could be interpreted in more than one way	CQue4	3.09	1.074	0.57	0.79
5	I was given problems which were not easy to understand clearly	CQue5	2.87	1.122	0.73	0.88
6	I was given questions which were not expressed clearly	CQue6	2.77	1.185	0.71	0.83
Zone of Proximal Development		**ZPD**				
1	I found tests and assignments to be very challenging	ZPD1	3.46	1.011	0.41	0.64

2	I was given work which was beyond what I could manage to do on my own	ZPD2	2.68	1.175	0.49	0.72
3	I was given work which required further guidance from the lecturers in order to complete it	ZPD3	3.16	1.121	0.54	0.82
4	I was given work which required consulting with more knowledgeable people in order to do it well	ZPD4	3.58	1.060	0.45	0.70
Self-Directed Learning		**SDL**				
1	I was required to find additional knowledge and information on my own	SDL1	3.94	0.998	0.64	0.80
2	I was given work which required me to learn new concepts on my own	SDL2	3.81	0.984	0.65	0.79
3	I was expected to expand on what was taught in class on my own	SDL3	3.89	0.985	0.67	0.84
4	I was required to learn on my own	SDL4	3.78	1.141	0.49	0.64

The KMO measure of sampling adequacy was 0.883 while the Bartlett's test of sphericity was significant (p=.0001) with a chi-square statistic of 4326.258 and a degree of freedom of 210. The factor analysis produced a four-factor solution which explained 58% of the total variance. All the items loaded on their *a priori* constructs when factor loadings of .50 were suppressed as recommended by Anderson & Gerbing (1998). Item 6 under Cognitive Loading (CogLd6) had a factor loading less than .50 while item 7 (CogLd7) cross loaded onto Complex and Ambiguous Questions. These two items were omitted from subsequent analyses. The remaining factor loadings ranged between .51 and .88 and so all the factor loadings meet the minimum threshold. Item-to-total correlations, which measure how well individual items correlate with eth rest of the items in the scale, ranged between .44 and .75 which exceeded the recommendation of .30. All these statistics are shown Table 2.

Table 3 shows the results of the reliability and validity statistics of the measurement instrument. Reliability was assessed using Cronbach's alpha and Composite Reliability (CR) while validity was assessed using Average Variance Extracted (AVE). Cronbach's alpha for all constructs ranged between .69 and .81. Three of the constructs exceeded the recommendation of .70 by Byrne (2006) while one construct (ZPD) marginally fell below this threshold. Hulland (1999) recommended a threshold of .60 for CR and all the constructs exceeded this threshold. Therefore, based on the Cronbach's alpha and the CR, the study constructs exhibit good reliability. Fornell and Larcker (1981) recommend AVE values to be greater than .50 and all the constructs exceeded this threshold indicate of good instrument validity.

Table 3. Reliability and Validity

	Construct	Cronbach's Alpha	CR	AVE
1	**CogLd**	.81	.71	.54
2	**CQue**	.85	.81	.63
3	**ZPD**	.69	.70	.52
4	**SDL**	.80	.78	.60

The constructs were further assessed for discriminant validity. For discriminant validity to exists, the square root of the AVE should be less than the shared variance (inter correlation) between the two constructs (Fornell and Larcker, 1981). Evidence of discriminant validity can be seen in Table 4 which shows the square root of the AVE in the diagonal and the inter-construct correlation in the remainder of the table. All the inter-construct correlations are less than the square root of the AVE indicating good discriminant validity. Further, all the inter-construct correlations are less than .80 suggesting that there is no multi-collinearity among them.

Table 4. Inter-construct Correlations and Discriminant Validity

	CogLd	CQue	ZPD	SDL
CogLd	**.73**			
CQue	.47**	**.79**		
ZPD	.34**	.35**	**.72**	
SDL	.20**	.22**	.29**	**.77**

**. Correlation is significant at the .01 level (2-tailed).
*. Correlation is significant at the.05 level (2-tailed).

Data Analysis

The hypotheses among the research constructs were assessed using structural equation modelling (SEM). SEM is a multivariate data analysis approach used to assess complex relations among constructs. It graphically models hypothesised relationships among constructs with structural equations (Byrne, 2006). The primary goal of SEM is the assessment of model fitness against empirical data and the estimation of the regression parameters (Byrne, 2006; Hu and Bentler, 1999). SEM was performed using IBM SPSS AMOS v25 software. While other software for performing SEM are available, the AMOS software was preferred because it was the available software at the time of the research.

Results of the Research

Structural Equation Modelling

Prior to assessing the structural relationships among the constructs, the measurement model was assessed for fitness. This two-step approach was suggested by Anderson and Gerbing (1998). The measurement model was assessed for fitness with thresholds as suggested by Bentler (1990), Browne and Cudeck (1993) and Marsh et al. (1996). The recommended fit indices and the measurement model fit indices are shown in Table 5. All but one index exceeded the minimum recommended thresholds. However, since the index which did not exceed the minimum equalled the threshold, the empirical data perfectly fit the measurement model.

The structural model fit was evaluated and the relationships between the study constructs assessed through path modelling. The structural model also showed a perfect fit based on thresholds suggested by Bentler (1990), Browne & Cudeck (1993) and Marsh et al. (1996). All the fit indices retained exactly the same values as the measurement model

Table 5. Measurement Model Fit Summary

Model Fit Index	Acceptable Threshold	Study Threshold	Met/Not Met
Chi-Square value: X/df	<3	2.154	Met
Comparative Fit Index (CFI)	>0.900	0.958	Met
Incremental Fit Index (IFI)	>0.900	0.959	Met
Normed Fit Index (NFI)	>0.900	0.926	Met
Tucker Lewis Index (TLI)	>0.900	0.944	Met
Relative Fit Index (RFI)	>0.900	0.900	Not Met
Random Measures of Sample Error Approximation (RMSEA)	<0.080	0.046	Met

Hypothesis Evaluation

Having checked the structural model for fitness with the primary data structure and accepted the model as being a representation of the empirical data, the hypothesized structural relationships among the variables were tested. The results of the hypothesis testing are shown in Table 6. The first hypothesis postulated that there is a positive relationship between Complex Questions and Cognitive Loading. The results provide support for the hypothesis with a statistically significant relationship at 99% confidence interval. Complex Questions contributed 59% of the explained variance on Cognitive Loading. The second hypothesis postulated that there is a positive relationship between ZPD and Cognitive Loading. The results support the hypothesis with a statistically significant relationship between the two variables with ZPD contributing 14% explained variance to cognitive loading. The third hypothesis postulated that there is no statistically significant relationship between Self-Directed Learning and Cognitive Loading. The results support the hypothesis with a non-significant association between the two constructs. The fourth hypothesis postulated that there is a positive relationship between Complex Questions and the ZPD. The results support the hypothesis with a statistically significant relationship between the constructs with complex questions explaining 42% of the variance in ZPD. The fifth hypothesis postulated that there is a positive relationship between ZPD and SDL. The results support the hypothesis with SDL explaining 32% of variance in ZPD which is statistically significant. The sixth and last hypothesis postulated that there is a positive relationship between Complex Questions and SDL. The results support the hypothesis with a statistically significant association with complex questions explaining 7% variance in SDL.

Table 6. Hypothesis Evaluation

Proposed Hypothesis			Hypothesis	Factor Loading	Rejected/Supported
CQue	→	CogLd	$+H_1$	.59**	Supported
ZPD	→	CogLd	$+H_2$	.14**	Supported
SDL	→	CogLd	H_3	-.05	Supported
CQue	→	ZPD	$+H_4$	.42**	Supported
ZPD	→	SDL	$+H_5$	.32**	Supported
CQue	→	SDL	$+H_6$	.07**	Supported

Discussion

When complex questions are used in learning tasks, students are likely to experience high levels of cognitive loading. This is evidenced by a strong association between complex questions and cognitive loading whereby complex questions account for almost 60% variation in cognitive loading. This is consistent with several other research findings which showed that when students are presented with complex tasks, they will experience high levels of cognitive loading (e.g. Amadieu, van Gog, Paas, Tricot, & Mariné, 2009; Ayres, 2006; Kirschner, 2002; Paas & van Gog, 2006). The high levels of cognitive loading which result from complex questions are likely to severely stress students to a point that they will hardly learn.

The findings also suggest that tasks which are in the ZPD of students also induce cognitive loading albeit significantly less than that induced by complex questions. The cognitive loading due to tasks located in the ZPD is about a quarter of that due to complex questions. This shows that whenever students are required to complete tasks which require help from others, and so are located in the ZPD, the students will experience some cognitive loading. Previous research findings on cognitive loading mainly focused on cognitive loading due to complex questions. Cognitive loading due to questions which are within the ZPD of students have not been reported. Rather, research findings suggest that simpler learning tasks such as worked examples induce little to no cognitive loading (Leppink, 2017). However, since learning consists of mastering tasks which are in the ZPD until the tasks can be performed without the help of someone more knowledgeable, the findings from this research suggest that all meaningful learning will yield some amount of cognitive loading. This argument resonates with the statistically significant relationship found between complex questions and ZPD which indicates that complex questions are in fact located in the ZPD of students. Being a zone, the ZPD accommodates a range of learning tasks of differing levels of complexity. Complex tasks would be located at the outer most edge of the zone next to the edge with what students cannot do even with some help. Simpler tasks, but which require to be scaffolded, would be at the edge next to what students can do on their own. The results therefore suggest that tasks in the ZPD will induce some cognitive loading relative to their level of complexity. The findings also suggest that engaging in SDL does not induce high levels of cognitive loading. This is because when engaging in SDL, students monitor their own learning and so have the option of abandoning tasks which induce high levels of cognitive loading.

The findings further suggest that subjecting students to tasks which are in their ZPD is likely to lead them to engage in SDL. While presenting them with complex questions also significantly leads to SDL, complex questions only accounted for about 7% variation in SDL while tasks in the ZPD accounted for 32% variation in SDL. That is to say that tasks which are in the ZPD, but are not perceived as being complex, are at least 4 times more likely to encourage students to engage in SDL than when the tasks are complex. This is because the high levels of cognitive loading associated with complex questions are likely to deter students from persevering with the complex tasks when students have to direct their own learning. On the contrary, because tasks which are in the ZPD induce far less cognitive loading than complex questions, students are likely to persist with SDL when the tasks are in the ZPD and are not complex.

Therefore, contrary to recommendations by Kahn and O'Rourke (2004) and Harinarain and Haupt (2016) that assessment tasks in constructivist pedagogy should be complex and ambiguous, it may be appropriate to avoid learning tasks which are too complex. This suggestion is consistent with the recommendation by Lim (2004) that complex tasks should be avoided as students may lose interest in the learning task. Complex tasks induce high levels of cognitive loading and do not encourage SDL. Less complex tasks located in the ZPD of students are more appropriate because they induce less cognitive loading compared to complex questions and encourage students to engage in SDL.

Conclusions

Consistent with other research findings, this study found that complex questions induce a statistically significant amount of cognitive load in students. This study also found that self-directed learning does not induce cognitive loading. Subjecting students to tasks which are in their ZPD is likely to induce some cognitive loading albeit much less than that from complex questions. It was also found that locating tasks in the ZPD of students is likely to encourage students to engage in some self-directed learning up to as much as four times more than when the tasks are complex.

Therefore, based on these findings and consistent with other studies, to reduce the amount of cognitive loading which students are subjected to, complex questions should be avoided for students with little subject prior knowledge. Otherwise, the resulting high levels of cognitive load will stress the students and interfere with learning. However, when exposed to questions which are perceived as complex by students, to mitigate the resulting high levels of cognitive load, students should be appropriately scaffolded. Otherwise they will not persist with the learning task especially if they are expected to engage in SDL which is often the case with pedagogy based on constructivism.

Also, in order to encourage students to engage in self-directed learning, the learning tasks assigned for SDL should not be complex relative to the knowledge level of the students as this discourages students from persisting with SDL. Even when students are given tasks which are not complex but in are in the ZPD, it is important to ensure that the resulting level of cognitive loading is manageable for the students. This is because tasks in the ZPD of students also induce cognitive loading.

Given that students are always working on tasks which are in their ZPD, they should be appropriately scaffolded at all times because they will experience some cognitive loading

Limitations and Future Research

While this research makes contributions to the body of knowledge and to educational practice, it has some limitations. Firstly, the research is based on self-reported measures of the constructs and so suffers from all the draw backs of self-reported measurement. Secondly, the data were collected from one province using instruments which have not been extensively tested. Therefore, future studies may validate the instruments used in this study or develop other instruments for the constructs under study to test the validity of the results and conclusions arrived at by this research. Thirdly, the conceptual model proposed in this study is not the only plausible representation of the data notwithstanding that model fit indices showed that the data perfectly fit the measurement model. Therefore, future studies can test other possible relationships among the constructs and also include other constructs to the model and even establish the effect of moderator variables on the model. Lastly, the research was cross-sectional and descriptive in nature and so does not suggest that the associations found among the constructs are causal. Longitudinal exploratory research designs can assess the impact of subjecting students to different levels of question complexity in order to establish the effect on their aptitude for self-directed learning.

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Review Feedback

1.	Is the article original, and does it contribute something new to the field? (Importance of article / Relevance and Appeal to national / international scholarly community)	**Excellent**	**Good**	**Moderate**	**Poor**
2.	Do the title and abstract together give an adequate summary of the article / paper?	**Excellent**	**Good**	**Moderate**	**Poor**
3.	Statement of problem (s) / aim (s) / objective (s)	**Excellent**	**Good**	**Moderate**	**Poor**
4.	Theoretical basis / Theoretical framework / Literature review / Clarification of concepts	**Excellent**	**Good**	**Moderate**	**Poor**
5.	Appropriateness of the research plan and design (if applicable) /Appropriateness of data-collection and procedure /Data analysis /Trustworthiness/ reliability and validity	**Excellent**	**Good**	**Moderate**	**Poor**
6.	Steps taken to ensure that the research complies with standard ethical guidelines (if applicable)	**Excellent**	**Good**	**Moderate**	**Poor**
7.	Data presentation / Discussion (Are the results clearly and correctly presented? Are they consistent with the methodology?)	**Excellent**	**Good**	**Moderate**	**Poor**
8.	To what extent is the line of argumentation in the article clear, cohesive and logical? standards?	**Excellent**	**Good**	**Moderate**	**Poor**
9.	Does the paper satisfy accepted criteria for academic writing in terms of coherence, grammar, layout and organisation?	**Excellent**	**Good**	**Moderate**	**Poor**
10.	Do the references adhere to APA?	**Excellent**	**Good**	**Moderate**	**Poor**
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12.	Conclusions /Implications and/or recommendations are relevant and useful.	**Excellent**	**Good**	**Moderate**	**Poor**
13.	Is article significantly international in nature to be of value to global audience? /underline/	**Excellent**	**Good**	**Moderate**	**Poor**

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13.15 Appendix 15 – Publication 6 – CHAID Modelling of Schema Construction Explained by Approaches to Learning

Paper Code: P1

CHAID Modelling of Schema Construction Explained by Approaches to Learning

Ephraim Zulu[1], Vittorio Tramontin[2] and Theodore Haupt[3]
University of KwaZulu-Natal, South Africa[1,2]
Mangosuthu University of Technology, South[3] Africa

Abstract

This study explores the relationship between approaches to learning and schema construction in undergraduate students. Students either engage in a deep or surface learning (memory learning) approach. Studies have explored how approaches to learning affect academic achievement generally and how they affect achievement in specific subject areas. Using CHAID modelling, the findings of this study show that deep learning is a significant predictor of schema construction. Memory learning was also a significant predictor of schema construction for students who either "sometimes" or "often engaged" in a deep learning approach. This suggests that memory learning may moderate the relationship between approaches to learning and schema construction or academic achievement generally.

Keywords: CHAID, Schema, Learning Approaches, Deep Learning, Memory Learning

Introduction

Learning approaches are student strategies for learning. Learning approaches are generally grouped into two, namely deep approaches learning and surface or memory learning approaches with some authors adding other dimensions such as strategic learning and achieving learning as dimensions of deep learning (von Stumm & Furnham, 2012; Yusoff & Arifin, 2015). Deep learning approaches and their other reported dimensions consist of exploring a topic to the greatest possible extent to achieve a greater understanding of the topic (von Stumm & Furnham, 2012). Several studies have reported the importance of learning approaches to academic achievement (Bakhtiarvand, Ahmadian, Delrooz, & Farahani, 2011; Chen & Hu, 2013; Çolak & Kaya, 2014; Genc & Tinmaz, 2013). Azar, Lavasani, Malahmadi, and Amani (2010) found that deep learning approaches positively influenced mathematics achievement. Several other studies have reported the positive influence of a deep learning approach on academic achievement. Surface learning, on the other hand, consists of learning only what is needed to pass and are often characterized by superficial knowledge of the topic through memorization (von Stumm & Furnham, 2012). Azar, Lavasani, Malahmadi and Amani (2010) found that a surface learning approach negatively influenced mathematics achievement while Hasnor, Ahmad, and Nordin (2013) found a negative correlation between memory learning and academic achievement.

While many studies have studied the relationship between learning approaches and academic achievement, none have studied the relationship with schema construction. Schema construction is a conceptualisation of learning based on schema theory. A schema is a group of common and logical notions which constitute a network of relationships that make up a person's knowledge and understanding structure (Hummel & Nadolski, 2002). It is anything that is learnt and is treated as a single entity by working memory and can incorporate a large and complex amount of information (Hummel & Nadolski, 2002; Kirschner, 2002; van Bruggen, Kirschner, & Jochems, 2002). Effective learning consists of the development and automation of schemata (Hummel & Nadolski, 2002).

Therefore, this research sought to explore the relationship between approaches to learning and schema construction. Specifically, the research addressed the question "What approaches to learning consistently predict schema construction? Schema construction is viewed as a better measure of learning than academic achievement since it attempts to measure the cognitive development in students due to learning activities. Conceptualising learning this way and relating it to learning approaches could validate other studies on the effects of different learning approaches. The research question was answered using Chi-square Automatic Interaction Detection (CHAID) modelling. CHAID modelling is a predictive decision tree based technique for determining a dependent variable by independent variables (Díaz-Pérez, Bethencourt-Cejas, 2016). The approach has been little used in research on education. It is therefore expected that using this different methodological approach to a fairly well researched topic in educational research could either provide new insights or validate already accepted research findings.

Research Methods

A quantitative research design with a positivist philosophy and a deductive research approach were used because the study sought to test hypothesized relationships among the study variables to which the quantitative design, a positivist philosophy and a deductive approach are all well suited (Saunders, Lewis, and Thornhill 2012; Sekaran and Bougie, 2010). The favoured data collection method was a cross sectional questionnaire survey due to the objectivity and low cost associated with its use compared to other methods of data collection. Non probability sampling was used for convenience and economy.

The research sample was drawn from three public universities in the province of KwaZulu-Natal in South Africa. The public universities were selected based on the convenience of proximity to the domicile of the researchers. All students present at the time of distributing the questionnaire were included in the sample. The students were not informed beforehand that the questionnaire would be circulated and so class attendance and therefore the sample was not influenced by the questionnaire administration.

Table 1 – Demographic Information

Year of Study	**Frequency**	**Percentage**
1	71	26.0%
2	30	11.0%
3	61	22.3%
4	111	40.7%
Total	**273**	**100%**
Gender	**Frequency**	**Percentage**
Male	158	57.9%
Female	115	42.1%
Total	**273**	**100%**
Program of Study	**Frequency**	**Percentage**
Construction Management	128	46.9%
Quantity Surveying	93	34.1%
Property Studies	52	19.1%
Total	**273**	**100%**

The questionnaires were circulated to students at the start of lectures. Students were assured of confidentiality and anonymity and also notified of their right not to participate or withdraw from the study at any time and for any reason. This was in tandem with the ethical conduct demanded by the university ethics committee. A sample of 273 responses from the students at the three public universities was obtained with demographics information as shown as shown in Table 1. The table shows the distribution of the respondents by year of study, gender and by programme of study. The population of interest was all student undertaking construction related programmes at the three selected public universities.

Results and Data Analysis

Measurement Instrument Analysis

The measurement instrument for the study is shown in Table 2. The instrument was subjected to factor analysis using IBM SPSS version 25 software to establish whether the items converged on the respective constructs as hypothesised *a priori* using principle component extraction with eigen values greater than 1.0 and Equamax with Kaiser Normalization. Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.827 and the Bartlett's Test of Sphericity was significant (p=0.000) indicating that the sample size was adequate for factor analysis.

Table 2 – Measurement Instrument

High Order Learning	
HiLn1	I studied the basic elements of a point, an idea, experience, or theory, in depth and considered its components
HiLn2	I combined and organised points, ideas, information, or learning experiences into new and more complex understanding, interpretations or relationships
HiLn3	I judged the value of information, arguments, or methods and lessons that I learned.
HiLn4	I applied theories or concepts that I learnt in class to practical problems or in new situations
Integrative Learning	
IntLn1	I worked on assignments or projects that required using ideas or information from various sources and modules
IntLn2	I looked at problems from several different points of view in class discussions or when writing assignments
IntLn3	I used ideas or concepts from other modules when completing assignments or during class discussions
IntLn4	I discussed ideas after studying or after classes with lecturers outside of class
IntLn5	I discussed ideas from my studies or classes with others outside of class (classmates, other students, family members, co-workers, etc.)
Reflective Learning	
RefLn1	I thought about the strengths and weaknesses of my own views and opinions on a topic
RefLn2	I tried to understand other people's views by thinking about how an issue or point looked from their perspective or view point
RefLn3	I learned something new or different that changed the way I understand things or a concept from another module
RefLn4	I learned something new or different from discussing difficult questions that have no clear answers
RefLn5	I used what I learned in a module in other modules
RefLn6	I enjoy doing assignments that require a lot of thinking and mental effort
Memory Learning	
MemLn1	I rehearse or practice until I can reproduce a definition word by word
MemLn2	If I do not understand a part of the learning material I just memorise it so that I do not forget it
MemLn3	I try to memorize everything that might be covered in my tests
MemLn4	I memorize as much as possible

Schema Construction and Automation	
SchCon1	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject
SchCon2	My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew
SchCon3	I connected points that I already knew with what I was being taught in class
SchCon4	I organised, categorised or connected anything new that I learnt with what I already knew
SchCon5	My lecturers clearly highlighted the main concepts and principles

The study constructs were assessed for reliability and validity. Reliability was assessed using Cronbach's alpha, inter-item correlations, composite reliability (CR) and average variance extracted (AVE). Cronbach's alpha for all constructs ranged between 0.615 and 0.855 which exceeded the recommendation of 0.60 by Hair et al. (2010). Item-to-total correlations ranged between 0.381 and 0.762. Therefore, some of the item-to-total correlations failed to meet the threshold of 0.50 recommendation by Hulland (1999) suggesting a poor reliability of these constructs. A threshold of 0.60 is recommended for CR (Ibid). Fornell and Larcker (1981) recommend AVE values to be greater than 0.50. However, three of the constructs had AVE values less than 0.50 indicating a marginally acceptable AVE for the constructs for these constructs. The three constructs which consistently exhibit poor reliability are HiLn, IntLn and RefLn suggesting that the items used to measure the constructs are poor measures. For discriminant validity to exists, the square root of the AVE should be less than the shared variance (inter correlation) between the two constructs (Fornell and Larcker, 1981). Evidence of discriminant validity can be seen in Table 3 which shows the square root of the AVE in bold in the diagonal and the inter-construct correlation in the remainder of the table. All the inter-construct correlations are less than the square root of the AVE indicating good discriminant validity.

Table 3 – Measurement Instrument Analysis

Research Constructs		**Mean**	**Cronbach's Test**		**C.R.**	**AVE**	**Communalities**	**Item Loadings**
			Item-total	**α Value**				
High Order Learning	HiLn1	3.604	0.499	0.685	0.472	0.366	0.724	0.738
	HiLn2		0.549				0.596	0.580
	HiLn3		0.419				0.592	0.544
	HiLn4		0.412				0.468	0.535
Integrated Learning	IntLn1	3.891	0.429	0.647	0.513	0.391	0.714	0.642
	IntLn2		0.514				0.635	0.629
	IntLn3		0.430				0.536	0.605
Reflective Learning	RefLn1	3.734	0.381	0.615	0.414	0.324	0.658	0.540
	RefLn2		0.498				0.630	0.626
	RefLn3		0.398				0.654	0.538
Memory Learning	MemLn2	3.597	0.520	0.798	0.879	0.692	0.668	0.747
	MemLn3		0.732				0.815	0.880
	MemLn4		0.689				0.805	0.863
Schema Construction	SchCon1	3.759	0.655	0.855	0.693	0.521	0.673	0.760
	SchCon2		0.762				0.751	0.812
	SchCon3		0.666				0.693	0.712
	SchCon4		0.667				0.639	0.660
	SchCon5		0.594				0.570	0.653

The constructs were tested for normality in order to establish whether to use parametric or non-parametric analyses.

The Shapiro-Wilk test of normality was used. It tests the null hypothesis that the sample is drawn from a normally distributed population. Results of the test are shown in Table 4. The null hypothesis is rejected since all the p-values for the constructs are significant (p=0.000) and so it can be concluded that he data does not follow a normal distribution. Therefore, only non-parametric tests will be conducted.

Table 4 – Tests of Normality

	Kolmogorov-Smirnova			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
HiLn	0.139	268	0.000	0.964	268	0.000
IntLn	0.116	268	0.000	0.955	268	0.000
RefLn	0.100	268	0.000	0.968	268	0.000
MemLn	0.121	268	0.000	0.949	268	0.000
SchCon	0.084	268	0.000	0.971	268	0.000

a. Lilliefors Significance Correction

A cross tabulation correlation of the constructs was done to check for discriminant validity. The non-parametric Spearman's Rho is reported in Table 5. The square root of the AVE is shown in bold in the diagonal of the table. All the inter-construct correlations are less than the square root of the AVE indicating good discriminant validity.

Table 5 – Inter-Construct Correlations and Discriminant Validity

	HiLn	**IntLn**	**RefLn**	**MemLn**	**SchCon**
HiLn	**0.605**				
IntLn	0.497**	**0.625**			
RefLn	0.495**	0.409**	**0.569**		
MemLn	0.090	0.136*	0.136*	**0.832**	
SchCon	0.390**	0.425**	0.355**	0.100	**0.722**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

CHAID Analysis

Chi-square Automatic Interaction Detection (CHAID) was the preferred data analysis methodology. CHAID is a distribution free (non-parametric) data analysis methodology which predicts a target variable using a decision tree. The analysis was chosen firstly because it was suggested by the *Auto Numeric* function of the IBM SPSS Modeller version 18.1 software. The *Auto Numeric* function suggests the appropriate data analyses based on the data set. Secondly, since the data were found to be non-parametric, the CHAID analysis was appropriate (Díaz-Pérez, Bethencourt-Cejas, 2016). Figure 1 shows the IBM SPSS Modeller version 18.1 graphic user interface (GUI) of the data analysis. Results of the CHAID are shown in Figure 2.

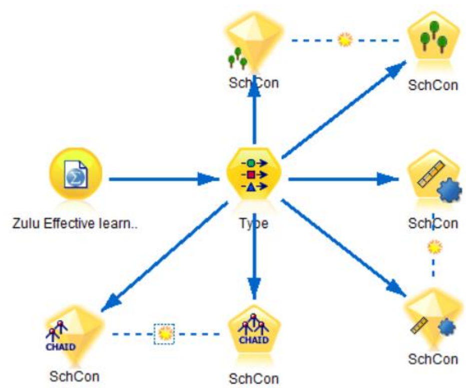

Figure 1 – IBM SPSS Modeller Data Analysis GUI

The CHAID model in Figure 2 shows that the most significant (p=0.000) predictor of SchCon is HiLn. In predicting SchCon, HiLn breaks up into three groups of respondents. The first group comprised of about 21% of respondents who responded either "almost never" or "seldom" in in response to phrases in HiLn. The second group comprised of about 61% of respondents who responded either "sometimes" or "often" to phrases in HiLn while the third group comprised of 18% of respondents who responded "almost always". For the respondents who responded either "sometimes" or "often", MemLn was a significant predictor of HiLn. Of the 18% who responded almost always, IntLn was a significant predictor of HiLn with the majority of then responding either "often" or "almost always" to phrases in HiLn. Therefore, respondents who responded "almost always" to HiLn are very likely to have also responded either "often" or "almost always" to IntLn.

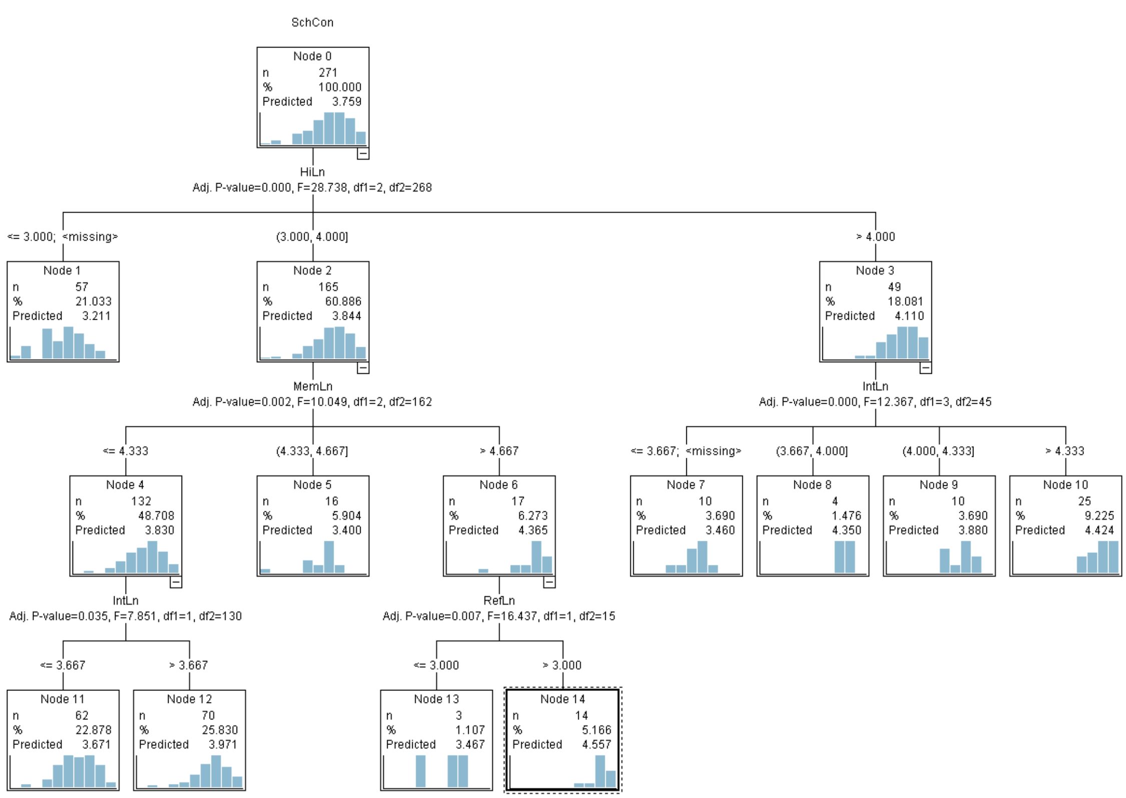

Figure 2 – CHAID Model of Schema Construction and Learning Approaches

Discussion of Findings

This study sought to investigate the relationship between student approach to learning and their engagement in schema construction. Specifically, the study sought to establish the approach to learning which predicted schema construction using CHAID modelling. Many studies have investigated the relationship between approach to learning and academic achievement. However, no studies were found which related approach to learning to schema construction nor any which used CHAID modelling. This study preferred to relate approach to learning to schema construction because approach to learning has been shown to have a significant impact on learning. Schema construction, rather than academic achievement, was used to conceptualise learning because it was felt that the creation of knowledge structures, which is schema construction, rather than academic achievement, more closely models learning. Similar studies but using different analyses and a different conception of learning have found that a deep learning approach positively influences learning (Bakhtiarvand et al., 2011; Chen & Hu, 2013; Çolak & Kaya, 2014; Genc & Tinmaz, 2013).

Consistent with other studies, it was found that a deep learning approach positively impacts on schema construction. However, and surprisingly, it was also found that a memory learning approach also consistently predicted schema construction among students who "sometimes" and "often" engaged in deep learning. However, students who indicated that they "almost always" engaged in deep learning never engaged in memory learning. Research on student approaches to learning has consistently shown that a deep learning approach is associated with academic achievement (Bakhtiarvand et al., 2011; Chen & Hu, 2013; Çolak & Kaya, 2014; Genc & Tinmaz, 2013). Consistent with previous studies, deep learning was found to significantly predict schema construction. However, results also show that students who engaged in deep learning also engaged in memory learning as well. The decision tree results show that students who "sometimes" or "often" engaged" in a deep learning approach also engaged in memory learning. Therefore, memory learning may moderate the relationship between deep learning approach and academic achievement in students who engage in both deep learning and memory learning. Students who indicated that they "almost always" engaged in deep learning did not have memory learning play any role in predicting their level of schema construction. This is consistent with findings that deep learning is associated with academic achievement.

Conclusion

While it accepted that deep learning is a stronger predictor of academic achievement and so learning, the findings from this study suggest that for students who engage in both deep learning and memory learning, memory learning is also associated with effective learning. Therefore, memory learning may be a moderator of the relationship between approach to learning and academic achievement or learning in students who engage in both deep learning and surface learning approaches. This particular finding is important because the findings show that about 61% of the students engaged in both deep learning and memory learning. Therefore, the effect of engaging in both deep learning and memory learning has implications for the majority of students.

The findings from this study have limitations. Firstly, the psychometric properties of some of the scales used were not completely satisfactory. Therefore, better scales need to be used in order to verify the findings. Secondly, the claim that memory learning may be a moderating variable needs to be verified with further studies memory learning as a moderating variable would need to be conducted to verify this suggestion.

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13.16 Appendix 16 – Publication 7 - Mediation of Reflective Thinking on the Relationship between Self-Directed Learning and Schema Construction

Mediation of Reflective Thinking on the Relationship between Self-Directed Learning and Schema Construction

Ephraim Zulu
University of KwaZulu-Natal
King George V Avenue
Durban, 4001, South Africa
+27312602719
zulue@ukzn.ac.za

Theodore Haupt
Mangosuthu University of Technology
511 Mangosuthu Highway, Umlazi
Durban, 4031, South Africa
+27318199294
Theo.haupt@mut.ac.za

ABSTRACT

Self-directed learning (SDL) refers to the ability for students to engage in independent learning activities without any explicit direction from anyone. It involves students identifying their own learning needs, setting learning goals, identifying appropriate learning resources, choosing and applying appropriate learning strategies and evaluating learning outcomes. SDL is a strong predictor of academic performance and learning. It has been found to enhance learning and can even improve the quality of life for students when they engage in it. This study assessed the mediating role of reflective thinking on the relationship between SDL and learning. Reflective thinking is the careful consideration of information to arrive at conclusions. Reflective thinking has been shown to predict academic achievement and mediates relationships with approaches to learning, study strategies and goal orientation. In the relationships, it acts as both a determinant and also a mediator. A self-administered questionnaire was circulated to a purposive sample of 521 undergraduate students studying towards qualifications in construction related disciplines. The PROCESS macro v3.0 by Andrew F. Hayes in IBM SPSS was used to test for mediation while Structural Equation Model (SEM) was used to test the goodness of fit of the SDL, reflective thinking and schema construction conceptual models. There was a significant indirect effect of SDL on schema construction through reflective thinking, b=0.13, 95% BCa CI [0.08, 0.20]. The SEM model demonstrated that the proposed conceptual model had an excellent fit to the empirical data; $\lambda^2/df=1.698$, GFI=0.974, NFI=0.967, IFI=0.986, TLI=0.979, CFI=0.986, RMSEA=0.037. Therefore, reflective thinking was found to mediate the relationships between SDL and schema construction. The results of the study make both theoretical and practical contributions to literature concerning the role of reflective thinking in the relationship between SDL and the building of knowledge structures.

Keywords

Reflective Thinking; Self-directed Learning; Schema Construction; Mediation Analysis

1. INTRODUCTION

Self-directed learning (SDL) is a strong predictor of academic achievement. Several studies have researched on the relationship between SDL and academic achievement and have consistently reported that there is either a direct or indirect relationship between the two [1-3]. Therefore, when students engage in SDL, they are very likely to have better academic performance. SDL is the ability for students to engage in independent learning activities without any explicit direction from anyone. It involves students identifying their own learning needs, setting learning goals, identifying appropriate learning resources, choosing and applying appropriate learning strategies and evaluating learning outcomes [1-3].

However, while there is a strong association between SDL and academic performance, it is very unlikely that the relationship is causal. This is because merely being able to direct one's own learning is not a plausible justification for one achieving better learning outcomes. Based on schema theory, learning consists of creating lasting cognitive knowledge structures and linking existing knowledge structures with any new knowledge or information. The knowledge structures are known as schemata. When learning is conceptualized this way, it is not likely that merely engaging in SDL will lead to the creation of schemata which is the basis of academic performance. Being a cognitive process, development of schemata should involve some amount of cognitive activity. Therefore, it is more likely that a secondary cognitive process aside from SDL itself is responsible for better academic achievement and so mediates the relationship between SDL and academic achievement.

One cognitive process which has been reported to significantly predict academic achievement is reflective thinking [4-6]. Reflective thinking is a meta-cognitive process which involves evaluating an issue seriously in the mind. Reflective thinking has also been found to mediate relationships with approaches to learning, study strategies and goal orientation. Therefore, this study assesses whether reflective thinking also mediates the relationship between SDL and learning. While most studies which research on learning conceptualize learning as academic achievement, this research conceptualized it as the extent to which students engage in the process of linking knowledge which they already have with any new information. This is based on the conception of learning as posited by schema theory. The resulting conceptual model for the research is shown in Figure 1.

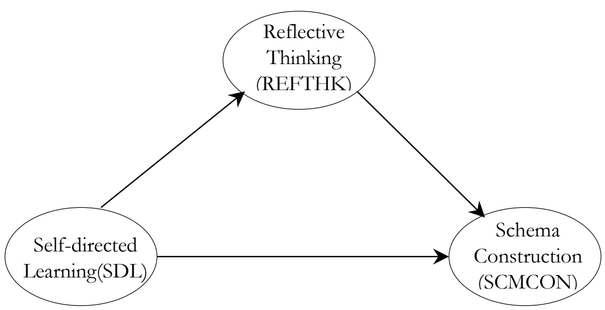

Figure 1. Conceptual Model of the Mediating Role of Reflective Thinking on the Relationship between Self-directed Learning and Schema Construction

The mediating role of reflective thinking on the relationship between SDL and learning is important because it could explain why SDL leads to better academic performance. A better understanding of why SDL leads to better academic performance has significant implications for both educational practice and its body of knowledge.

2. RESEARCH METHODOLOGY

2.1 Research Design, Approach and Data Collection

The research uses a quantitative design and a deductive approach to assess mediation because these lend themselves to hypothesis testing. The data were collected using a structured questionnaire in a cross-sectional survey with non-probability sampling. Non-probability sampling was favored due to its economy considering the limited resources available for the research. The target population for the research was public universities undertaking construction studies in South Africa. Three universities were conveniently selected to be included in the sample. The questionnaires were circulated to a captive audience of students before the start of lectures. In keeping with ethical research conduct, informed consent was obtained after explaining to the students the objectives of the research and what was being asked of them. The students were informed of their right to decline participation or to withdraw from the exercise for any reason and at any time. The students were also assured of both anonymity and confidentiality. An initial sample of 534 students was obtained. After data cleaning, a usable sample of 521 questionnaires was retained for analysis. The demographic information of the sample is shown in Table 1.

Table 1. Sample Demographic Statistics

Year of Study	Frequency	Percentage
First year	188	36.10
Second year	116	22.30
Third year	99	19.00
Fourth year	118	22.60
Total	**521**	**100.00**
Gender	**Frequency**	**Percentage**
Male	314	60.30
Female	207	39.70
Total	**521**	**100.00**
Programme of Study	**Frequency**	**Percentage**
Architecture	102	19.60
Construction Management	232	44.50
Quantity Surveying	144	27.60
Property Studies	43	8.30
Total	**521**	**100**

The first year students make up the largest number of the sample because subsequent years of study would be less by the number of students who failed to qualify to the second year of study. The fourth year students make the second largest number of students in the sample because it is the honors year. The students admitted to this year of study include students who finished their third of year study several years previously and opted to take a break from school and start working. This increases the size of the cohort of the fourth year students. The male students are more than the female student in tandem with the general gender distribution of students at public universities across the country. The distribution of the sample by program of study is also consistent with the general distribution of the population of the students across the universities. Therefore, notwithstanding that the universities selected for the survey were conveniently selected, the resulting sample is fairly representative of the population of interest.

2.2 Survey Instrument

The survey questionnaire items for self-directed learning and schema construction were developed by the authors. Self-directed learning was operationalized on the basis of the extent to which students were expected and encouraged to engage in self-directed learning. Schema construction was operationalized on the basis of the extent to which the students engaged in and were encouraged to relate any new knowledge learnt with knowledge they already possessed. Several instruments were found which measure reflective thinking of students. The Questionnaire for Reflective Thinking (QRT) by Kember, Leung, Jones, Loke, McKay, Sinclair, Tse, Webb, Wong, Marian, Wong and Yeung [7] was adapted for this research. The instrument has sixteen items with four sub-scales of habitual action, understanding, reflection and critical reflection. Four items from the reflection sub-scale were adopted for the research and appropriately modified to suit the current research context. The resulting research instrument is shown in Table2.

Table 2. Research Instrument

Self-directed Learning		
1	SDL1	I was required to find additional knowledge and information on my own
2	SDL2	I was given work which required me to learn new concepts on my own
3	SDL3	I was expected to expand on what was taught in class on my own
4	SDL4	I was required to learn on my own
Reflective Thinking		
1	REFTHK1	I question the way others do something and try to think of a better way
2	REFTHK2	I like to think over what I have been doing and consider alternative ways of doing it
3	REFTHK3	I reflect on my actions to see whether I could have improved on what I did

4	REFTHK4	I review my experience so I can learn from it and improve my next performance
Schema Construction		
1	SCMCON1	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject
2	SCMCON2	My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew
3	SCMCON3	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject
4	SCMCON4	My lecturers concentrated on making me connect new concepts and principles (points) with what I already knew
5	SCMCON5	My lecturers concentrated on making me understand the basic concepts and principles (points) of a module/subject

2.3 Data Analysis Methods

The results were subjected to exploratory factor analysis (EFA) to check scale dimensionality and the factorial structure of the indicator items. Principle components analysis (PCA) was used for factor extraction and Promax rotation with Kaiser normalization were the factor analysis approach used. PCA was preferred because it is a data driven approach suitable when no prior knowledge of the factor structure exists. Promax rotation is an oblique rotation method and so accounts for correlations among the research constructs and still performs well when the constructs are uncorrelated [8, 9]. EFA was performed using IBM SPSS v25. Confirmatory factor analysis (CFA) was performed to establish the model fit of the conceptual model and assess convergent and discriminant validity of the research constructs. CFA was performed using IBM SPSS AMOS v25. Finally, mediation analysis was performed to establish whether reflective thinking has a moderating effect on the relationship between self-directed learning and schema construction. Mediation was assessed using the PROCESS macro by Andrew F. Hayes in IBM SPSS v25. The PROCESS macro was preferred for the mediation analysis because it does not rely on the assumption of normality while at the same time being suitable for small samples [10].

3. RESULTS

3.1 Exploratory Factor Analysis

The results were first assessed for suitability for factor analysis using the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy. The resulting KMO score was 0.842 and so exceeded the recommended threshold of 0.80 [11, 12] indicating that the sample is adequate and suitable for EFA. All items had factor loadings exceeding the recommended minimum threshold of 0.50 [8] and loaded on their respective constructs without any cross-loadings when factor scores less than 0.50 were suppressed. The scale items were assessed for reliability using the Cronbach's alpha. All the constructs had Cronbach's alpha exceeding the widely recommended threshold of 0.70 [5, 13, 14] and the scores are shown in Table 3. The item correlations also exceeded the recommended minimum threshold of 0.50 [14] except for SDL4 which had a score of 0.499 which can be considered adequate. Therefore, the measurement scales exhibit good reliability and so all items were retained for further analysis.

Table 3. Factor Structure and Reliability Scores

Research Constructs		Cronbach's Test		Factor Loadings
		Item-total Correlation	α Value	
Self-directed Learning	SDL1	0.644	0.803	0.833
	SDL2	0.672		0.841
	SDL3	0.676		0.813
	SDL4	0.499		0.682
Reflective Thinking	REFTHK1	0.502	0.774	0.690
	REFTHK2	0.601		0.787
	REFTHK3	0.678		0.864
	REFTHK4	0.546		0.732
Schema Construction	SCMCON1	0.665	0.848	0.853
	SCMCON2	0.701		0.852

	SCMCON3	0.650		0.744
	SCMCON4	0.658		0.711
	SCMCON5	0.611		0.757

3.2 Confirmatory Factor Analysis

Maximum likelihood estimation with 500 bootstrap samples was used for the CFA analysis of the measurement model. The measurement model is shown in Figure 2. All the factor loadings exceeded the threshold of 0.50 recommended by Anderson and Gerbing [8]. The composite reliability (CR), average variance extracted (AVE) and maximum shared variance (MSV) are shown in Table 3. CR, AVE and MSV were computed the IBM SPSS AMOS plugin Master Validity Tool by Gaskin and Lim [15]. CR should be greater than 0.70, AVE greater than 0.50 and MSV less than the AVE [16]. Results in Table 3 show that all the scores exceeded the recommended minimum thresholds except for the AVE value for SCMCON which is 0.478. Values of AVE less than 0.50 but greater than 0.40 are also considered acceptable when other measures of validity and reliability are satisfactory because AVE is often too strict and CR alone can be used to assess reliability [17, 18]. Therefore, the AVE of 0.478 for SCMCOM is acceptable and the conceptual model exhibits good validity.

Table 4. Reliability and Validity

	CR	**AVE**	**MSV**
SDL	0.817	0.535	0.197
REFTHK	0.806	0.513	0.260
SCMCON	0.817	0.478	0.260

The resulting model fit indices for the model are λ^2/df=1.698, GFI=0.974, NFI=0.967, IFI=0.986, TLI=0.979, CFI=0.986, RMSEA=0.037. Based on widely accepted model fitness thresholds, λ^2/df should be less than 3, GFI should be greater than 0.900, NFI should be greater than 0.900, IFI should be greater than 0.900, TLI should be greater than 0.900, CFI should be greater than 0.900, RMSEA should be less than 0.080. Therefore, the theoretical model exhibited an excellent fit to the empirical data and inferences made from it are both theoretically and empirically valid and reliable [8, 12, 19-21].

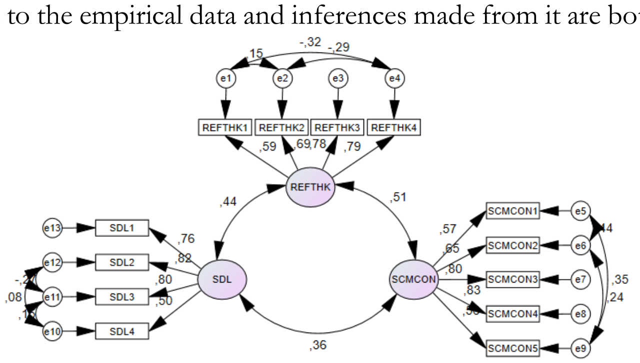

Figure 2. Confirmatory Factor Analysis Model

3.3 Mediation Analysis

The mediation analysis was performed with a bias corrected accelerated (BCa) bootstrapped confidence interval (CI) based on 5000 samples. Figure 3 shows the results of the analysis.

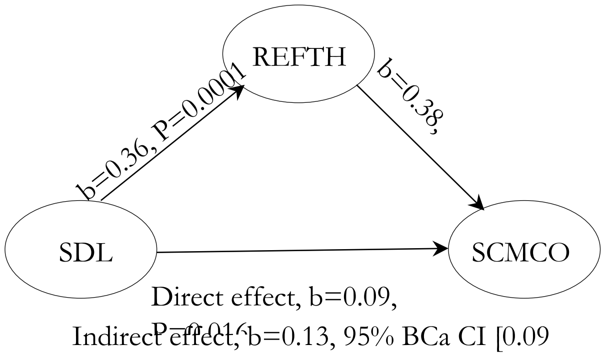

Figure 3. Model of Self-directed Learning as a Predictor of Schema Construction Mediated by Reflective Thinking

The indirect effect of SDL on SCMCON through REFTHK was significant (indirect effect = 0.13, 95% BCa CI = 0.09 to 0.18). This confirms that reflective learning is a mediator in the relationship between self-directed learning and schema construction.

4. DISCUSSION AND CONCLUSION

The aim of the research was to assess whether reflective thinking mediates the relationship between SDL and learning. A perception measure of the extent to which students engage in the development of schemata was used to measure learning. Consistent with other findings [e.g. 1, 2, 3], both SDL and reflective thinking were found to significantly predict learning while SDL also predicted reflective thinking. Reflective thinking was found to mediate the relationship between SDL and learning. This finding is in tandem with the argument that SDL does not have a causal link with learning because merely being able to direct one's own learning is not a plausible explanation for having an improved academic performance. While it significantly directly predicts learning, the effect of SDL is mediated by reflective thinking.

The mediating role of reflective thinking on the relationship between SDL and learning has important practical implications. Findings which show that SDL leads to improved academic performance suggest that SDL should therefore be encouraged for students to achieve better academic performance. The finding that reflective thinking mediates the relationship of SDL with learning suggests that it is important to recommend that students should engage in reflective thinking when they engage in SDL if they are to achieve better academic performance. Emphasizing on SDL alone in the absence of reflective thinking may lead to better academic performance but only because the students would inadvertently engage in reflective thinking. Placing emphasis on reflective thinking is likely to guarantee improved academic performance because it is the consequent reflective thinking arising from SDL rather than SDL itself which leads to improved academic performance.

On the theoretical front, the finding of the mediating role of reflective thinking on the relationship between SDL and learning provides a plausible explanation for why SDL leads to improved academic performance. Considering that learning and so academic performance is a cognitive development process, factors which directly influence learning should be cognitive in nature. Therefore, it is the cognitive aspects arising from learning activities which are responsible for learning. Therefore, the finding from this research suggests that even other learning activities and processes which are not purely cognitive processes in nature but are reported to lead to improved academic performance are very likely to only improve academic performance through mediators which are cognitive in nature.

However, it is worth noting that the findings in this research are based on some research instruments which have not been previously tested. Therefore, it is important to replicate the research with other instruments or with the same instruments used in this research in order to validate the findings and the conclusions arrived at by this research.

5. ACKNOWLEDGMENTS

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13.17 Appendix 17 – Best Paper Award

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